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Bureau of Economic Geology

John T. Lonsdale, Director

Issued December, 1945

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The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of Democracy, and while guided and controlled by virtue, the noblest attribute of man. It is the only dictator that freemen acknowledge, and the only security which freemen desire.

Mirabeau B. Lamar

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"Contributions to Geology," including shorter papers, have been issued by the Bureau of Economic Geology since 1928. Each volume of the "Contributions" bears a bulletin number and is thus a part of The University of Texas series. The volumes issued in this "Contributions" series are University of Texas Bulletins 2801, 2901, 3001, 3101, 3201, 3501; University of Texas Publication 3945; and the present volume, University of Texas Publication 4401. The papers of this volume of "Contributions" include two papers on stratigraphic subjects and selected studies of fossil groups as follows: graptolites from the Cambrian, corals from the Carboniferous, Foraminifera from the Upper Carboniferous, vertebrates from the Triassic, crustaceans from the Cretaceous, and vertebrates from the Pliocene.

This volume of "Contributions" was planned by Dr. E. H. Sellards who selected the papers and arranged for publication. The volume constitutes a valuable contribution to the geology of Texas and will be useful in many problems of economic geology.

J. T. LONSDALE, *Director*
Bureau of Economic Geology
The University of Texas

THE WILBERNS UPPER CAMBRIAN GRAPTOLITES FROM MASON, TEXAS

Charles E. Decker

INTRODUCTION

Cambrian graptolites have been secured from relatively few localities; hence their value in correlation of formations has been very limited. However, they are abundant in some horizons, and the limited number available for description is due rather to lack of thorough methods of collection than to sparseness of the graptolites. Because of experience in collecting during the past year, the writer is convinced that more species can be secured from many of the known localities than have been collected from those localities.

The value of these early dendroid graptolites has been questioned on the ground that they are said to be of long range and that they change slightly through many horizons. From the rather brief experience of the writer in the study of these early forms, it is thought that this conception of their limited value is due to the relatively few forms available for comparison and to the lack of very detailed study to detect varietal differences. While it may be learned that some of these early dendroid forms have a fairly long range, it will also be found that some of the species have a very short range, and that assemblages of them may be as characteristic and diagnostic of a horizon as practically any other group of invertebrate fossils. Some species of brachiopods, gastropods, and trilobites have an exceedingly long range. It is probable that workers have attempted to establish correlations with material which is too fragmental. These early dendroid graptolites were apparently very fragile and easily broken by the ocean waves. Accordingly, small fragments are much more numerous than large parts of colonies. Hence, more persistent and thorough methods of collecting should be adopted, and greater care exercised in the use of available material.

ACKNOWLEDGMENTS

Grateful acknowledgment is made for a grant from the University of Oklahoma Research Fund to defray part of the field expenses in collecting the graptolites; to E. H. Sellards for assistance in plans for publication; to F. B. Plummer for finding the graptolite horizon; to H. B. Fuqua for assisting in making the collections; to E. A. Frederickson for assisting in identification of the trilobites; to Mertie Staig for drawing them; to Caroline Pick for assisting with the plates; and especially to William Hilseweck whose alertness brought the graptolites to the writer's attention. Mr. and Mrs. Hilseweck took the writer to the graptolite locality, and he has continued his assistance in making the collections.

The outline maps in figures 1 and 2 show the Wilberns graptolite locality with reference to the State of Texas, Mason County, and Mason.

CHARACTERISTICS OF GRAPTOLITES

Graptolites lived in colonies which were simple individual stipes or rhabdosomes, or an assemblage of many stipes in a compound colony or synrhabdosome, or in complexly branched colonies known as dendroid graptolites. Each rhabdosome consists of a number of slender tubular cups (thecae or hydrothecae) in which the polyps lived. The colonies start with a tiny conical sicula generally less than 2 mm. in length. The sicula consists of thecal thread or nema, prosicula constituting the smaller end of the sicula, metasicula or middle portion, and apertural part next to the opening. A spine-like virgella is developed along one side, and it may extend beyond the opening as a sharp spine. Other apertural spines may also be developed. A foramen in one wall of the sicula permits a bud to pass to form the first theca from which successive other thecae are budded. The sicula, thecae, and branching tubes consist of chitinous material laid down in delicate slender rings in three layers.

In many of the early graptolites very slender elongate tubes (bithecae) occur associated with the thecae. While a suggestion has been made that they might

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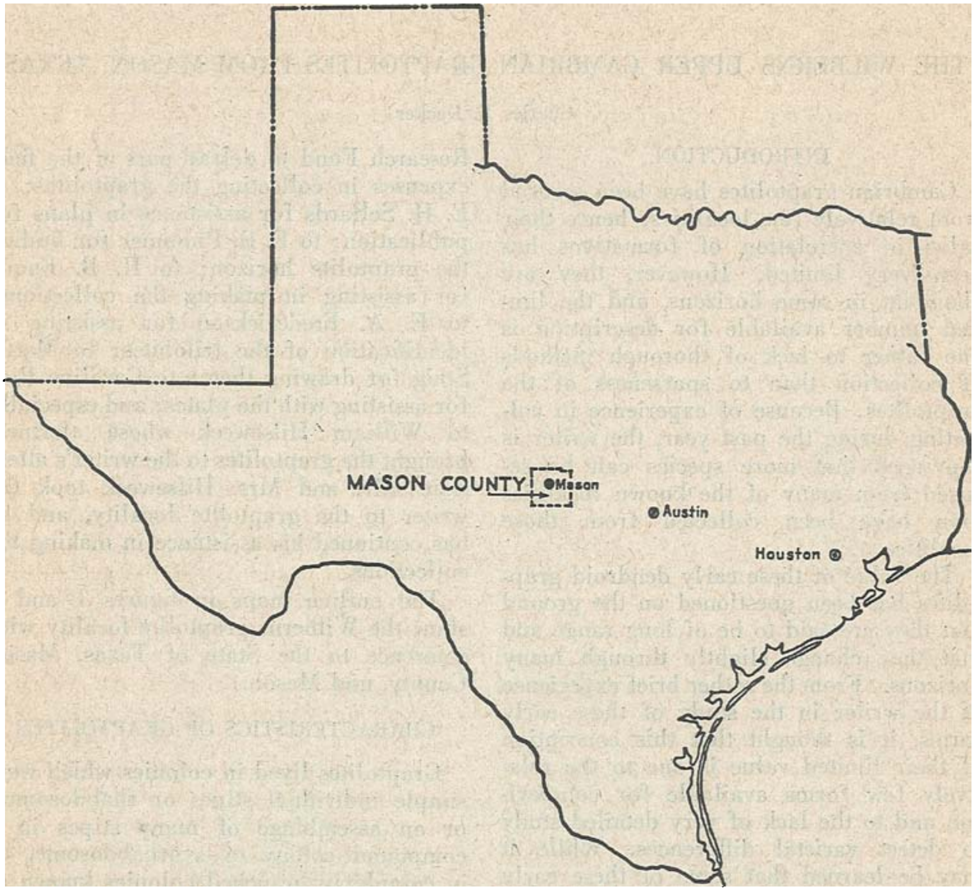

Fig. 1. Outline map of Texas showing location of Mason, 124 miles northwest of Austin on good highways. Point of arrow shows approximate position of graptolite locality 9 miles southwest of Mason. Map by W. W. Latson, Gulf Oil Company, Fort Worth, Texas.

represent reproductive structures, they are so similar to the tubes housing nematocysts in modern Hydrozoa that they seem more likely to represent tubes for the nematocysts. On some graptolites relatively large globular structures (gonothecae) were developed to serve as reproductive pouches.

RELATIONSHIPS OF GRAPTOLITES

As graptolites have been extinct since a time before the close of the Paleozoic, their place in the animal kingdom must be determined by their form, structure, parts and methods of growth as preserved in the fossil state.

Hall,[1] after making extensive study of the graptolites and in speaking of the

[1]Hall, James, Introduction to the study of the Graptolitidae: New York State Cab. Nat. Hist., 20th Ann. Rept. Univ., pp. 172–173, 1867.

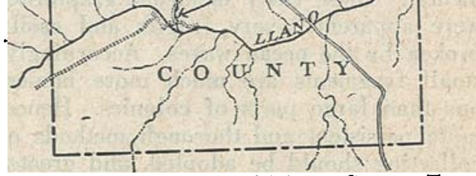

Fig. 2. Outline map of Mason County, Texas, showing drainage and roads leading to graptolite locality near point of arrow. Graptolites occur on the southeast side of a small bend in Honey Creek, 9 miles southwest of Mason, a little north of the confluence of Honey Creek and Llano River. Map by W. W. Latson, Gulf Oil Company, Fort Worth, Texas.

graptolite stipe with its thecae, says: "The establishment of the fact that these toothlets or serratules are the extensions of true cellules, each one having an independent aperture, and communicating with a common canal, should offer convincing argument against these bodies being other than polyp-bearing skeletons." And he concluded: "That they are true Polypi belonging to the Hydrozoa."

Ulrich[2] and Ruedemann have stressed the likeness of graptolites to bryozoans. A more appropriate title in general and for their article in particular would seem to have been, "Did Bryozoa Arise from Graptolites?" as graptolites are recognized as having preceded bryozoans by a very long period of time. These men emphasized the bilateral symmetry of the sicula and the presence of muscle scars in certain forms of the graptolites and the absence of a coenosarcal canal, as features linking them closely with Bryozoa. However, Bulman[3] in discussing the common canal suggests coenosarcal connection at the proximal ends of the thecae in a space which, while less regular, serves the purpose of a coenosarcal canal. In addition there are cross canals connecting the stipes with the sicular region.

Also, Bulman[4] has shown the results of Wiman's detailed studies of the structure of graptolites in which the irregular common canal is clearly shown, and the coenosarcal canal connecting the graptolite polyps is illustrated.

It is rather significant of the general relationship of graptolites and hydrozoans that five genera described by Hall, Spencer, and Ruedemann as graptolites have been placed with the hydrozoans by Chapman and Thomas.[5]

Also, these five genera, *Mastigograptus, Chaunograptus, Cactograptus, Acanthograptus,* and *Thallograptus,* which occur with graptolites, have been described as graptolites, and have the same general type of preservation as graptolites, have been recognized as hydrozoans in the Middle Cambrian of Victoria, Australia.

STUDY OF CAMBRIAN GRAPTOLITES

The term graptolite, meaning writing on the rocks, harks back to Linnaeus who in 1736 in his "Systema Naturae" gave to them the name "Graptolithus."

The first Cambrian graptolite discovered, *Dictyonema flabelliforme* (Eichwald), was named by the Russian naturalist Eichwald[6] in 1840, though at first he called it *Gorgonia flabelliforme.*

Ruedemann[7] in 1903 described the characteristics, distribution, and stratigraphic relations of *Dictyonema flabelliforme* in New York, Canada, Great Britain, Scandinavia, and Russia and considered it and related forms as definitely Cambrian in age.

In the next year Ruedemann[8] described *Dictyonema flabelliforme* in great detail and gave a synonymy of 27 references. Also, he has a plate illustrating this Cambrian form showing a number of growth stages from sicula well up toward the mature colony. There he assigned this species to the Upper Cambrian. In his later publication, without citing the evidence, Ruedemann[9] says that the *Dictyonema* beds considered Upper Cambrian in New York, Canada, and Europe are now generally placed at the base of the Ordovician (Canadian).

However, it is believed that his conclusions reached in his earlier excellent discussion of the *Dictyonema* shales assigning them definitely to the Upper Cambrian are still valid. Possibly some of the confusion has arisen by assigning part of the Upper Cambrian and Lower Ordovician to the Canadian, a subdivision which

[2]Ulrich, E. O., and Ruedemann, Rudolf, Are the graptolites bryozoans?: Bull. Geol. Soc. Amer., vol. 42, pp. 589–603, 1931.

[3]Bulman, O. M. B., Grap'olithena: Handbuch der Paläozoologie (O. H. Shindewolf), Lf. 2 (Bd. 2D), p. 32, 1938.

[4]Bulman, O. M. B., Carl Wiman's work on the structure of the Graptoloidea: Bull. Geol. Inst., Univ. Upsala, vol. 27, pp. 10–18, text fig. 1c, 1937.

[5]Chapman, Frederick, and Thomas, D. E., The Cambrian Hydroida of the Heathcote and Monegeeta Districts: Proc. Royal Soc. Victoria, vol. 48 (n.s.), pt. 2, pp. 202–209, 1936.

[6]Eichwald, Eduard, Ueber das Silurische Schichtensystem in Estland, St. Petersburg, p. 207, 1840.

[7]Ruedemann, Rudolf, The Cambric *Dictyonema* fauna in the slate belt of eastern New York: New York State Mus., Bull. 69, pp. 934–958, 1903.

[8]Ruedemann, Rudolf, Graptolites of New York, pt. 1, Graptolites of the lower beds: New York State Mus., Mem. 7, pp. 599–606, pl. 1, 1904.

[9]Ruedemann, Rudolf, The Cambrian of the upper Mississippi valley, pt. 3, Graptolitoidea: Bull. Milwaukee Pub. Mus., vol. 12, no. 3, p. 312, 1933.

has not been recognized by the United States Geological Survey.

In their article on the geology of St. John, New Brunswick, Hayes and Howell[10] have stated that the Navy Island formation containing *Dictyonema flabelliforme* is not Cambrian in age, and by inference they would take formations carrying *Dictyonema flabelliforme* elsewhere out of the Cambrian and place them in the Lower Ordovician or Canadian.

However, Matthew[11] in an earlier report discussing the faunas of the St. John terrain with reference to the Tremadoc *Dictyonema flabelliforme* zone said:

> On the whole it seems better to hold to the prevalent English opinion which places the line of division above the Tremadoc, notwithstanding the conditions that prevailed in northern Europe, and notwithstanding the fact that new and important genera of crustaceans appeared in the Tremadoc slates. To adopt the line drawn by the paleontologists of Scandivania and Germany would make necessary a revision of the Cambrian geology of America, whereby large areas and extensive faunas that have been classed as Cambrian would of necessity be transferred to Ordovician, or Lower Silurian.

Furthermore, in England where Cambrian and Ordovician were differentiated and named, the *Dictyonema* shales in the Tremadocian and equivalent horizons in Europe are still placed definitely in the Cambrian by the leading graptolite authorities. There is no disposition to attempt further to settle the problem of the age of the *Dictyonema flabelliforme* zone. The brief discussion is introduced in connection with the listing of the graptolites which have been described as belonging to the Cambrian. If the *Dictyonema flabelliforme* shales are retained in the Cambrian, Ruedemann's list is considerably augmented.

GRAPTOLITES ALREADY DESCRIBED AS CAMBRIAN

Dictyonema flabelliforme (Eichwald) described from the Baltic province of Russia occurs also in Belgium, Bavaria, France, Sweden, and Norway where also there is found *Dictyonema (Dictyograptus) flabelliforme* var. *norvegica* Kjerulf.[12]

In Great Britain Elles and Wood[13] have listed in the Cambrian (Tremadoc) *Dictyonema sociale, Bryograptus callavei, Clonograptus tenellus,* and *C. tenellus* var. *callavei.*

In a later publication Elles[14] lists besides *Dictyonema flabelliforme, Bryograptus kjerulfi* and *B. cambrensis, Clonograptus tenellus* and *C. callavei.* Also from England Bulman[15] has described four varieties of *Dictyonema flabelliforme—typica, sociale, anglica,* and *norvegica.* In an article on the Shineton shales of the Wrekin district, Stubblefield and Bulman[16] have given a table showing the distribution of *Dictyonema flabelliforme* in Europe, Great Britain, and Canada.

Australia.—While the Australian region has many excellent graptolite horizons with a great variety of species, Cambrian *Dictyonema* has not been recognized.[17] However, a fine series of Middle Cambrian hydroids[18] has been described and illustrated from Australia.

North America.—In Canada, Newfoundland, New Brunswick, a Cambrian *Dictyonema* zone has been found on Cape Breton Island, Nova Scotia, and at Cape Rosier, Gaspé; and in eastern New York at Schaghticoke on the Hoosic River, Ruedemann[19] discovered a wonderful series of growth stages of *Dictyonema flabelliforme* (Eichwald) and a *Clono-*

[10]Hayes, A. O., and Howell, B. F., Geology of Saint John, New Brunswick: Geol. Soc. Amer., Spec. Paper 5, p. 90, 1937.

[11]Matthew, G. F., Report on the Cambrian rocks of Cape Breton: Geol. Survey Canada, p. 181, 1903.

[12]Monsen, Astrid, Ueber Eine Neue Ordovicische Graptolithen Fauna: Separatdruck aus Norsk geologisk tidisskrift, Bd. 8, pp. 156–157, 1925.

[13]Elles, Gertrude, and Wood, E. M. R. (Mrs. Shakespear), A monograph of British graptolites: Paleontographical Soc. pp. 83, 84, 526, 1901–1918.

[14]Elles, Gertrude, The graptolite faunas of the British Isles (A study in evolution): Proc. Geol. Assoc., London, vol. 33, table op. p. 200, 1922.

[15]Bulman, O. M. B., A monograph of British dendroid graptolites, Pt. I: Palaeontographical Soc., vol. 86, pp. 12–29, text figs. 2–16, pls. 1, 2, 1927.

[16]Stubblefield, C. J., and Bulman, O. M. B., The Shineton shales of the Wrekin district: Quart. Jour. Geol. Soc., London, vol. 83, op. p. 118, 1927.

[17]Keble, R. A., and Benson, W. N., Graptolites of Australia; bibliography and history of research: Nat. Mus., Melbourne, Mem. 11, p. 53, 1939.

[18]Chapman, Frederick, and Thomas, D. E., The Cambrian Hydroida of the Heathcote and Monegeeta districts: Proc. Royal Soc. Victoria, vol. 48 (n.s.), pt. 2, p. 193, 1936.

[19]Ruedemann, Rudolf, Graptolites of New York, pt. 1, Graptolites of the lower beds: New York State Mus., Mem. 7, pp. 599–606, pl. 1, 1904.

graptus proximatus Mathew zone but indicated that he was unable to work out the relations of the two zones. However, in England the *Clonograptus* zone seems to occur a little above the *Dictyonema* zone.

If, as indicated above, the early *Dictyonema* zones and their closely associated forms are to remain definitely in the Upper Cambrian, it is interesting to note that Dendroidea did not hold full sway, for their ranks had been invaded by branching types of Graptoloidea in two genera, *Clonograptus* and *Bryograptus*.

The earliest Cambrian graptolite found in the upper Mississippi Valley area was discovered by one of those alert scientific physicians, H. A. Prout, M.D. It was a beautiful dendroid graptolite, first called *Graptolithus hallianus* in honor of James Hall and now called *Dendrograptus hallianus* (Prout).[20] It was described and illustrated in natural size and enlarged drawings. It was found at Osceola Mills, Wisconsin, near the falls of St. Croix River in a thin seam of calcareo-aluminous shale, 50 feet above the water level. A different drawing by Whitfield of this Cambrian graptolite from Wisconsin was published by the State geologist, T. C. Chamberlin.[21]

As has been characteristic of his work in so many other graptolite horizons, Ruedemann made an outstanding contribution to the study of Cambrian graptolites in his Milwaukee bulletin noted above on "Cambrian Graptolite Faunas of North America." While he omitted all forms in the *Dictyonema* zones, he included all other Cambrian graptolites collected up to 1933. As he listed the species by states, the presence of various species in the different states will be noted here, together with the horizons and localities given in connection with the descriptions and later emended by him.

Quebec:
Dendrograptus kindlei, 1½ miles west of Corner-of-the-Beach, Gaspé County, Quebec, Canada

Tennessee:
Haplograptus vermiformis Ruedemann, Nolichucky shale, 10 miles east of Knoxville (loc. 126a)
Dendrograptus edwardsi var. *major* Ruedemann, Nolichucky shale:
(1) 1½ miles southeast of Morristown (loc. 119)
(2) 10 miles northwest of Knoxville (loc. 107)
(3) 10 miles east of Knoxville (loc. 126a)
Callograptus antiquus Ruedemann, Nolichucky shale, 1½ miles southeast of Morristown (loc. 119)

Vermont:
Dictyonema schucherti Ruedemann, Russel slate, 1 mile west of Highgate Center

Wyoming:
Dictyonema wyomingense Ruedemann, Deadwood series, north side of Shoshone Canyon just above the bridge west of Cody

South Dakota:
Dendrograptus thomasi Ruedemann, Deadwood formation, north wall of Whitewood Canyon, Deadwood

Minnesota:
Acanthograptus priscus Ruedemann
Callograptus staufferi Ruedemann
Dendrograptus edwardsi Ruedemann
Dendrograptus hallianus (Prout)
Dendrograptus sparsus Ruedemann
Dictyonema minnesotensis Ruedemann
Trempealeau formation (31 feet below base of the Jordan (Norwalk) sandstone) in the St. Lawrence formation at Afton on the west side of St. Croix River about 15 miles southeast of St. Paul

In addition to the six species listed above from Minnesota, *Haplograptus wisconsinensis* was found by the writer in some fragmental material from that State. A number of the specimens from that locality and several of those from the type locality at Ontario, Wisconsin, exhibit a large number of small thecae extending nearly throughout their length. So these forms are not the small simple, conical, tapering tubes described by Ruedemann, but instead they are conical tubes containing many small thecae in their structure.

If the species of *Haplograptus* were to be kept in the graptolite group, these conical tubes with their small thecae might well have served as protoypes of higher forms of graptolites. These could serve in that role more appropriately than the much later Ordovician *Protistograptus* described by McLearn.[22] Indeed, the

[20]Prout, H. A., Description of a new graptolite found in the Lower Silurian rocks near the Falls of the St. Croix River: Amer. Jour. Sci., 2d ser., vol. 11, pp. 187–191, figs. 1b–f, 1851.

[21]Chamberlin, T. C., Paleozoic era, Cambrian age, Potsdam period, Life of the epoch, *in* Geology of Wisconsin, vol. 1, p. 126, fig. 12j, 1883.

[22]McLearn, F. H., The Lower Ordovician (*Tetragraptus* zone) at St. John, New Brunswick, and the new genus *Protistograptus*: Amer. Jour. Sci., 4th ser., vol. 40, pp. 49–59, 1915.

writer has wondered if these forms called *Protistograptus* may not represent genal spines which eventually may be found attached to the base of a trilobite cephalon. If they are genal spines, it will be the second instance in which parts of a trilobite have been mistaken for a graptolite.

Girty described as *Monograptus beecheri* forms from a much higher horizon, from the New Scotland beds (lower Devonian), Albany County, New York, and gave figures of these forms which later Ruedemann[23] decided were fragments of the spinose margin of an acidaspid trilobite.

Wisconsin.—Cambrian graptolites have been collected from 8 different localities in Wisconsin, though the material from one of them has been identified only as to genus. For each locality the graptolite horizon is given and the species of graptolites listed.

1. Osceola Mills, Polk County, in calcareous shale, 50 feet above the water level near the falls of St. Croix River.
   Dendrograptus hallianus (Prout)
2. Tomah, Monroe County, in road cut on County Trunk C, 6½ miles southwest of the city (loc. 90u), Trempealeau formation, near base.
   Dendrograptus edwardsi Ruedemann
3. Dorset Valley School, Monroe County, 1½ miles northeast in road cut sec. 25, T. 16 N., R. 1 W (loc. x25.25), near base of Trempealeau formation.
   Dendrograptus hallianus (Prout)
   Dendrograptus edwardsi Ruedemann
   Dendrograptus sparsus Ruedemann
   Mastigograptus sp.
4. Dorset Valley School, Monroe County, northeast corner sec. 26, T. 16 N, R. 1 W. (loc. 25–26), Trempealeau formation.
   Dendrograptus hallianus (Prout)
5. Ontario, Monroe County, in road cut 6 miles west of city; NW.¼ sec. 35, T. 15 N., R. 3 W. (loc. 16.1), in Lodi shale.
   Dendrograptus hallianus (Prout)
   D. hallianus var. *spissus* Ruedemann
   Dendrograptus edwardsi Ruedemann
   Haplograptus wisconsinensis Ruedemann
6. Richland Center, Richland County, just southeast of city (loc. x5.7), in Lodi shale.
   Dendrograptus hallianus (Prout)
   Haplograptus wisconsinensis Ruedemann
   Mastigograptus sp.
7. Spring Green, Sauk County, northeast of town; east side of road. near center of SW.¼ sec. 35, T. 9 N., R. 4 E., in Lodi shale.
   Dictyonema sp.
8. In Fox Glen, Sauk County, on the northeast flank of the Baraboo Range; Ironton, the lowest member of the Franconia formation.
   Dendrograptus sp.

The graptolite is associated with the brachipods and trilobites, and the fauna occurs in several feet of red and green shales. This seems to be the very lowest horizon in which graptolites have been found, lower than those in Texas, Tennessee, Vermont, and Canada. Though it has been impossible to do careful stratigraphic work on these zones to the present, the zone is very much lower than those for Minnesota and most of Wisconsin. Because this is thought to be the lowest zone in which graptolites have been found, it deserves special attention. Every effort should be made to search the fossiliferous beds thoroughly in the hope that a graptolite fauna may be secured which will throw more light on the beginnings and early development of the group.

With reference to the Cambrian graptolite localities in Wisconsin, it may be said that the writer attempted to visit a number of them during a part of a three-day trip. It was difficult in the short time available to find some of the collecting localities because of re-routing of roads, new grades, and fills, and doubtless some former outcrops are completely covered with vegetation. However, several hours were spent with remarkable success at two of the localities, west of Ontario and northeast of Spring Green. At each of these localities parts of more species were secured than had been collected previously from all the Wisconsin Cambrian localities. From west of Ontario three species were previously recognized, and the new collection contains parts of at least nine species including a new species of *Dictyonema* and a hydroid genus not recognized from the Cambrian, except in Australia. Enough other forms are present to correlate the horizon definitely with the one at Afton, Minnesota.

From the earlier collecting northeast of Spring Green, only part of one *Dictyonema* had been secured, while a recent collection by the writer contains part of at least ten different species. In this collection there are at least three new species

[23]Ruedeman, Rudolf, [Unit I] Graptolithina, *in* Type invertebrate fossils of North America (Devonian): Wagner Free Inst. Sci., card No. 12, 1939.

of graptolites and two genera of hydroids which have been found in a lower horizon in Victoria, Australia. The fauna from

Spring Green comes from the St. Lawrence dolomite below the Lodi shale zone west of Ontario and at Afton, Minnesota;

Table 1. Distribution of Known Graptolites Described as Cambrian

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Dendrograptus edwardsi	x						x								
D. edwardsi var. major					x										
D. hallianus	x						x								
D. hallianus var. spissus							x								
D. kindlei			x												
D. sparsus	x						x								
D. thomasi				x											
Callograptus antiquus					x										
C. staufferi	x						x								
Dictyonema minnesotense	x														
D. schucherti						x									
D. wyomingense								x							
D. flabelliforme		x	x			x				x		x		x	x
D. flabelliforme vars. typica, sociale, anglica											x				
D. flabelliforme norvegica													x		
D. tenellus callavei											x				
Bryograptus callavei											x				
B. kjerulfi													x		
Clonograptus tenellus											x				
C. proximatus		x	x												
Acanthograptus priscus	x														
Haplograptus vermiformis					x										
H. wisconsinsensis							x								
Mastigograptus sp.							x								
Four genera described with graptolites, now called hydroids (Middle Cambrian), Acanthograptus, Cactograptus, Chaunograptus, Mastigograptus									x						

Localities by number: 1, Minnesota; 2, New York; 3, Canada; 4, South Dakota; 5, Tennessee; 6, Vermont; 7, Wisconsin; 8, Wyoming; 9, Australia; 10, Belgium; 11, Great Britain and Ireland; 12, Russia; 13, Scandinavia; 14, Bavaria; 15, France.

Note: Eleven of the species in this table were shown by Ruedemann in his table of North American Cambrian graptolites, while five species and five varieties are from the *Dictyonema flabelliforme* zone which some would shift into the Lower Ordovician.

Bulman has listed *Tetragraptus*, *Triograptus*, and *Didymograptus* as Tremadocian and *Aspidograptus* as possibly Cambrian.

and while a little higher, it approaches more nearly the Nolichucky zone of Tennessee and the upper Wilberns of Texas.

The distribution by states and countries of graptolites which have been recognized as Cambrian is given in the preceding table which includes forms in the one by Ruedemann.[24]

THE UPPER WILBERNS FAUNA

The rich Wilberns graptolite fauna was secured from a gray shale 6 to 10 inches thick between limestone beds near the base of the bluff shown in figure 3. The graptolite horizon is shown by an indistinct, light, nearly horizontal line at the point of the arrow. An enlarged map in figure 4 shows the geology in the vicinity of the graptolite locality.

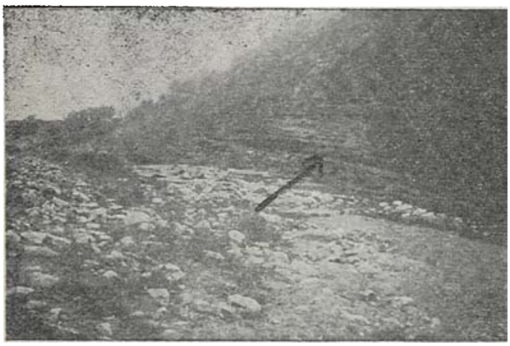

Fig. 3. Photograph showing position of Wilberns Upper Cambrian graptolite zone on the southeast side of Honey Creek, 9 miles southwest of Mason, Texas. The arrow which extends across the creek bed points to the graptolite zone in which the non-resistant shale has been eroded far back of the edges of the more resistant beds on either side of it. Photograph by William Hilseweck.

While the fauna in the upper Wilberns formation southwest of Mason, Texas, consists chiefly of graptolites, representatives of five other groups of fossils are associated with the graptolites. The five other groups are Hydrozoa, worms, brachiopods, trilobites, and a Merostomata. The graptolites will be treated first and the other five groups briefly in the order mentioned.

[24]Ruedemann, Rudolf, The Cambrian of the upper Mississippi Valley, pt. 3, Graptolitoidea: Bull. Milkaukee Pub. Mus., vol. 12, no. 3, p. 313, 1933.

DESCRIPTION OF SPECIES

Class GRAPTOLITHINA Bronn, 1846; emend. Lapworth, 1875

Order DENDROIDEA Nicholson, 1872

Genus DENDROGRAPTUS Hall, 1865

Hall, James, Figures and descriptions of Canadian organic remains, Decade II, Graptolites of the Quebec group: Geol. Survey Canada, p. 126, 1865.

Hall used *Dendrograptus hallianus* as the type of the genus, and his original description follows:

Fronds simple or aggregate, consisting of a strong footstalk, which is sometimes furnished below with a distinct root or rootlike bulb, and above is variously ramified, and subdivided into numerous branches and branchlets, which are but slightly divergent; the whole producing a broad spreading shrublike frond: (fronds sometimes flabellate). Branches celluliferous on one side: cellules appearing sometimes as simple indentations on the surface, and sometimes distinctly angular, with the denticles conspicuous. In some specimens the cellules are indicated by prominent pustule-like elevations, arranged along the center, or in subalternate order on one face of the branch. Substance of the stipe and branches corneous, solid or tubular: surface striated.

These bodies present specific distinctions in the strength of the stipe or stem, in the mode of bifurcation and number of branches, in the character of the surface, and in the general form of the frond. The celluliferous side usually adheres to the stone, and we perceive only some simple undulations or unequal thickening of the back of the branches. Often the branches have an alation on one side, like a thin pellicle flattened and extended along the more solid axis. The radix or radicle consists of an expansion of the footstalk, and in one species appears like a flattened bulb or disc or irregular form. The footstalks when well preserved, are marked by interrupted longitudinal striae, and the non-celluliferous faces of the branches are variously striated, the striae in most instances being unequal or interrupted in their course.

DENDROGRAPTUS EDWARDSI var. MAJOR Ruedemann

Pl. 2, fig. 4; Pl. 3, figs. 5–7; Pl. 6, figs. 4, 4a; Pl. 7, figs. 7. 7a; Pl. 10, fig. 6

Dendrograptus edwardsi var. *major*, Ruedemann, Rudolf, The Cambrian of the upper Mississippi Valley, pt. 3, Graptolitoidea: Bull. Milwaukee Pub. Mus., vol. 12, no. 3, p. 317, Pl. 49, figs. 1, 2, 5, 7, 1933.

Because of its large size Ruedemann differentiated as the variety *major* a large well-preserved colony from near Knoxville, eastern Tennessee. His description of this large variety follows.

Original description. — Rhabdosome large, either arborescent or bush-like with short trunk, attaining a width of 60 mm. and equal length. Branches straight, or but slightly curved, of rigid appearance, .5 to 1.4 mm. wide. Thecae projecting at 30°, their outer margins straight or slightly concave, apertural margins transverse, concave; overlapping about one-half their length, numbering 9–11 in the space of 10 mm.

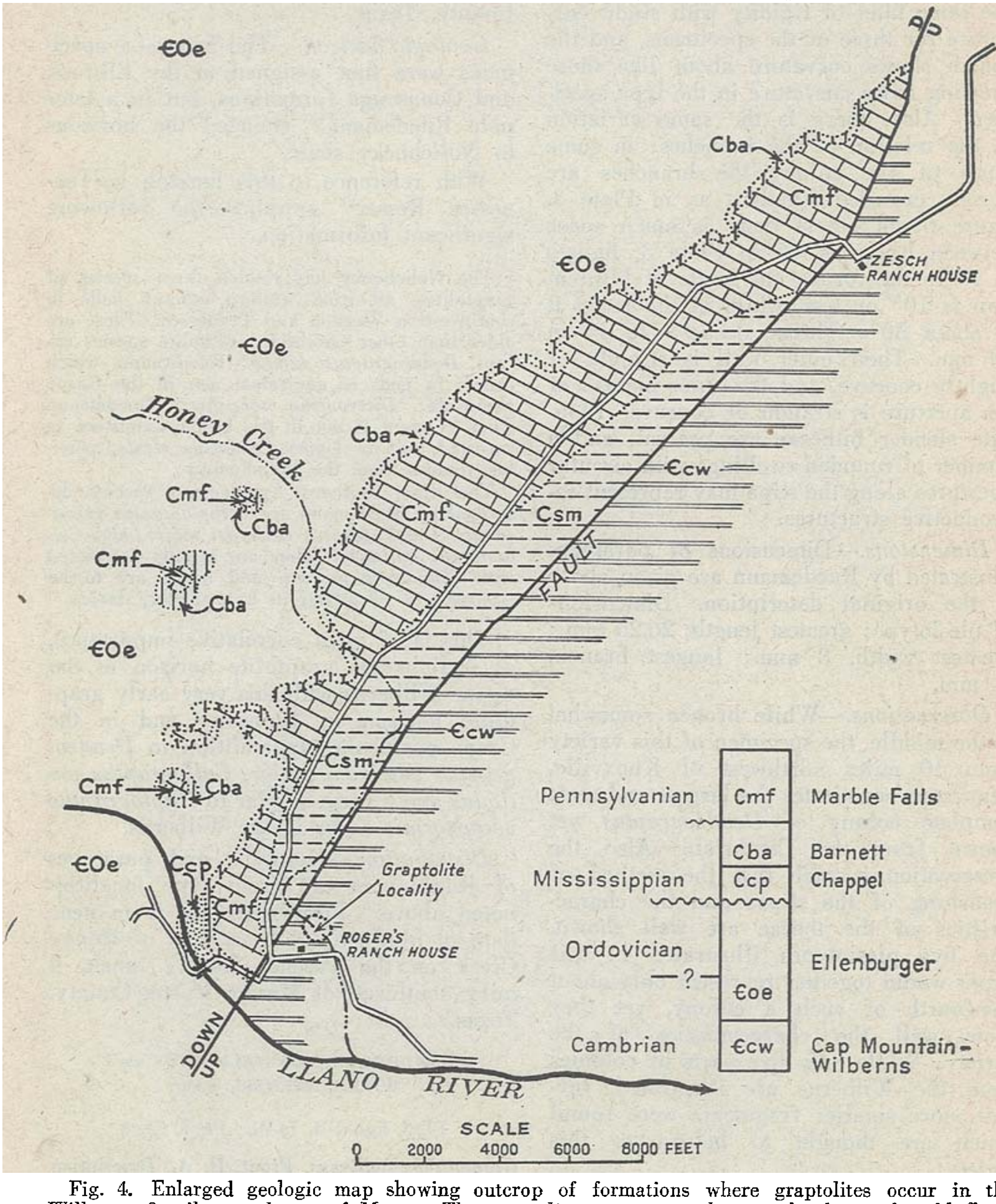

Fig. 4. Enlarged geologic map showing outcrop of formations where graptolites occur in the Wilberns, 9 miles southwest of Mason. The graptolites are exposed near the base of a bluff on the southeast side of a small bend in Honey Creek on the Paschal Rogers ranch near point of arrow. The Cambrian Wilberns formation in which the graptolites occur has been raised on the southeast side of a major fault so that it abuts against the much younger Pennsylvanian formations on the northwest side of the fault. Map adapted from Texas field trip map by W. W. Latson, Gulf Oil Company, Fort Worth, Texas. The formation designated by the symbol Csm and omitted from the legend is Smithwick shale of Pennsylvanian age.

Description of plesiotypes.—Five parts of colonies have been identified as belonging to this variety, and they agree well with the description and illustrations given by Ruedemann. The stipes show the same kind of rigidity with slight curvature for three of the specimens, and the fourth shows curvature about like those showing more curvature in the type specimen. Also, there is the same variation in the relation of the branches; in some parts of the colony the branches are closely crowded together, as in Plate 3, figure 6; in others there is much space between branches, as in Plate 3, figures 5, 7. In the former the angle of bifurcation is 10° or less, while in the latter it is about 30°. Thecae occur 9 to 11 in 10 mm. Their outer wall is straight or slightly concave, and the outer margin of the aperture is straight or concave. Elongate slender bithecae are present, and a number of rounded swellings with circular apertures along the stipe may represent reproductive structures.

Dimensions.—Dimensions of paratypes illustrated by Ruedemann are given above in the original description. Dimensions of plesiotype: greatest length, 26.25 mm.; greatest width, 8 mm.; longest branch, 21 mm.

Observations.—While broken somewhat in the middle, the specimen of this variety from 10 miles northwest of Knoxville, Tennessee, constitutes the largest and most complete colony of *Dendrograptus* yet known from the Cambrian. Also the preservation is such that the method of branching of the stipes and the characteristics of the thecae are well shown. The five plesiotypes illustrated in this paper would together represent only about one-fourth of such a colony, yet they show well the characteristics of the variety. While only five parts of colonies from the Wilberns are illustrated, several more smaller fragments were found which are thought to belong to this variety.

Type data.—Ruedemann's paratypes and holotype, U. S. National Museum. Plesiotypes, University of Oklahoma, Museum of Invertebrate Paleontology.

Type localities.—Holotype and paratypes, 10 miles east and 10 miles northwest of Knoxville and 1.5 miles southeast of Morristown, Tennessee. Plesiotypes near base of bluff on southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—The Tennessee specimens were first assigned to the Elbrook and Conasauga formations, but in a later note Ruedemann[25] changed the horizons to Nolichucky shale.

With reference to this horizon in Tennessee Resser[26] supplies the following significant information.

> The Nolichucky has yielded three species of graptolites, all from western outcrop belts in southwestern Virginia and Tennessee. These are older than other Cambrian graptolite species except *Dendrograptus kindlei* Ruedemann which occurs in beds of equivalent age in the Gaspé peninsula. *Dictyonema schucherti* Ruedemann from Vermont is not in the Lower Cambrian as reported, but in Upper Cambrian strata, possibly younger than the Nolichucky.
>
> The three southern Appalachian species described by Ruedemann are: *Haplograptus vermiformis*, *Dendrograptus edwardsi major*, and *Callograptus antiquus*. They are usually associated with *Lingulepis walcotti* and hence are to be regarded as occurring in a near-shore facies.

This is of great correlative importance, as it links the graptolite horizon in the upper Wilberns with this very early graptolite horizon in Tennessee and in the Gaspé peninsula. In addition to *Dendrograptus edwardsi major*, *Callograptus antiquus* and a form similar to *Haplograptus vermiformis* occur in the Wilberns.

Distribution.—Holotype and paratypes of Ruedemann are from type localities noted above. Plesiotypes are from near base of bluff on southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

DENDROGRAPTUS HALLIANUS var. WILBERNSENSIS, n.var.

Pl. 3, figs. 1–4, 1a–4b; Pl. 7, fig. 6

Graptolithus hallianus, Prout, H. A., Description of a new graptolite found in the Lower Silurian rocks near the falls of the St. Croix

[25]Ruedemann, Rudolf, Cambrian graptolites: Science, n.s., vol. 80, no. 2062, p. 14, 1934.

[26]Resser, Charles Elmer, Cambrian system (restricted) of the southern Appalachians: Geol. Soc. Amer., Spec. Paper 15, p. 37, 1938.

River: Amer. Jour. Sci., 2d ser., vol. 11, pp. 189–191, text figs. 1a–f, 2, 1851.

Graptolithus (Dendrograptus) hallianus, Hall, James, Organic remains of the Potsdam sandstone, *in* Report of the geological survey of the State of Wisconsin, vol. 1, pp. 20–24, figures 1a, b (non c), 1862.

Dendrograptus hallianus (Prout), Hall, James, Figures and descriptions of Canadian organic remains, Decade II, Graptolites of the Quebec group: Geol. Surv. Canada, pp. 126–127, figs. a, b (non c), 1865. Used as type for the genus.

Dendrograptus hallianus (Prout), Hall, James, Introduction to the study of the Graptolitidae: New York State Cab. Nat. Hist., 20th Ann. Rept. Univ., pp. 177, 178, fig. 10, two smaller figures (not one to the right), 1867.

Dendrograptus hallianus (Prout), Chamberlin, T. C., Paleozoic era, Cambrian age, Potsdam period, Life of the epoch, *in* Geology of Wisconsin, vol. 1, p. 126, fig. 12j, 1883.

Dendrograptus hallianus (Prout), Ruedemann, Rudolf, The Cambrian of the upper Mississippi Valley, pt. 3, Graptolitoidea: Bull. Milwaukee Pub. Mus., vol. 12, no. 3, pp. 314–316; Pl. 46, figs. 1–12; Pl. 47, fig. 3; Pl. 48, fig. 1; Pl. 54, fig. 3; Pl. 55, fig. 4, 1933.

Original description.—Polyparium hollow, well-defined, branching in a graceful raceme, much branched, branches mostly on one side, never opposite, with unilateral cells, each supporting the next one above it, no solid axis or stipe.

Polyp-cells—To the naked eye the cells appear closely serried, not appressed, transversely serrated; but under a magnifying glass they appear vaginated, hollow, having a connection with a common central tube, conical with point of cone downwards, sometimes having a faint appearance of a mucronate point on the outer lip, and two longitudinal lateral ribs, extending from base to the terminal border.

Ruedemann's later description in the Milwaukee bulletin noted above is as follows:

Rhabdosome of bushy or arborescent form, branches growing either from a long straight main stipe, either in series or in groups, or arranged in fan-like fashion around a short stem. All the branches have a wavy, slightly flexuous appearance. The rhabdosome is small to medium-sized, attaining a length of 60 mm. (in the type specimen) and a width of half that size. Flabellate groups reach a width of 45 mm. and a length of 20 mm.

The branches of the first order may be arranged serially on the stipe, and they themselves by rapid bifurcation form again flabellate groups (see Pl. 46, fig. 9). Their mode of division is always strict dichotomy. The main stipe is 1 mm., branches are .5 mm. wide and of uniform thickness. The thecae are slender, distinctly projecting, overlapping one-half their length, with nearly straight outer and straight transversal to slightly concave apertural margins. Their angle of divergence varies from 10° to 20°. They number 13 to 15 in the space of 10 mm. Although in frontal view (Pl. 47, fig. 3) the thecae appear striated longitudinally, no conclusive evidence of a composite structure was found, especially no distinct lateral apertures. The thecae were, as a rule, turned in one direction, so that a rhabdosome will show all either in frontal, or dorsal or lateral view.

A small form with thecae more crowded (16 in 10 mm.) was given the varietal name of *"spissus."*

Description of plesiotypes.—Five plesiotypes have been chosen from the Wilberns formation of Texas for description of the new variety. They are delicate, beautiful, symmetrically branched colonies with narrow stipes and frequently bifurcating branches. While some of the central stipes are larger, most of the branches bend toward one another, so that they approach a subparallel condition. Thecae are short and closely packed together, occurring 20 in 10 mm. Thecae are short and boxlike, and two little ridgelike swellings occur on the surface of many of them. Overlap of thecae is slight. Bithecae are present.

Dimensions.—The five plesiotypes illustrated in the figures noted above represent only parts of colonies. Two of the colonies have a length of 24.3 mm. and a width respectively of 12.5 and 11 mm. A third colony has a length of 22.5 mm. and a width of 13.75 mm. Of the two smallest colonies, the larger one has a length of 18 mm. and a width of 7 mm.; the smaller one has a length of 15.3 mm. and a width of 6.25 mm. The smaller branches have a width of 0.25 mm. or less.

Observations.—Many of the characteristics of this much earlier variety from the Wilberns of Texas are similar to those of the type of the species, *D. hallianus,* described so long ago by Prout from a much higher horizon in Wisconsin. Colonies from these two distant states are alike in general form of colony, method of branching, and shape and markings of thecae. However, the earlier Texas variety is more delicate and has thecae much more crowded, having about one-half more thecae in 10 mm. than the Wisconsin species. The relatively large number of thecae in the Wilberns specimens suggests that Ruedemann's variety *spissus* with an intermediate number of thecae may represent a transient from the earlier Wilberns variety to that of the type species with its reduced number of thecae in 10 mm. (Wilberns variety, 20; *spissus*, 16; Winconsin type, 13 to 15 thecae in 10 mm.). In his early description Prout definitely stated that the species *hallianus* did not have a solid axis or stipe. In none of the collections made has a solid axis or stipe been found attached to a *D. hallianus* colony. Accordingly, the very large solid axis illustrated by Hall with colonies of *D. hallianus* probably belongs to another species, as was suggested by Prout for these larger stipes.

Type data.—Ruedemann's plesiotypes of *D. hallianus* are in the Public Museum of Milwaukee and in the Paleontology Museum of the University of Minnesota. His holotype of the variety *spissus* is in the former. The plesiotypes from the Wilberns of Texas are at the University of Oklahoma, Museum of Invertebrate Paleontology.

Type localities. — Prout's holotype, Osceola Mills, Wisconsin, near Falls of St. Croix River, in thin seam of calcareo-aluminus shale 50 feet above the water level. Ruedemann's plesiotypes, Ontario and Dorset Valley, Monroe County; Richland Center, Richland County, Wisconsin; and Afton, Minnesota. The plesiotypes from the Wilberns, near base of bluff on southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Prout's holotype, shale in Potsdam sandstone, Upper Cambrian. Ruedemann's plesiotypes, Lodi shale member of Trempealeau formation, Upper Cambrian of Wisconsin and Minnesota. Texas plesiotypes, 85 feet below top of Wilberns formation, Upper Cambrian.

Distribution.—Holotype and Ruedemann's plesiotypes from Polk, Monroe, and Richland counties, Wisconsin, and at Afton, Minnesota. Specimens from the new variety in the Wilberns formation, type locality in Mason County, Texas.

DENDROGRAPTUS HELENAE, n.sp.

Pl. 2, fig. 7, 7a; Pl. 10, fig. 1

Description.—That this delicate graptolite is clearly a new species is indicated by its very thin branches and its elongate tubular thecae with very little overlap. The thecae are so elongate that only 12 occur in 10 mm. They overlap only one-eighth to one-fourth their length. Branches bifurcate at a small angle of about 20° and at intervals of about 2 mm. Apertures are nearly round. The branching is quite uniform, make a symmetrical colony.

Dimensions.—Length of colony a little over 10 mm.; width, 6+ mm. Thecae have a length of 1 to 1.25 mm., and they are four or five times as long as wide.

Observations.—This species differs from *D. thomasi* in having less flexuous branches, less overlap of thecae, only three-fourths as many thecae in 10 mm., and a shorter distance of bifurcation of branches.

The species is named in honor of Helen Hilseweck who did much to help secure the graptolite collection.

Type data.—Cotypes, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—Near base of bluff on southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Wilberns formation, Upper Cambrian, about 85 feet below the top of the formation.

Distribution.—Known only from the type locality in Mason County, Texas.

DENDROGRAPTUS HILSWECKI, n.sp.

Pl. 2, figs. 1–3; Pl. 7, fig. 1

Description.—This is by far the largest, most stately *Dendrograptus* in the Wilberns fauna. It is characterized not alone by its large size but by its wide main stipes, sparse branching, especially in the lower part, and by its large box-like thecae. In the lower part the bifurcation distance may be as much as 12.5 mm. while distally it is about 3.5 mm. Most of the branches are on one side of the main stipes, but a few branches may occur on the opposite side. The angle of divergence of branches is generally about 30°, but the angle varies from less than 20° to over 40°. In side view the thecal angle is seen to be about

30°. In side view the ends of the thecae may extend one-third their length beyond the margin of the stipe. The overlap of the thecae is one-fourth to one-third their length. Thecae generally occur 8 to 10 in 10 mm. but proximally on a large stipe, there may be as few as 6 or 7 in 10 mm.

Dimensions.—Greatest length of colony, 67 mm.; greatest width, 19 mm. Greatest length of branch preserved, 24 mm. Width at base of largest stipe, 1.5 mm.

Observations.—Not only is this one of the most conspicuous species found in the Wilberns formation, but it is also one of the most abundant. Besides the cotypes illustrated here, scores of small parts of colonies of the species occur scattered through the zone. As in most of the colonies the branches are sparse; they have a very open appearance.

The name of the species is given in honor of William Hilseweck who more than any other is responsible for bringing the Wilberns faunas to the attention of the writer and for continuing his assistance in collecting the graptolites.

Type data.—Cotypes, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—Near base of bluff on southeast side of Honey Creek, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Wilberns formation, Upper Cambrian, about 85 feet below top of the formation.

Distribution.—Known only from the type locality in Mason County, Texas.

DENDROGRAPTUS cf. KINDLEI Ruedemann

Pl. 3, figs. 8, 8a

Dendrograptus kindlei Ruedemann, Rudolf, The Cambrian of the upper Mississippi Valley, pt. 3, Graptolitoidea: Bull. Milwaukee Pub. Mus., vol. 12, no. 3, p. 318, Pl. 53, fig. 5; Pl. 54, fig. 4, 1933.

Original description. — Rhabdosome small, about 15 mm. long and 16 mm. wide in the largest specimen, forming an inverted conical bush branching frequently and irregularly. Branches subparallel, slightly flexuous or undulating, about .5 mm. wide. Sicula long and slender (1.4 mm. long, .4 mm. wide). Thecae arranged irregularly in earliest portion of rhabdosome, but in a series arrangement in later stages; about four times as long as wide (1.8 mm. and .4 mm.) overlapping one-half their length, slightly projecting, inclined about 20°, numbering 16 in the space of 10 mm., their ventral walls straight to slightly concave, the apertures round, transverse.

Description of plesiotype.—A slender part of a colony is referred to this Canadian species. It is small and slender with curved stipes with thecae occurring 16 in 10 mm., which is characteristic of *D. kindlei.* Overlap of thecae is one-half or more. In the few stipes discovered, the thecae do not have the regularity of those on the type specimen, nor are the stipes as closely crowded.

Dimensions.—The colony is 18 mm. long and 3.4 mm. wide.

Observations.—This Wilberns specimen is referred to this species because it has several similar characteristics. If more complete colonies were available, doubtless the identification could be made with greater assurance.

Type data.—Holotype, Canada Geological Survey. Plesiotype, University of Oklahoma, Museum of Invertebrate Paleontology.

Type localities.—Holotype, near Corner-of-the-Beach, Gaspé County, Quebec, Canada. Plesiotype, near base of bluff on southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Holotype thought to be Upper Cambrian. Plesiotype, 85 feet below top of Wilberns formation, Upper Cambrian.

Distribution. — Holotype from Gaspé County, Quebec. Plesiotype, near base of bluff at type locality in Mason County, Texas.

DENDROGRAPTUS MINUTUS, n.sp.

Pl. 7, figs. 2, 2a, 3, 3a

Description.—Small shrublike, rather open-branched colonies with parts of the branches relatively wide for the size of the colonies. Branches commonly have a relatively large bifurcation angle which appears rounded as the branches bend together almost to enclose large interspaces. Thecae numerous, 20 or more in 10 mm., and inclined to a low angle. Bithecae are present.

Dimensions.—The two cotypes have lengths respectively of 14.25 and 10.1 mm. and widths of 4.25 and 3.6 mm. The width of branches varies from less than 0.2 to 0.6 mm.

Observations.—These small colonies are similar to *Dendrograptus thomasi,* but they differ from the latter in having wider and more variable branches and much more numerous thecae.

Type data.—Two cotypes, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—Near base of bluff on southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Wilberns formation, Upper Cambrian, about 85 feet below top of the formation.

Distribution.—Known only from the type locality near Mason, Mason County, Texas.

DENDROGRAPTUS THOMASI Ruedemann

Pl. 2, figs. 5, 5a, 6; Pl. 7, fig. 5; Pl. 10, fig. 8

Dendrograptus thomasi Ruedemann, Rudolf, The Cambrian of the upper Mississippi Valley, pt. 3, Graptolitoidea: Bull. Milwaukee Pub. Mus., vol. 12, no. 3, p. 317, Pl. 51, figs. 1-4, 1933.

Original description.—Rhabdosome bush-like, of small size (15 mm.), delicate and somewhat flexuous appearance, the branches uniformly only about .25 mm. thick, dividing quite regularly in intervals of 4.5 mm. under angles of 30°-40°, mostly nearer to 40°; slightly undulating or flexuous. Thecae projecting about 10°, their outer margins straight to slightly concave with transverse apertural margins which are continued into a distinct acute, but short spine. They appear to overlap but little, about one-quarter of their length, and number 16 in the space of 10 mm. Bithecae are present and appear as narrow tubes opening half way between the apertures of the thecae.

Description of three plesiotypes.—The three plesiotypes from Texas have many of the characteristics of the holotypes from South Dakota. They have the thin flexuous branches and bifurcate at the short intervals of about 1 mm. (The bifurcating distance given above is apparently 5 times too much, as the amount given in the description is the amount shown in the specimen which is magnified 5 times.) The colonies are rather open with interspace between branches about 4 times the width of the branches. Thecae occur 16 in 10 mm. and the pointed ends of some of, them extend beyond the edge of the stipes. Bithecae are present. Outer margins of thecae are straight or slightly concave.

Dimensions.—The length of 15 mm. given for the holotype corresponds with that of the figure; the width is 5 mm.

The parts of colonies used as the plesiotypes vary greatly in size. The largest one is 18.4 mm. long by 18 mm. wide, the intermediate one 9 mm. long by 8 mm. wide, the smallest one 7.5 mm. long by 2.13 mm. wide. The stipes generally are 0.25 mm. wide.

Observations.—The largest specimen appears more open than the others. This open appearance is in part due to the fact that some branches are broken out of the middle of the colony. If the identification of the plesiotype is correct, it suggests another relatively long distance correlation from central Texas to South Dakota.

Type data.—Holotype and paratypes, University of Iowa, Iowa City. Plesiotypes, University of Oklahoma, Museum of Invertebrate Paleontology.

Type localities.—Holotype and paratypes, north wall of Whitewood Canyon in the northern part of Deadwood, South Dakota. Plesiotypes from near base of bluff on southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Holotypes and paratypes, Deadwood formation, Upper Cambrian. Plesiotypes, about 85 feet below the top of the Wilberns formation, Upper Cambrian.

Distribution.—Holotype and paratypes from type locality in South Dakota. Plesiotypes from the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Genus CALLOGRAPTUS Hall, 1865

Hall, James, Figures and descriptions of Canadian organic remains, Decade II, Graptolites of the Quebec group: Geol. Survey Canada, pp. 133-134, 1865.

Original description.—Flabellate fronds, with numerous slender bifurcating branches proceeding from a strong stem or axis. Branches and divisions celluliferous on one side, the opposite side striate; sometimes distinctly and irregularly united by transverse dissepiments. The non-celluliferous side sometimes presents a semi-reticulate appearance.

The aspect of these fronds is intermediate between *Dictyonema* and some forms of *Dendrograptus;* but they have not the regular reticulate structure of the former, while the subdivisions of the branches are quite similar to some of the species of that genus. In the mode of branching and the form of cell-apertures, the present genus is quite different from the typical species of *Dendrograptus.*

The slender branches and minute points which indicate the cell-apertures render it impossible, with the specimens in my possession, to determine satisfactorily the characters of the latter; they appear as simple oval impressions upon the surface of the compressed branches.

It is possible that some of the species of this genus may have grown in funnel-shaped fronds, as *Dictyonema.*

CALLOGRAPTUS cf. ANTIQUUS Ruedemann

Pl. 4, figs. 1–3, 1a

Callograptus antiquus Ruedemann, Rudolf, The Cambrian of the upper Mississippi Valley, pt. 3, Graptolitoidea: Bull. Milwaukee Pub. Mus., vol. 12, no. 3, p. 320, Pl. 50, figs. 8, 9, 1933.

Original description.—Rhabdosome of medium size, attaining a length of 30+ mm. Main branches straight to slightly flexuous, about 1 mm. wide giving off side-branches, half as wide, at nearly right angles. Thecae arranged on one side, curved, projecting 40° and becoming free and tubular in the distal half, as described by the writer for the genotype, *C. compactus* Walcott (1925, p. 42); with straight transversal apertures, overlapping about one-half, numbering 10 in 10 mm.

Description of plesiotypes.—The parts of colonies preserved in the Wilberns formation of Texas have much in common with the form from Tennessee. They have the large central stipe from which the branches extend almost at right angle, though most of the central stipes are exfoliated. The gentle curve for most of the branches is also characteristic. Thecae are relatively large and tubular. Some of them are disposed nearly at right angles to the direction of the branches, and they extend for nearly half their length beyond the edge of the branches. Thecae 10 in 10 mm.

Dimensions.—The parts of colonies preserved are much wider than long. Of the three colonies the length is respectively 12, 8, and 8 mm. and the width 20.5, 13.25, and 8 mm. The large exfoliated main stems have a width of 0.75 to 1 mm.

Type data.—Holotype, U. S. National Museum. Plesiotypes, University of Oklahoma, Museum of Invertebrate Paleontology.

Type localities.—Holotype, 1½ miles southeast of Morristown, Tennessee (loc. no. 119). Plesiotypes from near base of bluff on southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Distribution.—At the type locality near Morristown, Tennessee, and near Mason, Mason County, Texas.

CALLOGRAPTUS MINIMUS, n.sp.

Pl. 10, figs. 3, 3a

Description.—A small colony of *Callograptus* differs greatly from other species of this genus, especially by its small size, the irregularity of branching, and the small crowded thecae. The angle of bifurcation of branches varies from 20° to 80°. Some thecae are inclined along the edge of the stipes, but more of them are normal to and extend considerably beyond the edge of the stipe. Those normal to the surface occur 40 to 48 in 10 mm. Some small circular apertures are present on the sides of the stipes. Some larger thecae may represent gonothecae. Bithecae occur at short intervals.

Dimensions.—Length of colony, 15.1 mm.; width, 7.75 mm. Width of stipes, 0.25 to 0.65 mm.

Observations.—This small *Callograptus* approaches quite closely to those apparently tubular stipes of the form *Haplograptus vermiformis.*

Type data.—Holotype, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—Near base of bluff on southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Wilberns formation, Upper Cambrian, about 85 feet below top of the formation.

Distribution.—Known only from type locality near Mason, Mason County, Texas.

CALLOGRAPTUS PLUMMERI, n.sp.

Pl. 1, figs. 1–3, 1a, 1b, 2a, 2b; Pl. 4, figs. 7, 7a, 8, 8a

Description.—Parts of colonies of this new species occur beautifully preserved in the Wilberns. They are highly branched and beautifully symmetrical. They are well preserved and are among the outstanding colonies. They are profusely branched with bifurcation distance of about 2 to 2.5 mm. The colonies are very shrublike. There are central larger stipes from which many orders of smaller branches divide with bifurcation angles of 15° to 30°. Branches diverge slightly, and most of them soon become subparallel. Branches are closely spaced with about 14 in the space of 10 mm. Interspaces are a little wider than adjacent branches. Dissepiments are slender and sparse. Thecae 16 to 20 in 10 mm. with overlap of one-fourth to one-third. While the branches are numerous and closely spaced, the fact that they do not overlap indicates that the colony grew in a single plane.

Dimensions.—The largest part of a colony has a length of 40 mm. and width of 20 mm. Some of the larger stipes are about 1 mm. wide while the smaller ones are only 0.25 mm. wide.

Observations. — These colonies are usually well preserved, so their dark color contrasts strongly with the light shale in which they occur. This species is similar in some respects to the younger *C. staufferi* of Minnesota, but it differs from the latter in having a much shorter bifurcation interval, branches more closely crowded, and thecae smaller and more numerous. They are found practically at the base of the thin graptolite zone which rests on a somewhat irregular surface. Although these forms branch regularly and profusely, they are among the simplest of the dendroid types. The coarser more irregular *C. antiquus* occurs in a slightly higher position near the middle of the narrow graptolite zone, 3 to 4 inches higher. These and still earlier members of this genus may have been the precursors of *Dictyonema* with its many more dissepiments.

Type data.—Cotypes, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—Near base of bluff, southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Wilberns formation, Upper Cambrian, about 85 feet below top of the formation.

Distribution.—Known only from type locality near Mason, Mason County, Texas.

CALLOGRAPTUS SUBTYPICUS, n.sp.

Pl. 10, figs. 19, 19a

Description.—A rather small colony in which there is a larger main stipe with a number of much smaller branches and a few of the third order. Branches are much more slender than the main stipe. Thecae are elongate and tubular, and many of them extend with free ends beyond the general margin of the stipe. Thecae are closely crowded, occurring 28 to 35 in the space of 10 mm. The divergence angle is small, 10° to 15°.

Dimensions.—Length of colony, 20.5 mm.; width, 5 mm. Width of main stipe, 0.5 to 0.75 mm.; width of narrow branches, 0.15 mm. Branching interval generally 1.5 mm.

Observations.—This colony has the general form of a *Callograptus*, and, like *C. plummeri*, it has larger stipes from which much more slender branches diverge. This differs from most later Calligrapti in that in the later forms, after branching begins, all branches are about the same width, and the slender branches maintain the same width throughout their length.

Type data.—Holotype, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—Near base of bluff on southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Wilberns formation, Upper Cambrian, about 85 feet below the top of the formation.

Distribution.—Known only from the type locality, Mason County, Texas.

Genus CALLODENDROGRAPTUS, n.gen.

Description.—This new genus combines the characteristics of a *Callograptus* with those of a *Dendrograptus.* The specimens generally are coarse, having broad irregular main stipes, some of which are nearly straight, but others are curved. Branching is irregular, and the branches are short and thick-set. They remind one of a locust tree after the ends of the limbs have been broken off by the wind.

Three kinds of thecae are present: the thecae are either inclined or normal to the stipes serving for regular feeding polyps, elongate slender bithecae, and enlarged thecae either swollen or elongate which are thought to represent gonothecae. *Callodendrograptus sellardsi,* the most common and characteristic species under the genus, is designated as the genotype.

CALLODENDROGRAPTUS ELONGATUS, n.sp.

Pl. 9, fig. 11; Pl. 10, fig. 7

Description. — Two especially long stipes were secured that show no sign of branching throughout their length. They are narrow elongate and nearly straight. Part of the thecae are inclined at a low angle; others are normal to the edge of the stipe. They seem something like Ruedemann's *Dendrograptus sparsus* but have small, much more numerous thecae. Besides the regular thecae, bithecae are present as well as some enlarged structures which may be gonothecae. Thecae occur 25 to nearly 50 in 10 mm.

Dimensions.—The largest stipe has a length of 27.5 mm. and a width of 0.75 mm. The smaller stipe is 15.2 mm. long and 0.25 mm. wide with no branches in evidence.

Observations.—These appear to be very long narrow colonies which show no evidence of branching. Conceivably, these might be branches of other colonies, but few branches maintain their identity without developing branches of a lower order. Possibly a number of small linear fragments may belong to this species.

Type data.—Cotypes, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—Near base of bluff on southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

CALLODENDROGRAPTUS ROBUSTUS, n.sp.

Pl. 6, figs. 9, 10; Pl. 8, fig. 6; Pl. 9, figs. 2, 2a, b, 5, 6, 6a, b

Description.—Colonies with relatively short, broad main stipes and relatively few branches. The bifurcation angle is generally small, 20° to 30°, but for a few it is larger. Most branches are short and stubby, but one colony has a longer branch. The thecae vary greatly in size, shape, and orientation. Besides regular thecae, bithecae, and gonothecae, there are clusters of short tubes around the apertures of some of the best specimens of the swollen (gonothecal) tubes (Pl. 9, figs. 2a, 2b). These probably housed nematocysts.

Dimensions.—The length of the colonies varies from less than 10 mm. to 10.35, 12.5, 18.5, and 19 mm.; width, 7 mm. or less. The lower part of the main stipe has a width of 2.12 mm., and the width of that stipe may continue that wide for considerable distance distally.

Observations.—The short colonies are very noticeable because of the width of the stipes. They are fairly common in the Wilberns as six colonies were secured and are illustrated. Possibly some of these broad, short colonies were the precursors of some of the larger types of *Dictyonema.*

Type data.—Cotypes, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—Near base of bluff on southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Wilberns formation, Upper Cambrian, about 85 feet below the top of the formation.

Distribution.—Known only from the type locality near Mason, Mason County, Texas.

CALLODENDROGRAPTUS ROGERSI, n.sp.

Pl. 5, figs. 6, 6a

Description.—The large basal part of this colony is exfoliated, but it still has sufficient diagnostic characteristics to describe the species. It is a coarse form with broad stipes, some of which are ribbed with the interlocking thecae and bithecae. The branches diverge at angles of 10° to 45° with most of them near the larger angle. Bifurcation occurs at 2 to 3 mm. Thecae are disposed at angles of 20° to 60°, and some long slender bithecae are present. Thecae occur 16 to 20 or more in 10 mm., and on some stipes apertures occur on both margins. In one part, a little above the middle of the colony, thecae opening in opposite directions seem to interlock in the center something as those do in the Ordovician biserial *Diplograptus (Amplexograptus) amplexicaulus* (Hall).

Dimensions.—Monotype, length of part of colony, 23 mm.; length of longest main branch, 17 mm.; width, 8.5 mm. (above base, 10.5 mm.); width of larger branches, 1 to 1.25 mm.; width of narrow branches, 0.5 mm.

Observations.—Most of the branches of this colony are wide, and the surface is very characteristically ribbed with the interlocking of thecae and bithecae. In detailed enlarged drawings of *Callograptus salteri* and *C. hopkinsoni*, Bulman[27] shows how the elongate thecae and bithecae may be responsible for such ribbing. An enlarged part of the right branch of this colony (Pl. 5, fig. 6a) shows a condition similar to that noted above in Bulman's illustrations.

Type data.—Holotype, University of Oklahoma, Museum of Invertebrate Paleontology. The species name is given in honor of Paschal Rogers on whose ranch the graptolites are found.

Type locality.—Near base of bluff, southeast side of Honey Creek, 9 miles southwest of Mason, Mason County, Texas.

Distribution.—Known only from the type locality in Mason County, Texas.

CALLODENDROGRAPTUS SELLARDSI, n.sp.

Pl. 1, figs. 4, 4a; Pl. 4, fig. 5; Pl. 6, figs. 3, 5–8; Pl. 8, figs. 1, 1a, 5; Pl. 9, figs. 3, 3a, 10

Description. — Large, strong central stipes which vary from nearly straight to markedly curved. Most of the branches are short and thick-set. Bifurcation interval about 2 to 3.5 mm. Bifurcation angle varies from 10° to 45° or more, most commonly 20° to 30°. Attitude of thecae is variable; some are inclined at angles of 20° to 30°; others are normal to the edge of the stipe. Some occur on the face of the stipe. Thecae which belonged to the regular feeding polyps are most numerous, but bithecae occur, as do also some larger thecae which may represent gonothecae. Thecae 20 to 25 in 10 mm.

Dimensions.—Length of colonies varies from a few mm. to nearly 30 mm.; width varies also from a few mm. up to nearly 10 mm. Width of larger stipes, 1.25 mm.

Observations.—This is the most common and best-preserved species collected from the Wilberns formation. Accordingly, about a dozen colonies are illustrated to show variation in form. Some of these colonies resemble the general form of the specimen from a higher horizon at Afton, Minnesota, illustrated by Ruedemann[28] as *Callograptus staufferi*. Possibly this earlier Texas species may be a precursor of the higher Minnesota form which was found in the Lodi shale.

Type data.—All cotypes, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—All cotypes are from a short distance above base of bluff on the southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Wilberns formation, Upper Cambrian, about 85 feet below the top of the formation.

Distribution.—Known only from the type locality near Mason, Mason County, Texas.

CALLODENDROGRAPTUS SELLARDSI var. EXPANSUS, n.var.

Pl. 4, figs. 4, 6, 6a; Pl. 7, fig. 8; Pl. 8, figs. 2–4

Description.—This variety is much like the species *sellardsi* except that it spreads widely in primary branches that diverge almost at right angles. Branches of the second and third orders are like those in *C. sellardsi* with divergence of 20° to 45°.

[27]Bulman, O. M. B., A monograph of British dendroid graptolites, Part III: Paleontographical Soc. London, vol. 86, pp. 85, 86, text figs. 40b, 41a, c, 1934.

[28]Ruedemann, Rudolf, The Cambrian of the upper Mississippi Valley, pt. 3, Graptolitoidea: Bull. Milwaukee Pub. Mus., vol. 12, no. 3, pl. 50, fig. 6, 1933.

Type data, locality, horizon, and distribution are like those of the species *sellardsi*.

CALLODENDROGRAPTUS SEMICIRCULARIS, n.sp.

Pl. 9, figs. 4, 4a, 7, 7a, 12; Pl. 10, fig. 17

Description. — Several specimens are characterized primarily by the presence of long semicircular thecae at intervals along the stipe and by great irregularity of other thecae. The sparsely branched form of Plate 9, figures 4, 4a, 12, and the form shown in Plate 10, figure 17, are taken as the cotypes of the species. Thecae about 20 in 10 mm. Besides the regular thecae, bithecae, and the peculiar semicircular thecae, there are some large swollen ones which are thought to be gonothecae.

Dimensions.—The more complete colony measures 21.75 mm. long and 8.5 mm. wide. The thickness of stipes varies from 0.33 to 0.93 mm. Some of the unbranched stipes measure 8.7 mm. in length and 0.25 to 0.5 mm. in width; one measures 4.2 long and 0.75 mm. wide. Semicircular thecae are 1 mm. long.

Observations.—These elongate curved thecae are so different from other thecae that the forms bearing them are given specific rank. The purpose of these curved thecae is not known. Some of them near the proximal end look as though they were represented only by the impression of part of the polyp. Particularly is this true in the more highly magnified part of Plate 9, figure 4a.

Type data.—Cotypes, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—Near base of bluff on southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Wilberns formation, Upper Cambrian, about 85 feet below top of the formation.

Distribution.—Known only from the type locality near Mason, Mason County, Texas.

Genus DICTYONEMA HALL, 1851

Note by the editors on "New Genera of Fossil Corals" from the report by James Hall on Paleontology of New York: Amer. Jour. Sci., 2d ser., vol. 11, art. 45, p. 401, 1851. (Called a bryozooid.)

Genolectotype—*Gorgonia retiformis* Hall, Rept. 4th Geol. Dist., New York, p. 115, 1843.

Genus *Dictyonema,* Hall, James, Niagara group, *in* Paleontology of New York, vol. 2, p. 174 (1851), 1852.

Original description.—Frond circular or flabelliform, composed of slender radiating branches which frequently bifurcate as they extend toward the margin; branches and subdivisions united laterally by fine transverse dissepiments; branches impressed with deep striae or grooves, producing indentations that sometimes have an elongated rhomboidal form; axis subcalcareous with a corneous exterior.

The general structure of this coral is very similar to *Fenestella* in its diverging bifurcating branches with black threads united laterally by finer ones leaving quadrangular interstices. One species forms large circular fronds sometimes a foot in diameter, while the other has been seen only in flabellite forms. The branches of these corals consist of a black film enveloping a semi-calcareous or corneous interior, and they have the appearance and texture of graptolites, to which they are doubtless closely allied. A single branch, where the lateral connection with others is broken off, can scarcely be distinguished from some species of graptolites.

Observations.—While in these earlier descriptions Hall[29] classed *Dictyonema* as a coral, fourteen years later he placed it in the graptolite group and indicated that there is an almost insensible gradation from *Callograptus* to *Dictyonema.*

DICTYONEMA EOMINNESOTENSE, n.sp.

Pl. 5, fig. 8, 8a

Description.—Only the upper part of the colony is preserved as in the case also with the *Dictyonema minnesotense* Ruedemann.[30] The branches are narrow and diverge at a small angle, and they occur 10 to 12 in the space of 10 mm. Bifurcation takes place at short intervals, only 4 mm. Dissepiments are thin and relatively rare. Branches are subparallel. Thecae are small and numerous, occurring 24 to 40 in 10 mm.

Dimensions.—Height of part preserved, 9 mm.; width, 12 mm.; width of branches, 0.25 to 0.5 mm.

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[29]Hall, James, Figures and descriptions of Canadian organic remains, Decade II, Graptolites of the Quebec group: Geol Survey Canada p. 12, 1865.

[30]Ruedmann, Rudolf, The Cambrian of the upper Mississippi Valley, pt. 3, Graptolitoidea: Bull. Milwaukee Pub. Mus., vol. 12, no. 3, p. 321, Pl. 55, fig. 3, 1933.

Observations.—This earlier species has the same general form as *D. minnesotense*, but it has slightly narrower branches, bifurcates at much shorter intervals, and has much smaller, more closely set thecae.

Type data.—Holotype, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—Near base of bluff on southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Wilberns formation, Upper Cambrian, about 85 feet below the top of the formation.

Distribution.—Known only from locality on southeast side of Honey Creek, 9 miles southwest of Mason, Mason County, Texas.

DICTYONEMA FLEXIBILIS, n.sp.

Pl. 5, fig. 4

Description.—This species is characterized by its flexible, curved stipes, its few thin dissepiments, and its relatively large meshes. The thecae are elongate and tubular, and they are inclined at an angle of 30° to 40°; they occur 20 in 10 mm. A few bithecae are present.

Dimensions. — Holotype, incomplete specimen, length, 13.75 mm.; width, 17 mm. The width of the stipes varies from 0.3 to 0.75 mm. The meshes are irregular. Smaller ones have dimensions of 0.5 mm. by 1.25 mm. and the larger ones 1.75 mm. by 4 mm.

Observations.—A few smaller fragments of this species were found, but they are too small to be of value for illustration.

Type data.—Monotype, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—Near base of bluff on the southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Wilberns formation, Upper Cambrian, about 85 feet below the top of the formation.

Distribution.—Found only at the type locality near Mason, Mason County, Texas.

DICTYONEMA MAXIMUS, n.sp.

Pl. 5, figs. 2, 2a, 7

Description.—Holotype (Pl. 5, fig. 2): Expanded basal part preserved; almost solid V-shaped part of colony above the base due to joining of lower part of the branches by anastomosing. This part has only a few narrow elongate meshes. In the middle and upper parts of the colony only the central branches are preserved. A few slender dissepiments are present, but most of them are wider, being formed by anastomosing. The main branches are wide, and meshes in the upper part of the colony are large. While some of the thecae are disposed at a low angle, 15° to 30°, along the edge of the branches, most of them are nearly at right angles with the stipe. They occur 20 to 24 in 10 mm. A paratype, a small part of another colony, is shown in Plate 5, figure 7. It is of little value except to show that another specimen with branches characteristic of the species was present.

Dimensions.—Length, 36.5 mm.; width, 12.5 mm.; width of branches, 0.25 to 1.25 mm. Meshes vary from 0.25 to 1.25 mm. in the lower part to 1 by 3.5 mm. in the upper part.

Observations.—The basal and central parts of this large colony are well preserved except that two of the main branches are exfoliated for a distance of about 5 mm. This large form, together with five other species in this genus, shows that the characteristics of *Dictyonema* had become extremely varied even in this early graptolite zone. In some respects this *Dictyonema* is much like a *Callograptus* in that the thecal apertures appear on both sides of some of the larger stipes. Some of the thecae are disposed almost at right angles to the margin of the stipe, and part of them protrude beyond the margin of the stipe.

As to orientation of the colonies, Bulman[31] has indicated that some of the *Dendroidea* were provided with either nema and disc or several slender fibers for attachment to floating objects. Forms attached in these ways were oriented with the proximal end up and with expanding

[31]Bulman, O. M. B., Graptolithena: Handbuch der Paläozoologie (O. H. Schindewolf), Lf. 2 (Bd. 2D), p. D9, 1938.

branches extending downward. These then were free to be carried to all parts of the seas open to them. However, it is thought that most of the *Dendroidea* developed either an enlarged basal part or several rootlike strands for attachment to the bottom of the sea, and from these attachments the branching stipes grew upward. Distribution of species whose colonies were attached to the bottom doubtless was accomplished during the reproductive stages when the young were free to move and to be carried by currents. Possibly some of the tiny young forms were light enough to rise to or near the surface of the ocean for a sail on the sea before they settled down to colony building.

Type data.—Holotype and paratype, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—Near base of bluff, southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Wilberns formation, Upper Cambrian, about 85 feet below the top of the formation.

Distribution.—Known only from the type locality in Mason County, Texas.

DICTYONEMA cf. SCHUCHERTI Ruedemann

Pl. 5, fig. 3

Dictyonema schucherti Ruedemann, Rudolf, The Cambrian of the upper Mississippi Valley, pt. 3, Graptolitoidea: Bull. Milwaukee Pub. Mus., vol. 12, no. 3, p. 321, Pl. 54, figs. 1, 2, 1933.

Original description.—Rhabdosome probably infundibuliform or broadly flabellite; of small to medium size possibly reaching a length of 30+ mm. and a width of 50 mm. Branches fairly frequently dividing, subparallel, about .5 mm. wide, connected by stout curved dissepiments, that with the branches form square to shortly rectangular meshes, about as wide as the branches or wider. Thecae disposed on one side of the branches, simple straight tubes, closely arranged and numbering 20–16 in 10 mm.; with straight, transverse apertures. Bithecae not observed.

Description of plesiotype.—This species is represented in the Wilberns of Texas by only a part of a single colony. However, the size and shape of the branches, the size and number of the thecae, and the shape of the meshes seem close enough to refer it to the described species. Thecae are simple tubes along the sides of the branches at an angle of 50° to 60° and occur 20 or more in 10 mm.

Dimensions.—Height of holotype, 30 mm.; width, 26 mm.; width of branches, 0.5 to 0.75 mm.; length of meshes, 1.5 to 3 mm.; width of meshes, 0.5 to 1.25 mm. The plesiotype fragment has a height of 6 mm. and a width of 5.5 mm., and the meshes have a length of about 2.5 mm. and width of 0.75 mm. The width of branches varies from 0.5 to 0.65 mm.

Observations. — While the plesiotype represents only a small part (about one-fifth) of a colony, the characteristics of branches, meshes, and thecae are so similar that it may well be referred to the species.

Type data.—Plesiotype, figured specimen (Pl. 5, fig. 3), University of Oklahoma. Museum of Invertebrate Paleontology.

Type locality.—The holotype locality is about 1 mile northwest of Highgate Center, Vermont. The plesiotype is from the Paschal Rogers ranch about 9 miles southwest of Mason, Mason County, Texas, near the base of a cliff on the southeast side of Honey Creek.

Geologic horizon.—The holotype was at first reported from the Colchester formation in the Lower Cambrian, but later this was changed to the Russell slate in the Upper Cambrian. The plesiotype is from a shale about 85 feet below the top of the Wilberns formation in the Upper Cambrian.

Distribution.—Only at the holotype and plesiotype localities.

DICTYONEMA cf. WYOMINGENSE Ruedemann

(Corrected from DICTYONEMA cf. MINNESOTENSE)

Pl. 5, figs. 10, 10a, 11, 11a

Dictyonema cf. minnesotense, Ruedemann, Rudolf, The Cambrian of the upper Mississippi Valley, pt. 3, Graptolitoidea: Bull. Milwaukee Pub. Mus., vol. 12, no. 3, pp. 322, 323, text figs. 1–4, 1933.

Original description.—The rhabdosome is frequently branching, the bifurcations about 3 mm. apart and 10° to 20° wide, the resulting branches remaining subparallel and separated by interspaces not wider than the branches. The branches are narrow, only .56 mm. wide. The thecae are little prominent, diverging at angles of about 20° and numbering 16 in the space of 10 mm.

Description of two plesiotypes.—Elongate parts of two colonies which occur in the Wilberns of Texas have been assigned to this species. The branches are narrow and they bifurcate at intervals of 2 to 4 mm. The bifurcation angle is small, about 10° to 20°, and the branches remain subparallel. Dissepiments are thin and few. Thecae are simple and tubular; they diverge at angles of 20° to 30°, and they occur 16 in the space of 10 mm.

Dimensions.—The larger of the two colonies has a length of 27.5 mm. and a width of 7 mm.; it has 12 to 14 branches in the space of 10 mm. The smaller colony has a length of 22.5 mm. and for nearly half of its length a width of 2.5 mm. One diverging branch at the top increases the width there to 9 mm.

Observations.—Described first as *Dictyonema* cf. *minnesotense.* In a statement correcting a number of mistaken horizons in his Milwaukee bulletin Ruedemann[32] indicated that the name would be changed to *Dictyonema wyomingense.* The Wilberns specimens fit well the description of this species by Ruedemann, though neither of the specimens has an enlarged basal part attached. In Ruedemann's figures there are only the expanded basal parts with three stubs of branches attached and two separate fragments of branches having a length of 6.25 and 9.25 mm. respectively.

Type data.—Two plesiotypes, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—Holotype, north side of Shoshone Canyon, just above the bridge, west of Cody, Wyoming. Plesiotypes, near base of bluff, southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Holotype, name of Upper Cambrian formation not given. Plesiotypes, Wilberns formation, Upper Cambrian, about 85 feet below top of the formation.

[32]Ruedemann, Rudolf, Cambrian graptolites: Science, n.s., vol. 80, no. 2062, p. 15, 1934.

Distribution.—Holotype, only type locality. Plesiotypes, only from Mason County, Texas.

DICTYONEMA sp.

Pl. 5, fig. 9

Description.—As only a few small fragments of this *Dictyonema* have been found it is not designated by a species name. However, it is clearly different from any other Wilberns species of this genus. The branches are subparallel and occur in a broad open curve. The dissepiments curve concentrically from one side of the stipes, and they resemble extensions of apertural spines. These extensions are similar to those of *Dictyonema flabelliforme* shown by Ruedemann[33] for a Schaghticoke form. Thecae occur along the margin of the stipes about 36 to 40 in 10 mm.

Dimensions.—For the small fragment of a colony, length, 9 mm.; width, 2.5 mm.; width of stipes varies from 0.25 to 0.5 mm.; and the interspaces are a little wider than the stipes which remain subparallel.

Observations.—This small fragment is clearly part of a *Dictyonema,* and it is distinctly different from others in this horizon. In fact it seems to approach more nearly than the others to the more regular types of *Dictyonema* which occur in the upper part of the Upper Cambrian, in Lower Ordovician, and in still higher zones.

Type data.—Specimens, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—Near base of bluff on southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Distribution.—Known only from the type locality, Mason County, Texas.

Genus ASPIDOGRAPTUS Bulman, 1934

Bulman, O. M. B., A monograph of British dendroid graptolites, Part III: Paleontographical Soc., vol. 86, p. 69, 1934.

Because of marked complications in the use of the terms *Clematograptus* and *Am-*

[33]Ruedemann, Rudolf, Graptolites of New York, pt. 1, Graptolites of the lower beds: New York State Mus., Mem. 7, p. 602, text fig. 27, 1904.

phigraptus, Bulman proposed the new genus name of *Aspidograptus* and described it as follows:

Diagnosis.—Rhabdosome apparently bilaterally symmetrical, branching laterally from principal stipe; these are strongly curved and the lateral branches closely set and irregularly produced, but arising from the convex sides of the principal stipes and bifurcating repeatedly at short intervals; the rhabdosome is always so preserved as to be discoidal, with the stipes spread out in a radiating manner. Dissepiments rarely developed.

The genotype is taken as *Clematograptus implicatus*, Hopkinson, 1875.

ASPIDOGRAPTUS sp.

Pl. 10, figs. 9–14

Description.—Only fragmentary parts of rhabdosomes have been collected; hence no species is described. Yet numerous fragments occur which seem to belong to this genus. Some of them represent about one-fourth of a colony, but none has been found attached to a main central curved stipe. These are small bushlike forms in which bifurcation is at the short distance of 1.25 mm. Thecae occur 20 to 24 in 10 mm.

Dimensions.—The parts of colonies measure about 8.5 to 9 mm. in length and 5 mm. in width. The branches are numerous and short.

Observations.—If these fragments are parts of an *Aspidograptus*, they are the first representatives of this genus to be found in the Cambrian, though Bulman has listed this genus as possibly Cambrian. Heretofore this genus has been known only from the Lower Ordovician in Great Britain where two species occur, *A. implicatus* and *A. minor*. The Wilberns specimens from Texas seem more like the latter smaller species.

Type data.—All specimens, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—Near base of bluff on southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Wilberns formation, Upper Cambrian, about 85 feet below the top of the formation.

Distribution.—Known only from the type locality near Mason, Mason County, Texas.

Class HYDROIDA

Genus HAPLOGRAPTUS Ruedemann, 1933

Description.—This genus is used for a number of species which under low magnification appear as simple tubelike structures but which upon higher magnification are shown to have numerous tiny thecae. Some of the forms from Minnesota and Wisconsin are described by Ruedemann as *Haplograptus wisconsinensis* and from Tennessee as *H. vermiformis*.

HAPLOGRAPTUS VERMIFORMIS Ruedemann

Pl. 3, figs, 9, 9a, b; Pl. 9, fig. 1

Description.—The small simple colonies are sparsely branched with bifurcation angle varying from 30° to 90°. Under low magnification the branches look like simple tubes. Higher magnification reveals the presence of numerous small thecae which are closely crowded; those normal to the surface, 48 in 10 mm.; elongate slender ones inclined at 30°, 32 in 10 mm. The latter slender ones may represent bithecae or nematophores. Also higher magnification reveals the presence of numerous small circular apertures on the surface of the stipes.

Dimensions.—The largest part of a colony of this species measures 12.1 mm. long and 7 mm. wide. The longest branch has a length of 5 mm. Width of stipes, 0.5 mm.

Observations.—As the tubelike structures in this species are similar to the coenosarcal canals in Hydrozoa, these forms are here shifted into the hydrozoan group. These tubelike stipes are like those described by Ruedemann as *Haplograptus vermiformis*.

Type data.—Plesiotypes, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—Near base of bluff on southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Wilberns formation, Upper Cambrian, about 85 feet below the top of the formation.

Distribution.—Known only from the locality near Mason, Mason County, Texas, and from the Nolichucky shale at the type locality 10 miles east of Knoxville, Tennessee.

Genus ACANTHOGRAPTUS Spencer, 1878

Spencer, J. W., Niagara fossils: Trans. St. Louis Acad. Sci., vol. 4, no. 4 (1878–1886), pp. 555–610, 1886; revised description, p. 581, May, 1884. Original brief description in Spencer, J. W., Graptolites of the Niagara formation: Canada Nat., n.s., vol. 8, no. 8, 1878.

Revised description.—Frond shrub-like, consisting of thick branches, principally rising from near base, with little divergence and some bifurcations. One side of the branches, furnished with prominent spines or denticles, appearing to mark the position of the apertures of the cells. Texture corneous, and indistinctly striated longitudinally.

ACANTHOGRAPTUS sp.

Pl. 7, fig. 4

Description of plesiotype.—As only a small fragment of a colony was secured, no specific name is given. However, it shows the elongate tubular denticles characteristic of the genus. Denticles occur about 20 in 10 mm. Denticles are about 0.7 mm. long, and they extend almost that much beyond the margin of the stipe.

Dimensions.—Very small part of a colony, single stipe, a little over 6 mm. in length and about 0.5 mm. in width, but at the ends of the thecae the total width is about 1 mm.

Type data.—Species not described, representative of the genus, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—Near base of bluff on the southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Wilberns formation, Upper Cambrian, about 85 feet below the top of the formation.

Distribution. — *Acanthograptus priscus* occurs at Afton, Minnesota. The small fragment of a stipe is from the type locality near Mason, Mason County, Texas.

Genus CHAUNOGRAPTUS Hall, 1879

Dendrograptus (Chaunograptus) novellus Hall, James, Abstract: Trans. Albany Inst., vol. 10, p. 2, 1879.

Genotype. — *Chaunograptus novellus* Hall,[34] the description of which serves as description for the genus as follows:

Fossil occurring free in the shales, or upon other fossil bodies, in slender branching fronds. Branches diverging, lax and slender, with numerous branchlets, both marked by numerous cellules which are usually indicated by the appearance of abrupt expansion and contraction of the branches. The angular projection of the cell-aperture can be observed in many parts of the fossil.

This species is more lax and diffuse than any form of *Dendrograptus* known, and therefore has been separated from the typical forms of the genus. It occurs free among other fossils, or attached to some fragmentary portions of other bodies. In its habit of growth it is quite distinct from any of the forms heretofore illustrated, and it is probable it belongs to a division of the Hydrozoa which has not been recognized in the Paleozoic formations.

CHAUNOGRAPTUS IRREGULARIS, n.sp.

Pl. 3, figs. 11, 12; Pl. 5, fig. 5; Pl. 6, figs. 1, 2

Description.—The species name *irregularis* is given to a series of colonies in most of which the hydrothecae are arranged irregularly attached to a crooked, sparsely branched, threadlike structure which doubtless was tubular. Two small colonies (Pl. 3, fig. 11, and Pl. 5, fig. 5) are more regular in general form and simulate in their branching that of the more delicate Dendroidea. In some of the colonies the hydrothecae are oriented in all sorts of directions and some larger swollen structures are thought to represent gonothecae.

Dimensions. — The colonies of the cotypes vary greatly in size—length, 1.75 to 6 mm.; width, 0.75 to 2 mm. The hydrothecae are tiny and have length of 0.15 mm. to 0.375 mm.

Observations.—Colonies of these tiny forms are scattered over the surface of a number of slabs, and they show up best when magnified 16 to 20 times. In one of the colonies (Pl. 6, fig. 1) the hydrothecae are considerably smaller than those

[34] Hall, James, Descriptions of the species of fossils found in the Niagara group at Waldron, Indiana: Indiana Dept. Geol. Nat. Hist., 11th Ann. Rept., 1881, p. 225, Pl. 1, figs. 1, 2, 1882.

in other colonies. Colonies of this genus extend from this early zone in the Wilberns up through Ordovician and Silurian into the Lower Devonian without much change in their general form, and even those in the Middle Cambrian of Australia are quite similar to the later forms.

Chapman and Thomas[35] class *Chaunograptus* definitely as a hydroid together with *Acanthograptus, Cactograptus, Mastigograptus,* and *Thallograptus,* all of which they found in the Middle Cambrian of Australia. The chief reason for calling these forms hydroids rather than graptolites is that they have gonothecae developed along the sides of the stipes. However, there has been no suggestion that graptolites with gonothecae[36] grouped around their pneumatocysts be classed as hydrozoans. In fact, the problem of distinguishing hydrozoans from graptolites becomes a difficult one when they occur together in the same zone, particularly as their exterior characteristics and method of preservation seem identical. Especially does this problem become acute when one finds that certain of the Dendroidea have three different kinds of thecae along their stipes, namely thecae for regular feeding polyps, elongate slender bithecae, and enlarged thecae of various shapes which are thought to represent gonothecae. This condition seems most prevalent in forms assigned to the new genus *Callodendrograptus.*

Type data.—Cotypes, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—Near base of bluff on southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Wilberns formation, Upper Cambrian, about 85 feet below the top of the formation.

Distribution.—Known only from the type locality, 9 miles southwest of Mason, Mason County, Texas.

[35]Chapman, Frederick, and Thomas, D. E., The Cambrian Hydroida of the Heathcote and Monegeeta districts: Proc. Royal Soc. Victoria, vol. 48 (n.s.), pt. 2, p. 204, Pl. 16, fig. 23, 1936.

[36]Ruedemann, Rudolf, Development and mode of growth of *Diplograptus* McCoy: New York State Mus., 48th Ann. Rept., vol. 2, p. 228, Pls. 1-5 (1894), 1895 [1897].

CHAUNOGRAPTUS PALAEODICTYOTOIDES, n.sp.

Pl. 3, figs. 10, 10a

Description.—In the Wilberns of Texas a small colony of *Chaunograptus* is assembled in the general form of *Palaeodictyota buffaloensis* illustrated by Ruedemann[37] from the Silurian of New York; hence the name given to the new species. The illustrations in Plate 3, figures 10, 10a, are from opposite views of the same colony. The colony is nearly circular, and the meshes are circular to oblong. In the New York Silurian form no thecae seem distinguishable, while in the one from the Wilberns small wedge-shaped thecae are clearly visible. These wedge-shaped thecae are assembled in an irregular manner around the open meshes.

Dimensions.—The Wilberns colony is small with a diameter of only 4.5 mm.; diameter of meshes, 0.75 to 1 mm.

Observations.—Only a single colony of this species has been found in the Wilberns, though parts of quite a number of colonies of *C. irregularis* occur.

Type data.—Holotype, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—Near base of bluff on southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Wilberns formation, Upper Cambrian, about 85 feet below the top of the formation.

Distribution.—Known only from the type locality, 9 miles southwest of Mason, Mason County, Texas.

Genus ARCHAEOCRYPTOLARIA Chapman, 1919

Chapman, Frederick, On some hydroid remains of Lower Paleozoic age from Monegeeta near Lancefield: Prod. Royal Soc. Victoria, vol. 30, p. 392, 1918.

Original description of genus.—Hydrocaulus slender, more or less erect or slightly flexuous, length up to about 30 mm. Hydrothecae cylindrical or long-conical, narrowing very slightly toward the base; adnate and attached for some distance along the axis; aperture circular and lip slightly everted. Periderm coarsely wrinkled

[37]Ruedemann, Rudolf, Some Silurian (Ontarian) faunas of New York: New York State Mus., Bull. 265, p. 33, text fig. 20, 1925.

or scaly. Gonothecae elongately pyriform and incurved to the axis.

ARCHAEOCRYPTOLARIA GONOTHECATUS, n.sp.

Pl. 5, figs. 1, 1a; Pl. 9, figs. 8, 9; Pl. 10, figs. 2, 4, 5

Description. — Small though rugged sparsely branched colonies with many swollen gonothecae. A few hydrothecae are irregularly placed. Bifurcation angle large, 45° to 70°.

Original description of similar Australian species *A. flabelloides*[38] follows:

Description of Australian holotype.—Stem stout, erect, and branching off of both sides; the branches bear long and slender hydrothecae. The form and habit closely recall *Cryptolaria flabellum.*

Dimensions.—Length of colonies, 23 and 8.8 mm.; width, 4.25 mm. Width of main stipe, 0.25 mm. Length of gonothecae, 0.75 mm.; width, 0.25 to 0.35 mm.

Observations.—It is noteworthy that two types of fossil hydrozoans occurring in the Wilberns of Texas have some similarity to Middle Cambrian Australian forms.

Type data.—Cotypes, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—Near base of bluff on southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Wilberns formation, Upper Cambrian, about 85 feet below the top of the formation.

Distribution.—Known only from the type locality near Mason, Mason County, Texas.

ARCHAEOCRYPTOLARIA SIMPLICIMUS, n.sp.

Pl. 10, figs. 15, 16, 18, 18a, 20, 21

Description. — Five elongate, slender, unbranched cotypes are shown. In these the hydrothecae are placed end to end with little if any overlap, and they occur 14 to 16 in 10 mm. Ends of some hydrothecae project beyond the margin of the stipe. A few swollen gonothecae are present and also a few bithecae.

Dimensions.—The longest colony has a length of 12.5 mm., two 10.25 mm., one 8.1, and the shortest one 5.5 mm. The stipes are 0.25 mm. wide.

Observations. — These specimens are very similar to *A. recta* illustrated by Chapman and Thomas[39] from the Middle Cambrian of Victoria, Australia. A significant feature of two colonies is an initial hydrothecae from which the colony buds out. Budding takes place on one side of this initial structure near its aperture. This is very similar to the sicula of typical graptolites. However, this main axis of this initial hydrothecae is normal to instead of parallel with the direction of the stipe.

Type data.—Cotypes, University of Oklahoma, Museum of Invertebrate Paleontology.

Type locality.—Near base of bluff southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas.

Geologic horizon.—Wilberns formation, Upper Cambrian, about 85 feet below the top of the formation.

Distribution.—Known only from the type locality near Mason, Mason County, Texas.

Class VERMES

Pl. 8, figs. 7, 8

Two worms occur with the graptolites, and they look as though they were in a position for copulation. They have a length of about 9 mm. and vary in width from 0.75 to 2.1 mm. Some extensions on one side look like setae, and some small circular openings may represent nephridia.

Class BRACHIOPODA

Numerous small circular brachiopods of the general *Acrotreta* type with a diameter of about 4 mm. occur from about 40 feet below the graptolite zone to about 10 feet above the zone.

[38]Chapman, Frederick, and Thomas, D. E., The Cambrian Hydroida of the Heathcote and Monegeeta districts: Proc. Royal Soc. Victoria, vol. 48 (n.s.), pt. 2, p. 199, Pl. 14, fig. 4, 1936.

[39]*Idem*, p. 198, Pl. 14, fig. 1, 1936.

Class TRILOBITA

PROSAUKIA TUBERCULATA Ulrich and Resser

Pl. 9, fig. 14

Prosaukia tuberculata Ulrich, E. O., and Resser, C. E., The Cambrian of the upper Mississippi Valley, pt. 2, Trilobita, Saukiinae: Bull. Milwaukee Pub. Mus., vol. 12, no. 2, p. 159, Pl. 28, fig. 5, 1933.

Description.—The specimen from the graptolite zone in the upper Wilberns formation of Texas seems to agree in all respects with the type form from Wisconsin. It has a relatively large glabella on which the two furrows are deep at the sides and slightly developed on top. The tubercles are large and closely spaced.

Observations.—This species occurs with *Chariocephalus whitfieldi*[40] and *Ptychaspis* sp., and these three associated forms have great significance in assisting with the correlation.

Type data.—Plesiotypes, University of Oklahoma, Museum of Invertebrate Paleontology.

Type localities. — Trempealeau and Reedsburg, Wisconsin, and near Mason, Mason County, Texas.

Geologic horizon.—About 85 feet below the top of the Wilberns formation of Texas, Fort Sill formation of Oklahoma, and Franconia formation of Wisconsin.

Distribution.—Near base of bluff on southeast side of Honey Creek on the Paschal Rogers ranch, 9 miles southwest of Mason, Mason County, Texas; sec. 28, T. 6 N., R. 14 W., on the north side of the Wichita Mountains, Oklahoma; near Trempealeau and Reedsburg, Wisconsin.

CHARIOCEPHALUS WHITFIELDI
Ulrich and Resser

Pl. 9, fig. 15

Chariocephalus whitfieldi Ulrich, E. O., and Resser, C. E., The Cambrian of the upper Mississippi Valley, pt. 2, Trilobita, Saukiinae: Bull. Milwaukee Pub. Mus., vol. 12, no. 2, p. 264; Pl. 24, fig. 3 (middle), 1933.

Description.—This species has a glabella rather evenly rounded but a little wider at the front than at the rear; 3.5 and 3 mm. wide and 3.5 mm. long, slightly convex or almost flat with glabellar sutures effaced. Occurs sparsely with *Prosaukia tuberculata* in zone noted above.

Class MEROSTOMATA

Pl. 9, fig. 13

In addition to the trilobites, a poorly preserved cephalon and a partial outline of the abdomen of a merostome occur in the graptolite zone with the trilobites in the Wilberns formation of Texas. In shape it looks something like the much later form *Aglaspella eatoni*[41] from the Lodi shale member of the Trempealeau formation near Prairie du Sac, Sauk County, Wisconsin.

REVIEW OF THE WILBERNS FAUNA

It is purposed here to analyze the Wilberns fauna and compare it with other Cambrian graptolite faunas. There is a total of 27 species and varieties, 5 of which are recognized as hydroids, all from the Upper Cambrian, and for 2 forms only generic names have been given. All of the 22 graptolite forms are Dendroidea with no representatives of the order Graptoloidea present. This is one more than the 26 known species and varieties from the Upper Cambrian of the entire world listed in Table 1 (p. 19). Four in that list have been considered hydroids. Also from the Middle Cambrian of Australia these 4 genera of hydroids had been described earlier as graptolites, and a total of 20 species of hydroids are illustrated from the Middle Cambrian zone in Australia.

As compared with 27 forms from the Wilberns formation, Ruedemann has listed 14 from the Cambrian of North America. From a check of his descriptions, and from a later note of corrections, two species and a variety should be added to his list.

The 27 graptolites from the Wilberns of Texas may be compared with the known Cambrian graptolites from other localities as follows: Minnesota 6, Wisconsin 7, Great Britain and Ireland 4, Scandinavia 3, Canada 3, Tennessee 3, New York 2,

[40] Ulrich, E. O., and Resser, C. E., The Cambrian of the upper Mississippi Valley, pt. 2, Trilobita, Saukiinae: Bull. Milwaukee Pub. Mus., vol. 12, no. 2, Pl. 24, fig. 3 (middle specimen), 1933.

[41] Raasch, Gilbert O., Cambrian Merostomata: Geol. Soc. Amer., Spec. Paper 19, Pl. 10, fig. 6, 1939.

Vermont 2, South Dakota 1, Wyoming 1, Belgium 1, Russia 1, Bavaria 1, France 1.

The Wilberns fauna contains 1 new genus, 16 new species, and 2 new varieties. The graptolites and hydroids of this fauna are distributed among the genera as follows: *Dendrograptus* 7, *Callograptus* 4, *Callodendrograptus* 5, *Dictyonema* 4 (and one species undetermined), *Aspidograptus* 1 (species undetermined), *Haplograptus* 1, *Chaunograptus* 2, and *Archaeocryptolaria* 2.

CORRELATION

Only a few known species of graptolites have been recognized in the Wilberns fauna, as this fauna comes from a much earlier horizon than the fossiliferous Cambrian graptolite zones in Wisconsin and Minnesota. Accordingly, the new species in this Texas fauna will have value in correlation only when extensive collections are secured from a similarly low zone in other localities. The richness and high development of the forms in this fauna give promise not only that similar varied faunas will be secured elsewhere as the result of extended search and thorough collecting methods, but also that the origin of the graptolites will of necessity be found in much lower zones.

While some of the material is too fragmental and the faunas too limited to give assured accurate correlations, the presence of certain known forms in the Texas fauna seem to have correlative value.

Dendrograptus thomasi connects the upper Wilberns of Texas with the Deadwood formation of South Dakota; *Dictyonema wyomingense* connects the upper Wilberns with the Upper Cambrian in Shoshone Canyon near Cody, Wyoming; *Dictyonema schucherti*, the Wilberns with the Russell slate near Highgate Center, Vermont; *Dendrograptus kindlei*, the Wilberns with the Upper Cambrian near Corner-of-the-Beach, Gaspé County, Quebec, Canada; and *Dendrograptus edwardsi major* and *Callograptus antiquus*, with the Nolichucky formation near Morristown and Knoxville, Tennessee.

The following table shows the relations of the Upper Cambrian graptolite zones in five states, though as yet the zone has not been found in the Fort Sill, of Oklahoma nor the Hudson of Wisconsin.

The correlation of the upper Wilberns with the lower Fort Sill of Oklahoma and with the Hudson member of the Franconia of Wisconsin and Minnesota is made very definite by the presence of *Ptychaspis-Prosaukia-Chariocephalus* faunule in the Wilberns graptolite zone, in the lower part of the Fort Sill, and in the Hudson member of the Trempealeau formation.

SUMMARY

The Wilberns graptolite fauna occurs relatively low in the Upper Cambrian. This zone is much lower than the *Dictyonema flabelliforme* zone which is so widespread in Europe and North America and which has long been considered as belonging to the uppermost part of the Upper Cambrian. In Great Britain, where the Cambrian was named and delimited,

Table 2. Upper Cambrian of five states. Graptolite zones indicated by an X.

Texas	Oklahoma	Wisconsin-Minnesota	Tennessee
Lower Ellenburger	Butterly Signal Mountain Royer	Trempealeau Madison Jordan Lodi—X St. Lawrence	Knox dolomite
	Fort Sill	Franconia	
Upper Wilberns—X		Bad Axe Hudson Goodenough	Nolichucky—X
Lower Wilberns	Honey Creek	Ironton—X	Marysville
Cap Mountain			
	Reagan	Dresbach	Rogersville
Hickory			

the leading graptolite authorities still place the Tremadoc—*Dictyonema flabelliforme* zone definitely in the Upper Cambrian. As indicated above, this zone is so high in the Cambrian that some American, Scandinavian, and German paleontologists would shift it into the Ordovician.

The Wilberns graptolite zone is also much lower than the main Upper Cambrian graptolite zone in Wisconsin and Minnesota. The zone in these two states is in the Lodi shale member of the Trempealeau formation, while the upper Wilberns by its trilobite faunule is correlated with the Hudson member of the Franconia formation. Thus these graptolite zones are separated not only by parts of the formations in which they occur, but also by two other complete members, the St. Lawrence in the Trempealeau formation and the Bad Axe in the Franconia formation.

The Wilberns zone seems to be the same as those in the Upper Cambrian of Tennessee, Vermont, South Dakota, Wyoming, and Gaspé, Canada. This is the lowest zone in which any number of graptolites have been found. From only one lower zone has a graptolite been reported, and that a poorly preserved *Dendrograptus* from the Ironton member of the Franconia formation from Fox Glen on the northeast flank of the Baraboo Range, Wisconsin.

Although the Wilberns graptolite fauna comes from a relatively low horizon, still it is a varied and highly developed fauna with a number of genera in each of which several species and varieties are distinguishable. The high development of the Wilberns fauna gives promise that graptolites will be found in much lower zones, and this high development of the fauna indicates that the beginnings of the graptolite group will of necessity be found in much earlier horizons.

While graptolites are the dominant forms in the Wilberns fauna, hydrozoans lived with the graptolites in an indiscriminate manner, and at death both were preserved by what seems to have been an identical method.

Significant indeed is the presence in the narrow graptolite zone of three important index trilobite genera. Occurring in this zone are *Prosaukia tuberculata, Chariocephalus whitfieldi,* and *Ptychaspis* sp. These forms occur in definite zones in the lower part of the Fort Sill formation of Oklahoma and in the Hudson member of the Franconia formation of Wisconsin.

Some worms, a longer range brachiopod, and a merostome occur with the graptolites.

SUPPLEMENTARY NOTES

While descriptions and figures of Cambrian graptolites from Glenwood Canyon 100 miles west of Denver, Colorado, have not been published, C. F. Bassett[42] listed from the Dotsero dolomite a number of forms identified by Rudolf Ruedemann. The list includes the known species *Dendrograptus edwardsi, D. hallianus, D.* cf. *thomasi* and new species *Cryptograptus bassetti, Conograptus simplex, Ptiograptus coloradoensis, Dictyonema coloradoense.*

After this manuscript was submitted for printing, the writer's attention was called by Mr. P. E. Cloud, Jr., of the United States Geological Survey, to the monograph on graptolites on which R. Kozlowski[43] has been working and on which some advance information has been released. He has separated graptolites from the matrix and has found evidence of tripartite-branching stolons which, with some other characteristics, he thinks relates graptolites with *Rhabdopleura* of the Pterobranchiata belonging to the Chordata.

However, Bulman,[44] who has made thin sections of isolated stipes of Dendroidea and has some of the graptolites from Poland and is familiar with Kozlowski's work on the graptolites of Poland, sums up his discussion on the affinities of the graptolites as follows:

> Detailed comparison of the graptolites with any living class has not proved fruitful of results, but if they are to be placed in some existing phylum (which seems a reasonable supposition), it is perhaps as a separate class of the Coelenterata that their assemblage of characters can most readily be accommodated.

[42]Bassett, C. F., Paleozoic section in the vicinity of Dotsero, Colorado: Bull. Geol. Soc. Amer., vol. 50, p. 1856, 1939.

[43]Kozlowski, R., Informations preliminaries sur les Graptolithes du Tremadoc de la Pologne et sur leur protecthcoiquic: Annals Mus. Zoologici, Tom 13, Nr. 16, pp. 183–196, Warszawa, July 27, 1938.

[44]Bulman, O. M. B., Graptolithena: Handbuch der Paläozoologie (O. H. Schindewolf), Lf. 2 (Bd. 2D), p. 64, 1938.

PLATE 1

	PAGE
Callograptus plummeri, n.sp.	28
1–3. A large part and two smaller parts of colonies, x4. Univ. Oklahoma, Mus. Pal. Nos. B2001–B2003.	
1a, 1b, 2a, 2b. Parts of individual stipes enlarged to show shape of thecae and details of structure, x8.	
Callodendrograptus sellardsi, n.sp.	30
4, 4a. A small colony in side view showing numerous thecae, x8 and x4, respectively. Univ. Oklahoma, Mus. Pal. No. B2004.	

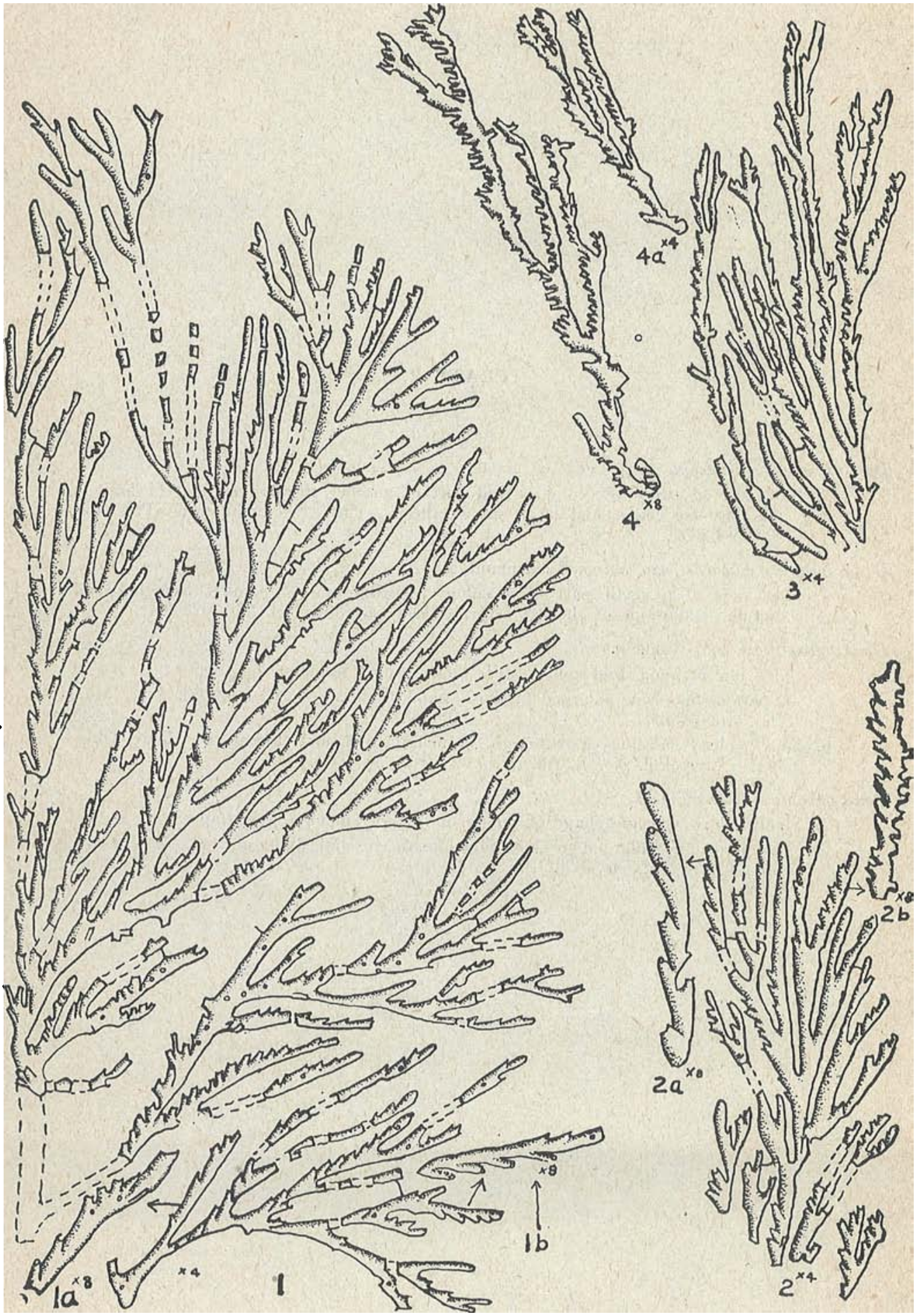

4a x4
4 x8
3 x4
2b x8
2a x8
2 x4
1b x8
1a x8
x4
1

PLATE 2

PAGE

Dendrograptus hilswecki, n.sp., x4 24

1–3. Side view of two large colonies and part of another showing method of branching, box-like shape, and large size of thecae. Univ. Oklahoma, Mus. Pal. Nos. B2005–B2007.

Dendrograptus edwardsi var. *major* Ruedemann, x4 20

4. Side view of a small part of a colony showing closely parallel branches and angular extensions of thecae. Univ. Oklahoma, Mus. Pal. No. B2008.

Dendrograptus thomasi Ruedemann 26

5. Side view of good-sized colony with some central branches missing, x4.

5a. A part of one stipe enlarged to show shape of thecae, x8. Univ. Oklahoma, Mus. Pal. No. B2009.

6. Small colony showing characteristic branching and small thecae, x4. Univ. Oklahoma, Mus. Pal. No. B2010.

Dendrograptus helenae, n.sp., x4 24

7. Small colony showing shape of thecae and small amount of overlap.

7a. Part of colony enlarged to show tube-like thecae and slight overlap. Univ. Oklahoma, Mus. Pal. No. B2011.

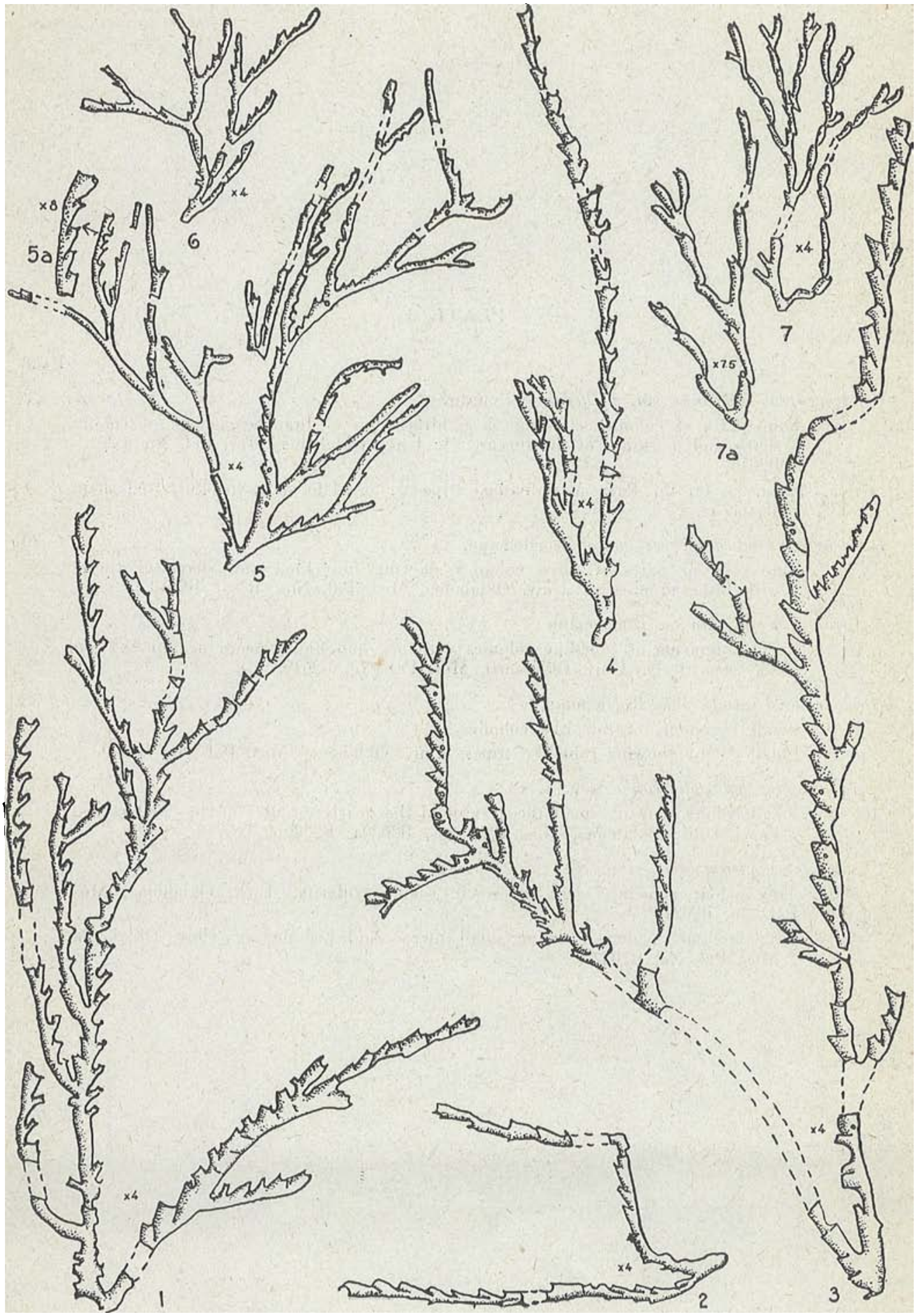

x8
5a
x4
6
x4
5
x4
4
x4
7
x7.5
7a
x4
1
x4
2
x4
3

PLATE 3

PAGE

Dendrograptus hallianus var. *wilbernsensis*, n.var. 22

1–4. Four parts of colonies showing close bifurcation of branches, shape of colony, shape and markings of the thecae, x4. Univ. Oklahoma, Mus. Pal. No. B2012–B2015.

1a, 1b, 2a, 3a, 4a, 4b. Parts of individual stipes enlarged to show structure and shape of thecae, x7.5.

Dendrogaptus edwardsi var. *major* Ruedemann, x4 20

5–7. Side view of parts of three colonies showing branching and shape of thecae with bithecae present. Univ. Oklahoma, Mus. Pal. Nos. B2016–B2018.

Dendrograptus cf. *kindlei* Ruedemann 25

8, 8a. Small fragments of tube-like colonies with low and higher magnification, x4 and x8, respectively. Univ. Oklahoma, Mus. Pal. No. B2019.

Haplograptus vermiformis Ruedemann, x4 35

9, 9a. Small fragments of tube-like colonies.

9b. Small colony showing tube-like stipes. Univ. Oklahoma, Mus. Pal. No. B2060.

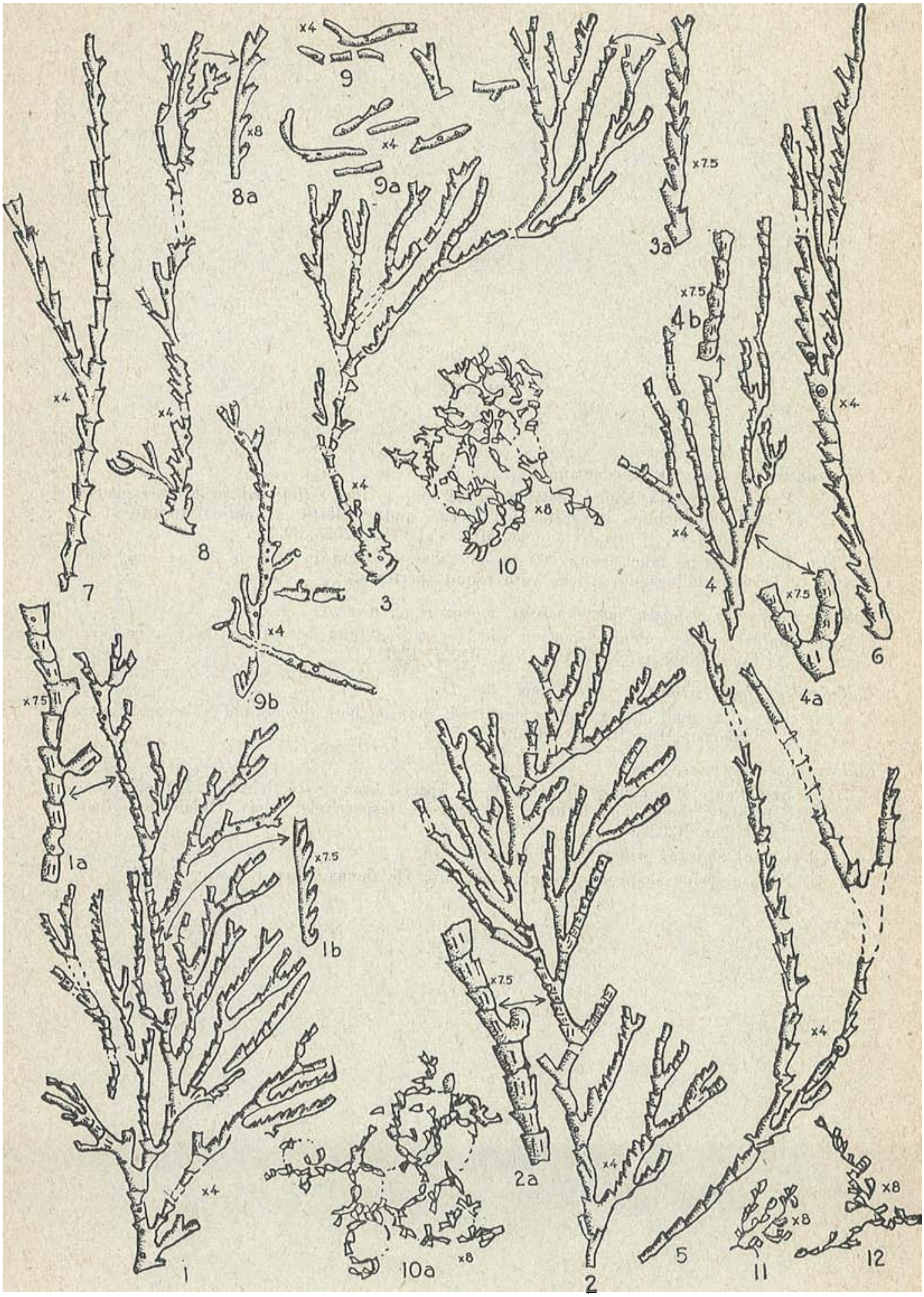
Chaunograptus palaeodictyotoides, n.sp., x8 37

10, 10a. Small colony showing small thecae around the nearly circular meshes and reverse view. Univ. Oklahoma, Mus. Pal. Nos. B2020a, B2020b.

Chaunograptus irregularis, n.sp., x8 36

11. Tiny colony showing small thecae in some regularity. Univ. Oklahoma, Mus. Pal. No. B2021.

12. Irregular small colony showing small thecae and gonothecae. Univ. Oklahoma, Mus. Pal. No. B2022.


1
x4
1a
x7.5
1b
x7.5
2
x4
2a
x7.5
3
x4
3a
x7.5
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x4
4a
x7.5
4b
x7.5
5
x4
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7
x4
8
x4
8a
x8
9
x4
9a
x4
9b
x4
10
x8
10a
x8
11
x8
12
x8

PLATE 4

PAGE

Callograptus cf. *antiquus* Ruedemann 27

1–3. Parts of three colonies showing broad main stipes exfoliated, wide divergence angle of branching, large inclined thecae, and small thecae normal to direction of stipes, x4. Univ. Oklahoma, Mus. Pal. No. B2023–B2024a.

1a. Part of stipe much enlarged, x8, to show variation in size of thecae and two large swellings on surface with round apertures.

Callodendrograptus sellardsi var. *expansus*, n.gen., n.sp., n.var. 30

4, 6, 6a. Rather coarse colonies showing wide, spreading branches. 4 and 6, x4; 6a, x7. Univ. Oklahoma, Mus. Pal. Nos. B2025, B2026.

Callodendrograptus sellardsi, n.gen., n.sp., x8 30

5. Part of a small colony highly magnified, showing both thecae and bithecae. Univ. Oklahoma, Mus. Pal. No. B2027.

Callograptus plummeri, n.sp. 28

7, 7a. Small part of a colony showing closely spaced branches with stipe (7a) enlarged to show thecae and bithecae, x4 and x8, respectively. Univ. Oklahoma, Mus. Pal. No. B2028.

8. Colony showing wider spaced branches, x6.

8a. Stipe showing shape of thecae, x7.5. Univ. Oklahoma, Mus. Pal. No. B2029.

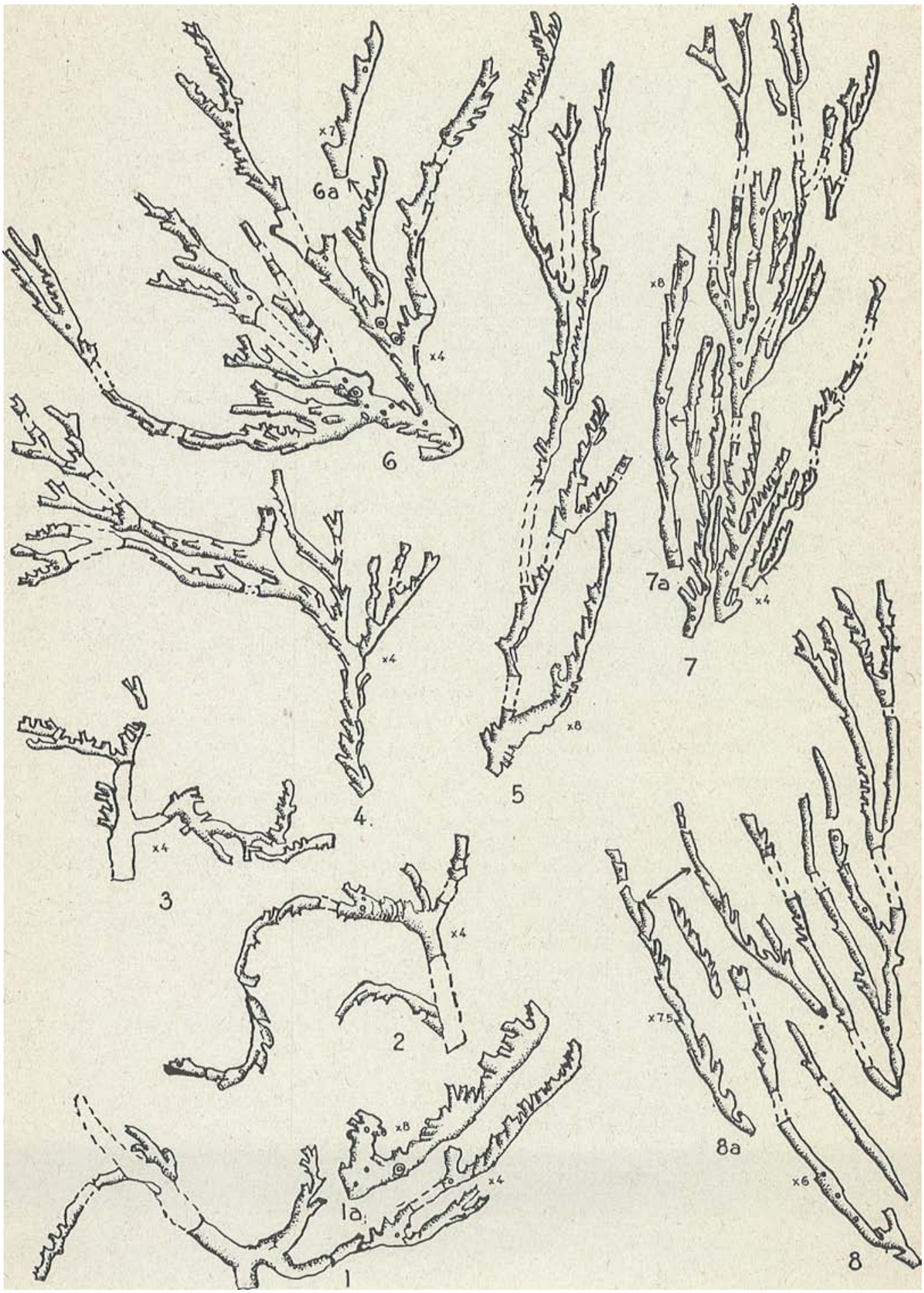
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PLATE 5

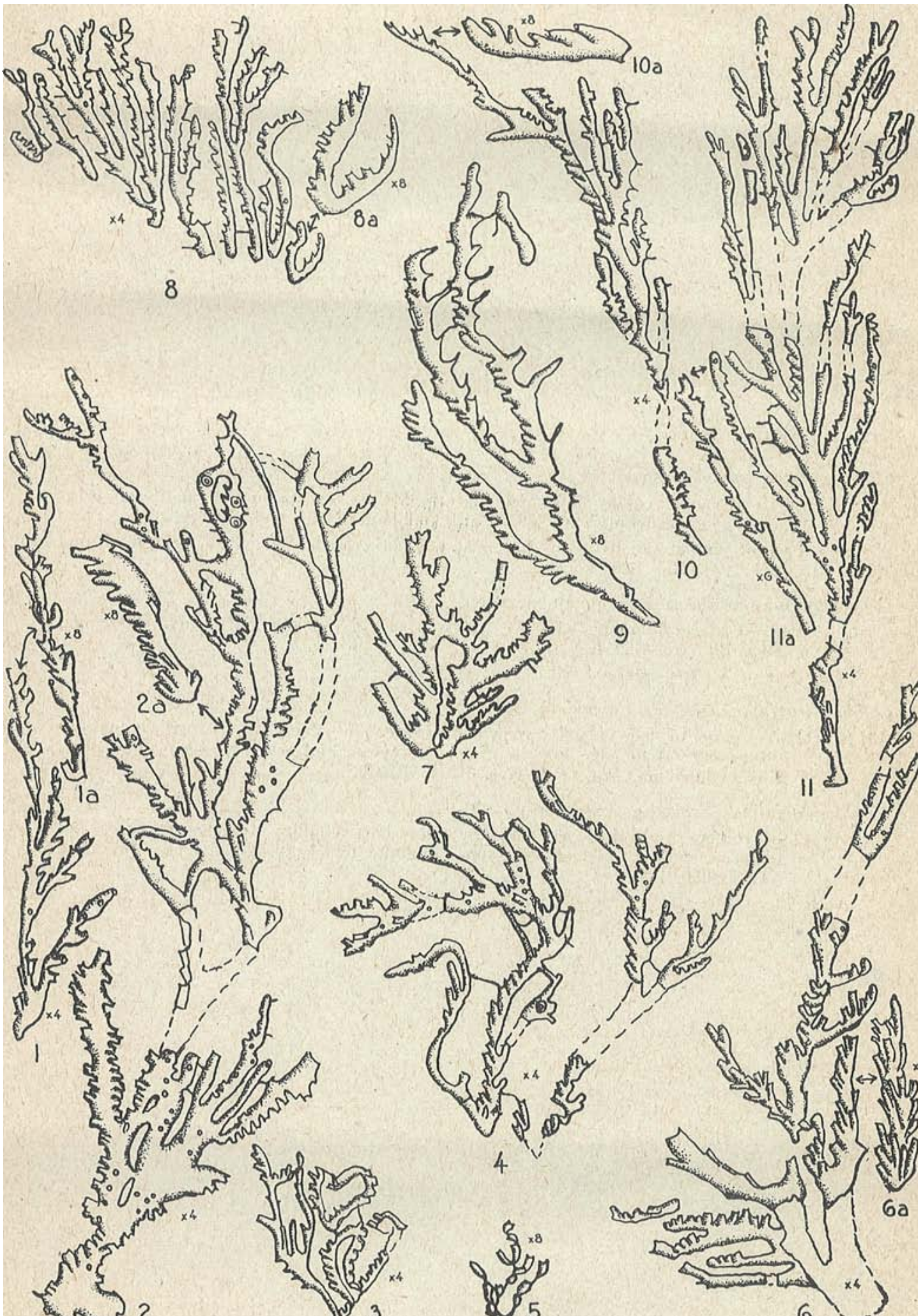
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PLATE 6

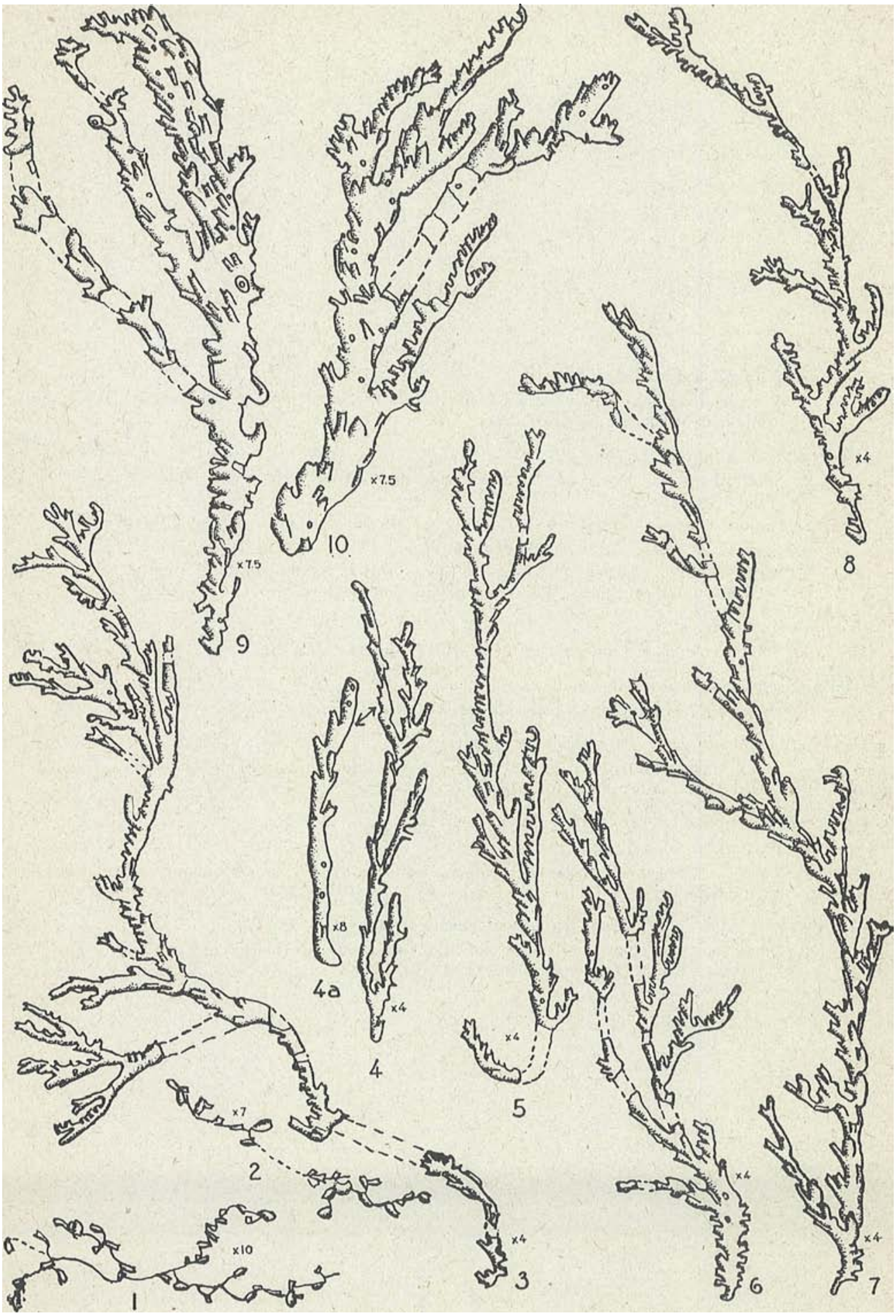
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PLATE 7

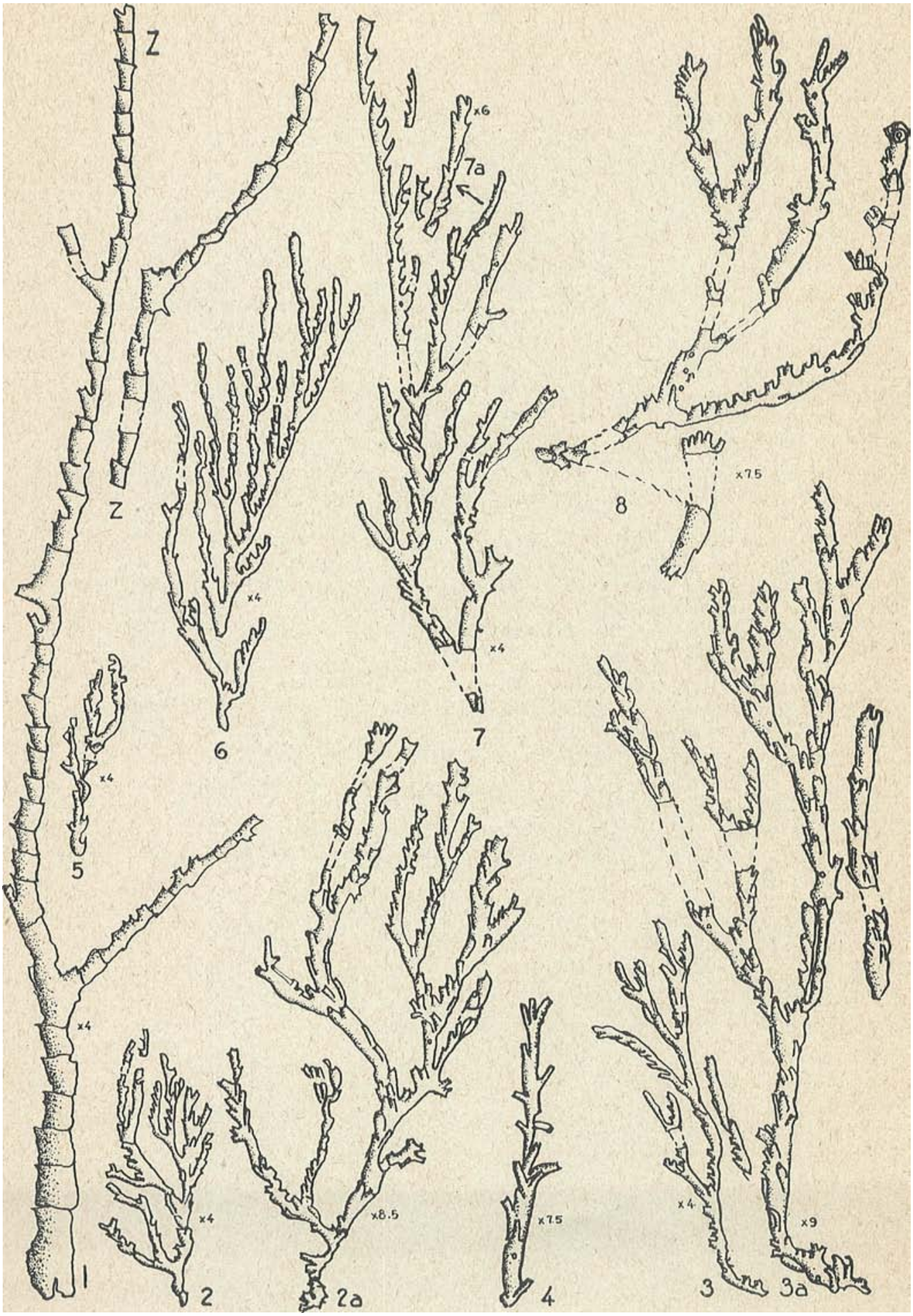
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PLATE 8

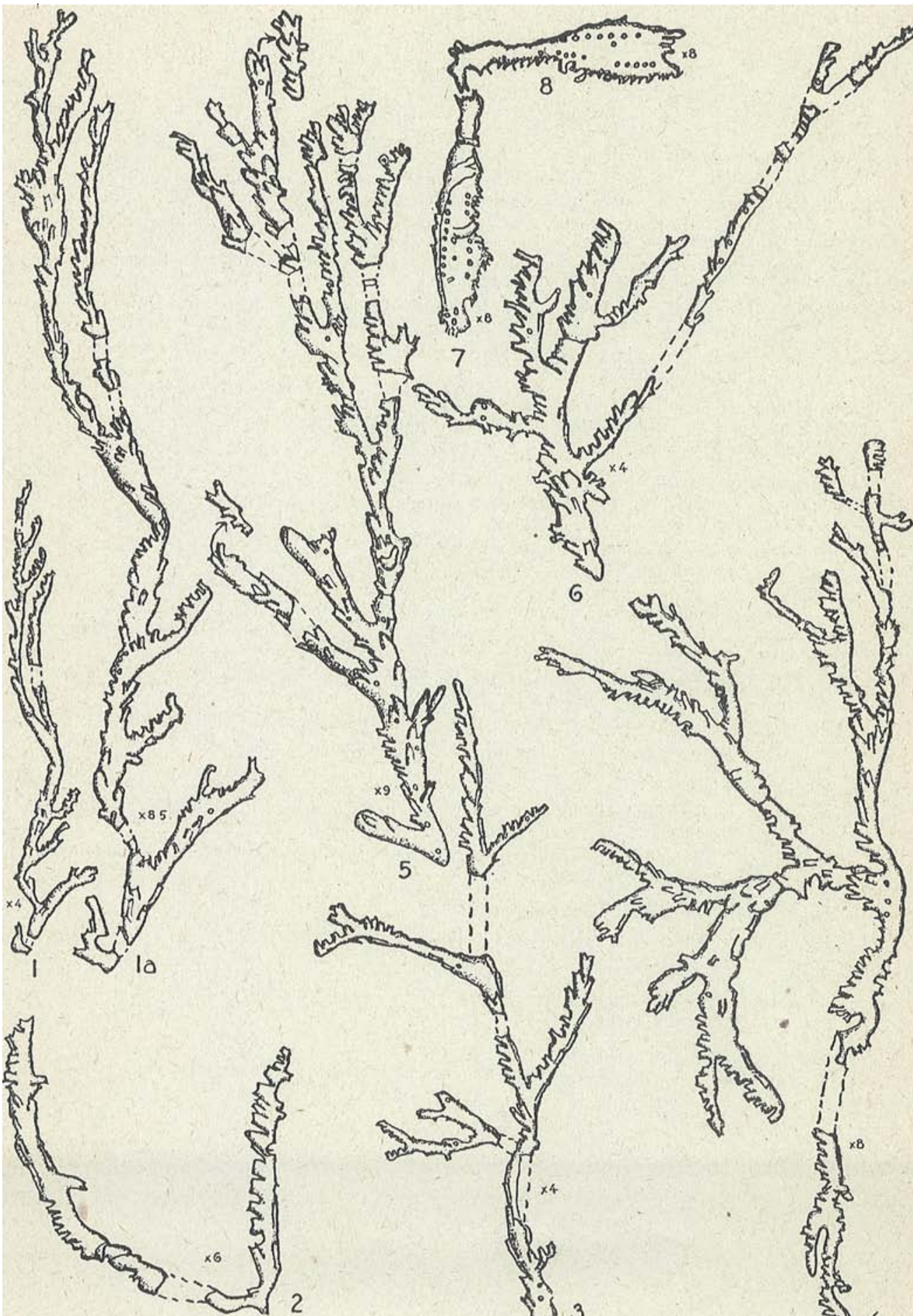
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PLATE 9

PAGE

Haplograptus vermiformis Ruedemann, x8 35

1. Small colony enlarged showing small thecae normal to edge of stipe and elongate, narrow inclined thecae. Univ. Oklahoma, Mus. Pal. No. B2060.

Callodendrograptus robustus, n.gen., n.sp. 29

2. Short stubby colony with variable thecae, regular bithecae, and gonothecae, x4. Univ. Oklahoma, Mus. Pal. No. B2061.

2a, 2b. Two thecae enlarged from top of left proximal branch, showing tiny tubes for nematocysts around apertures, x12. Univ. Oklahoma, Mus. Pal. No. B2062.

5. Colony with large base showing three kinds of thecae, x7.5. Univ. Oklahoma, Mus. Pal. No. B2063.

6. Colony with many thecae on face, x4. Univ. Oklahoma, Mus. Pal. No. B2064.

6a, 6b. Parts of two stipes enlarged showing shape and attitude of three kinds of thecae, x7.

Callodendrograptus sellardsi, n.gen., n.sp. 30

3. Colony enlarged to show shape and attitude of the different thecae, x8. Univ. Oklahoma, Mus. Pal. No. B2066.

3a. Same colony showing less detail, x4.

10. Part of small colony, x7. Univ. Oklahoma, Mus. Pal. No. B2067.

Callodendrograptus semicircularis, n.gen., n.sp. 31

4. Sparsely branched colony showing peculiar thecae, x4. Univ. Oklahoma, Mus. Pal. No. B2068.

4a. Part of stipe enlarged to show three kinds of thecae, especially the semicircular ones, x7.

7, 7a. Parts of colony, x4 and x7, respectively. Univ. Oklahoma, Mus. Pal. No. B2070.

12. Part of elongate branch of a colony, x4. Univ. Oklahoma, Mus. Pal. No. B2069.

Archaeocryptolaria gonothecatus, n.sp. 38

8. Small colony enlarged showing many gonothecae, x7.5. Univ. Oklahoma, Mus. Pal. No. B2072.

9. Elongate colony with a single branch and numerous gonothecae, x4. Univ. Oklahoma, Mus. Pal. No. B2073.

Callodendrograptus elongatus, n.gen., n.sp., x4 29

11. Elongate slender stipe with no branching. Univ. Oklahoma, Mus. Pal. No. B2071.

Merostomata 39

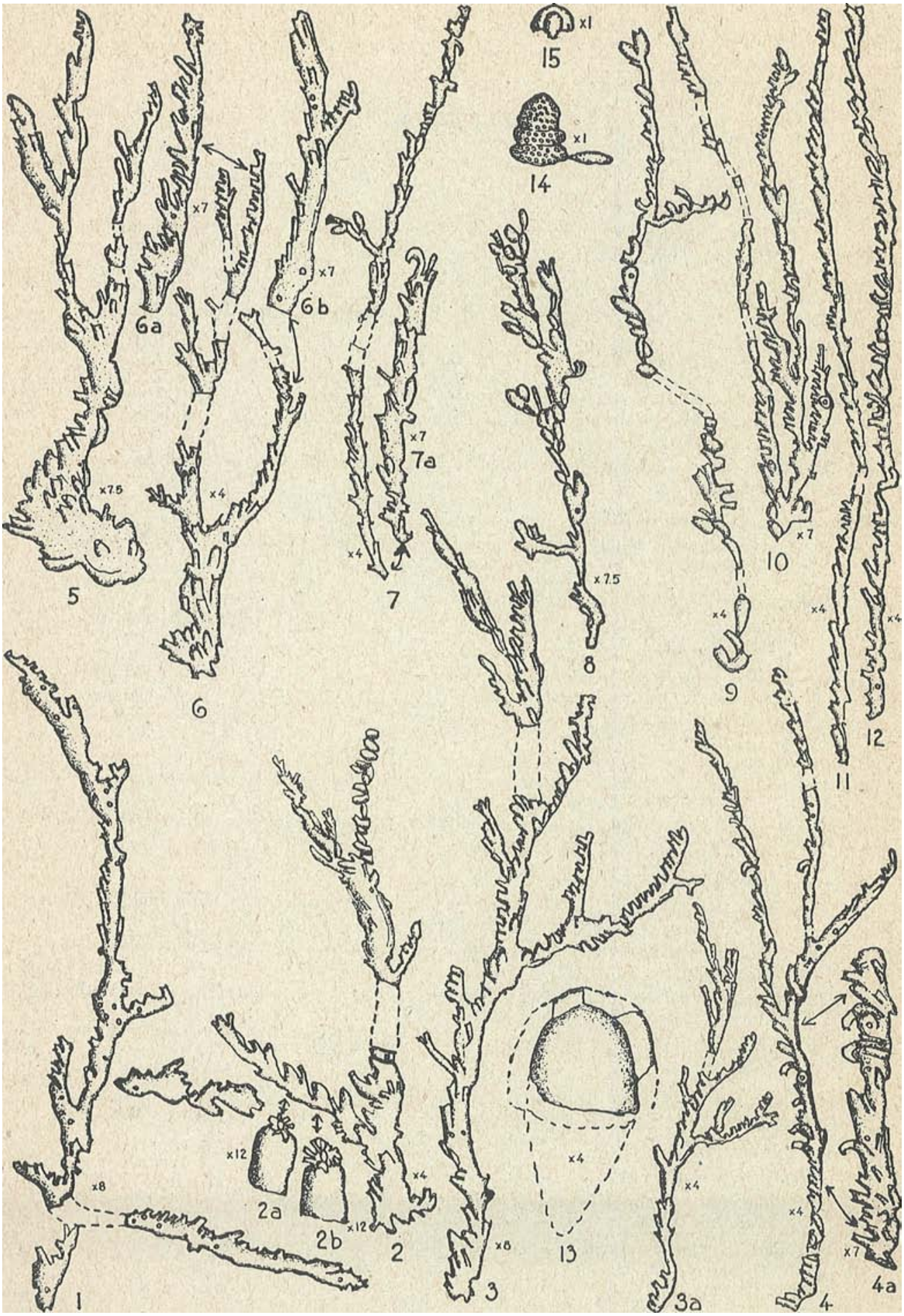
13. A poorly preserved merostome showing most of cephalon and outline of abdomen, x4. Univ. Oklahoma, Mus. Pal. No. B2074.

Prosaukia tuberculata Ulrich and Resser, x1 39

14. Tuberulate glabella showing furrows deep at the margins. Univ. Oklahoma, Mus. Pal. No. B2075.

Chariocephalus whitfieldi Ulrich and Resser, x1 39

15. Broad cephalon with wide smooth glabella. Univ. Oklahoma, Mus. Pal. No. B2076.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2a
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2b
x4
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x8
3
x4
13
x4
3a
x4
4
x7
4a

PLATE 10

PAGE

Dendrograptus helenae, n.sp., x8 — 24

1. Delicate colony enlarged showing open branching, thecae with little overlap, and bithecae. Univ. Oklahoma, Mus. Pal. No. B2077.

Archaeocryptolaria gonothecatus, n.sp. — 38

2. Colony with numerous gonothecae, x4. Univ. Oklahoma, Mus. Pal. No. B2078.

4, 5. Small colonies enlarged with numerous gonothecae, x8 and x4, respectively. Univ. Oklahoma, Mus. Pal. Nos. B2079, B2080.

Callograptus minimus, n.sp. — 27

3. Colony enlarged showing detail of numerous thecae, x7. Univ. Oklahoma, Mus. Pal. No. B2081.

3a. Same colony showing simple tube-like appearance with lack of detail in reverse of figure 3, x4.

Dendrograptus edwardsi var. *major* Ruedemann, x4 — 20

6. Small part of a colony showing thecae in side view. Univ. Oklahoma, Mus. Pal. No. B2083.

Callodendrograptus elongatus, n.gen., n.sp., x8 — 29

7. Long, slender, unbranched stipe showing detail of thecae. Univ. Oklahoma, Mus. Pal. No. B2084.

Dendrograptus thomasi Ruedemann, x4 — 26

8. Parts of a colony showing narrow, slightly curved branches. Univ. Oklahoma, Mus. Pal. No. B2082.

Aspidograptus sp., x4 — 35

9–13. Small parts of colonies which may belong to this genus. Univ. Oklahoma, Mus. Pal. Nos. B2085–B2089.

14. Part of a colony like the curved central part of *Aspidograptus.* Univ. Oklahoma, Mus. Pal. No. B2090.

Archaeocryptolaria simplicimus, n.sp. — 38

15. Small stipe showing initial transverse theca from which the stipe budded, x4. Univ. Oklahoma, Mus. Pal. No. B2091.

18. Small stipe with similar initial transverse theca, x4. Univ. Oklahoma, Mus. Pal. No. B2092.

18a. Proximal part of opposite of stipe enlarged to show detail of initial and other thecae, x11.

16, 20, 21. Parts of three small stipes, x7. Univ. Oklahoma, Mus. Pal. Nos. B2093–B2095.

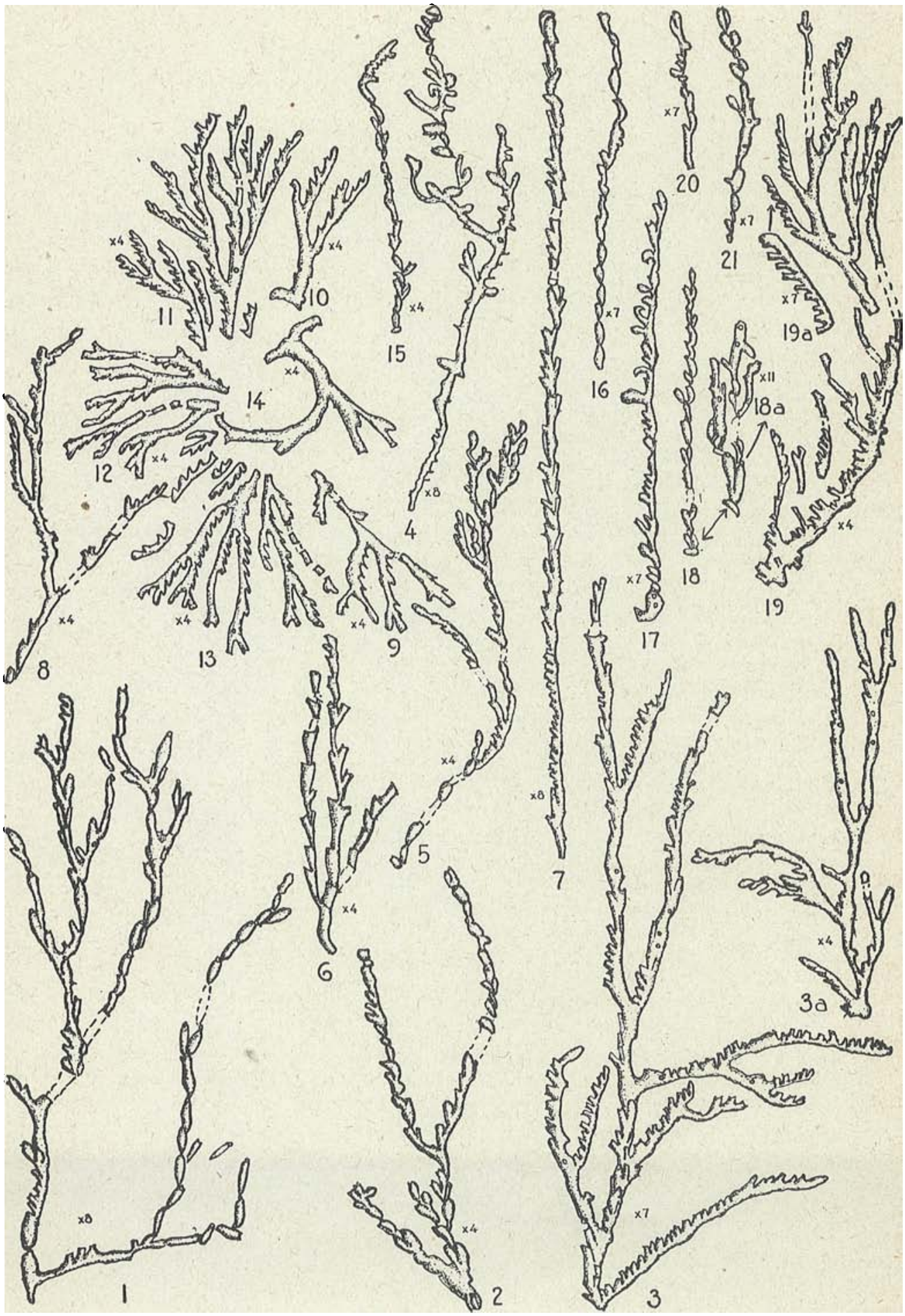
Callodendrograptus semicircularis, n.gen., n.sp., x7 — 31

17. Short stipe with a number of semicircular thecae. Univ. Oklahoma, Mus. Pal. No. B2097.

Callograptus subtypicus, n.sp. — 28

19. Colony with main stipe and several slender branches, x4. Univ. Oklahoma, Mus. Pal. No. B2096.

19a. Part of stipe enlarged, x7.



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x4
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17
x7
18
18a
x11
19
x4
19a
x7
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x7
21
x7

Map showing distribution of the Marble Falls formation on north side of Llano uplift and localities from which corals have been collected.

STRATIGRAPHY OF THE LOWER PENNSYLVANIAN CORAL-BEARING STRATA OF TEXAS

F. B. Plummer

INTRODUCTION

Review of geological investigations.—Lower Pennsylvanian rocks have been known in central Texas since the days of Roemer (1847). Roemer, accompanying an exploring party of German colonists under the command of Count Meusebach, entered the Llano region in central Texas from the south, traveled on horseback from Fredericksburg northward to an Indian camp near Walnut Spring in San Saba River valley and westward along San Saba River to the old Spanish Mission near the present town of Menard. The party then turned back along the south side of the valley to Camp San Saba, which is north of the present town of Mason, and returned southward to Fredericksburg. Roemer had opportunity to study the formations and collect fossils. Later he published a very interesting account of his travels (1849) and paleontologic observations (1852). He described four species of fossils from the Lower Pennsylvanian.

Four years later, 1856, G. G. Shumard (1886) accompanied an expedition of Army Engineers through the same region and made brief notes on the geology along the route, listing the Pennsylvanian fossils that he collected. Three decades then elapsed before any noteworthy geological work was undertaken on the Pennsylvanian. In 1889, R. T. Hill (1889) described briefly the Pennsylvanian limestones along Colorado River at Marble Falls. At about the same time (1888) a new Geological Survey of Texas was established, and numerous papers by Dumble (1890), Tarr (1889–1890), Cummins (1890), and Drake (1893) gave the first adequate descriptions of the several formations and names to the stratigraphic divisions. In 1898 the United States Geological Survey entered the region and surveyed the Llano and Burnet quadrangles, and Paige (1911, 1912) published two reports and geologic maps on the area. The first comprehensive map of the whole region was made by Udden, Baker, and Böse (1916), and this was followed by a bulletin by Plummer and Moore (1922) that described the rocks on the north side of the region. Since 1922 the only discussions of the Lower Pennsylvanian of Texas are by Cheney (1929, 1940), and the only map is the geological map of Texas published by the U. S. Geological Survey in 1937.

Importance of Lower Pennsylvanian coral studies.—In all the literature on the Carboniferous rocks of Texas, amounting to more than forty papers, the only Lower Pennsylvanian coral formally described and named is *Hadrophyllum aplatum* by Cummins (1890) from the Smithwick; Bassler later (1937) described the same coral. In the bulletin by Plummer and Moore (1922) two corals from the Lower Pennsylvanian rocks were illustrated but not described. Accordingly, work on the Lower Pennsylvanian corals of the Southwest is long overdue and much needed both for an adequate knowledge of Lower Pennsylvanian faunas and for Pennsylvanian stratigraphy in general, and particularly to extend the knowledge of phylogeny and taxonomy of Carboniferous corals of America.

Scope of discussion of stratigraphy.—The present work on the corals by Moore and Jeffords (following paper) has been undertaken to fill this need and is of much aid in the correlation and classification of these least well known of Carboniferous strata. The following account of stratigraphy of the Lower Pennsylvanian formations is intended to summarize the stratigraphic relationships of the different units in which corals occur. It is hoped by this effort that the many

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The articles in this volume have been issued simultaneously. Separates of the paper by R. C. Moore and R. M. Jeffords which follows, containing description of new species, have been distributed in advance of distribution of this paper in which these specific names have been used in discussing stratigraphy.

excellently described corals may be of maximum use in further stratigraphic work in this and adjacent regions.

The corals from Texas described by Moore and Jeffords were collected from the Marble Falls limestone and Smithwick shale, which outcrop in the Llano region in central Texas (map, Pl. 11), and the following discussion of the stratigraphy is limited to these two formations.

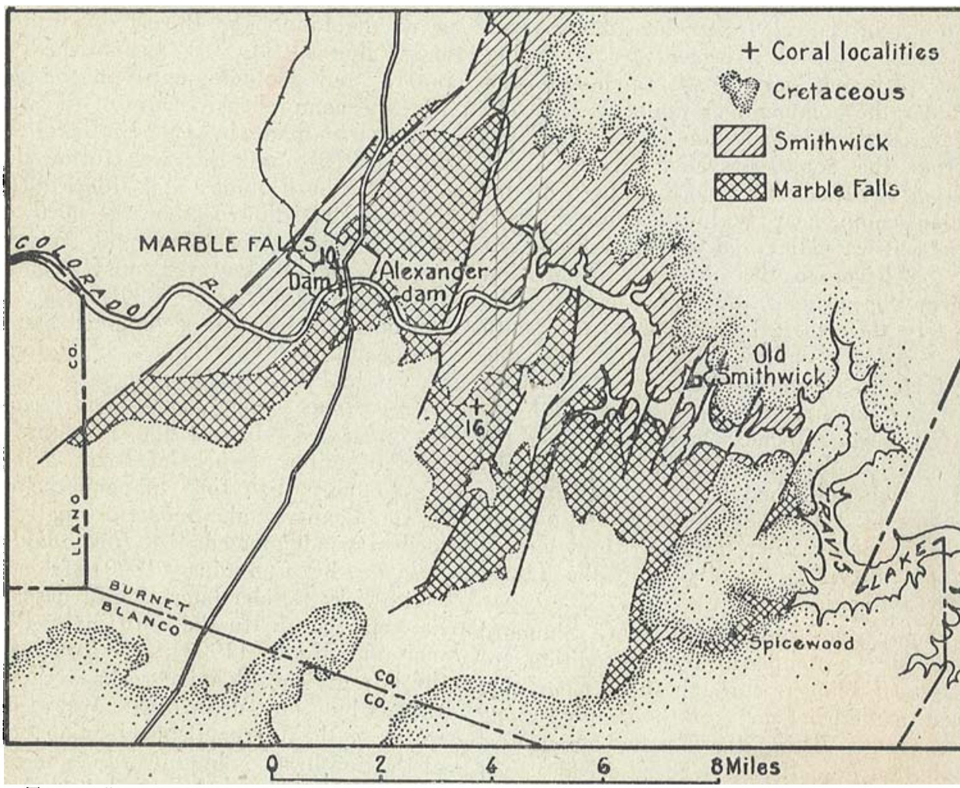


Fig. 1. Map showing the distribution of Marble Falls and Smithwick formations in the area around Marble Falls, Burnet County, Texas. Two localities where corals have been collected are indicated, and the species are described in the following paper by Moore and Jeffords.

STRATIGRAPHY

Marble Falls Formation

General description.—The Marble Falls limestone was first named by Hill (1901, p. 94). The type locality is the excellent exposure along the banks of Colorado River from the dam at Marble Falls to the base of the strata 1 mile below the highway bridge at Marble Falls. It is one of the most interesting of the succession of Carboniferous formations in Texas, because it is highly variable in respect to lithology and paleontology, complicated stratigraphically and structurally, very thick, and little known.

The formation consists generally of dark-gray and black, siliceous, fossiliferous limestones and black shales. The upper limestones grade eastward into shale and give rise to much confusion among geologists, because the shale facies is mistaken persistently, both on the outcrop and in the well sections, for the Smithwick shale. The formation occurs in isolated patches on the east side of the region in the valley of Pedernales River, along Cypress Creek, in Colorado River valley near Marble Falls (fig. 1), and along Sulphur Creek near Lampasas. It is found on the west side of the region in the valley of Llano River southwest of Mason and in San Saba River valley west of Camp San Saba. An extended belt crosses the northern portion of the area, extending from the vicinity of Nix in western Lampasas County across San Saba County to a point 4 miles south of Brady in McCulloch County (map, Pl. 11). Excellent exposures occur along Colorado River east of Bend.

The thickness of the Marble Falls formations varies markedly (Pl. 12) in different locations along the outcrop and in its several isolated exposures, due to overlap of upper beds on older Paleozoic rocks with resulting incomplete sections, erosion of upper beds, non-deposition of middle beds, and lenticular thickening of certain layers in some reef facies. Consequently the thickness of measured sections varies from only 30 feet near Brady to more than 400 feet near Pedernales Falls. In general the Marble Falls formation is thickest in synclinal areas and thinnest over structural ridges and arches. Generally it is more uniformly thick in subsurface sections north of the Llano area than along the outcrop in contact with the Mississippian strata and is thinner in the western part of the region (McCulloch and Mason counties) than in the eastern part (Lampasas and Burnet counties). The thickening is most pronounced in the middle, more massive layers than in the upper or lower layers of the formation, as indicated by a comparison of the plotted sections (Pl. 12).

The Marble Falls formation is made up essentially of dark-gray and black, siliceous, fossiliferous and generally thin-bedded limestone ledges containing some layers of black shale. The limestone grades eastward into a shale facies, a change that was not recognized till recently when samples from deep water wells have become available. This change in facies of the upper beds also takes place in deep synclinal valleys where mud and silts were deposited in place of limestone. The change may be observed in the deep syncline at Bend and in the Wallace creek syncline.

The Marble Falls formation on the north side of the region has been divided into four units, as follows:

4. Lemons Bluff member
3. Big Saline member
2. Sloan member
1. Gibbons conglomerate lentil

Gibbons conglomerate.—A basal conglomerate known as Gibbons member marks the contact of the Marble Falls and Barnett formation in some places. In other places a thin glauconitic sand intervenes containing phosphatic nodules, and in many others the Marble Falls limestone or shales lie directly on Barnett strata. The most interesting exposure of conglomerate is in a small branch one-half mile south of the Leonard ranch headquarters and about 900 feet west of the Leonard ranch-Berry Springs road. It consists of a dark-gray, coarse, fossiliferous, glauconitic sand containing a large number of sub-rounded cobbles and pebbles from a small fraction of an inch up to 10 inches in diameter. The pebbles are black, subcrystalline limestone, have a petroliferous odor, and resemble the limestone at the top of the Barnett. Many waterworn, poorly preserved fossils, such as corals, the brachiopods, *Orthotetes* and *Marginifera*, and crinoids similar to forms in the lower Marble Falls, occur in the sandy matrix between limestone cobbles. Some of the sand is cemented into a hard rock and contains veins of white calcite. The conglomerate grades upward into a coarse calcareous sandstone layer which is about 1 foot thick. The conglomerate lentil is about 30 feet long east and west, 1 foot thick at each end and about 4 feet in the middle. It grades laterally into medium- to coarse-grained sand.

A thin pebble conglomerate 6 to 12 inches thick lies between the Marble Falls and Barnett in an exposure on the Gibbons ranch, 2½ miles south of Hall, 0.4 of a mile east of the point where the road crosses the west-facing Marble Falls escarpment (locality 102 in San Saba County, map, Pl. 11). The conglomerate is 8 to 12 inches thick and comprises remarkably uniform pebbles that vary from three-quarters of an inch to 1 inch in diameter, set in a matrix of coarse sand or very small pebbles. The grains of the matrix vary from 1 to 3 millimeters in diameter. The pebbles of the conglomerate consist of subangular limestone and chert derived mostly, it is thought, from the Ellenburger dolomite. The conglomerate ledge is consolidated and when broken, fractures across the pebbles without disintegration, although a few pebbles weather out by solution and can be picked up on the surface. In most other places the Marble Falls lies directly upon the Barnett shale without any intervening conglomerate, sand, or very pronounced break, although careful observation in most sections shows a few phosphatic nodules and grains of glauconite to mark the base of the Pennsylvanian strata.

Sloan member.—The Sloan member of the Marble Falls in the northern part of the region is best exposed along San Saba River and its branches on the Sloan, Lemons, and Gibbons ranches, west and southwest of San Saba, western San Saba County, and along Colorado River above the old Alexander dam site at Marble Falls in Burnet County (fig. 1). The dark, thin-bedded strata between the basal glauconitic sand and the massive, coarsely crystalline *Chaetetes*-bearing limestone are exposed most typically along the bluff opposite Lemons Camp on San Saba River (about three-fourths mile west of locality 84, Pl. 11). They are exposed also along the north side of King Branch on Sloan ranch and along the upper portion of Turkey Roost Creek on Sloan ranch (localities 65 and 84, Pl. 11). The Sloan member is distinctly thin-bedded; the beds are uneven, have rough surfaces, and contain distinctive fossils. The basal bed in most places is a subcrystalline to crystalline, dense, black, cherty limestone 4 to 16 feet thick and commonly carries more than 40 per cent black chert. This cherty zone is overlain by 50 to 100 feet of thin-bedded, black, subcrystalline, fossiliferous limestone. The lower layers generally are most fossiliferous. They contain *Ethelocrinus texasensis* Moore and Plummer, *Marginifera roemeri* Girty, *Wellerella osagensis* (Swallow), *Derbya crassa* Meek and Hayden, *Dictyoclostus morrowensis* (Mather), and *Paeckelmannia,* n.sp. The fossils are less common in the upper layers of this member, and one zone near the top is yellowish-gray and relatively low in density and contains many impressions of plant stems and leaves of a reedlike plant. In certain places, particularly along the bluffs of Turkey Roost Creek on the Sloan ranch and in a small branch of Wallace Creek, 10 miles southwest of San Saba (locality 43, Pl. 11), calcareous shale partings, 2 to 30 inches thick, are interbedded with the limestone layers. In most places these shales are fossiliferous, and some of the best fossils from the Sloan member of the Marble Falls come from these shaly zones.

This member has been found at the base of the Marble Falls section on Colorado River below Marble Falls, just above the Barnett formation, from Cherokee Creek west across San Saba County to the Pontotoc-San Saba highway in Wallace Creek valley, 10 miles southwest of San Saba (locality 43, Pl. 11), and at a few places along the contact of the Marble Falls and Barnett on the Sloan and Gibbons ranches in western San Saba County. It is present in most synclinal areas in San Saba County and absent on the structural highs, where it was either never deposited or was removed by erosion before the deposition of the Big Saline and Lemons Bluff members. It has not yet been found west of San Saba County and is thought to be absent on the Brady uplift in McCulloch County and along the granite ridge in Mason County. It has not been identified east of Cherokee Creek in the Colorado River exposures southeast of Bend or in Lampasas County.

It is rather difficult to correlate the Sloan fossil assemblage with faunas of other regions, because most of the older Pennsylvanian species of Oklahoma, Arkansas, and Illinois have been identified by paleontologists twenty years or more ago, before modern splitting of genera and species into narrow limits of differentiation was undertaken. It has been possible, however, to compare our species of brachiopods with the collections in Walker Museum, and Moore and Plummer (1939) and Moore and Jeffords (following paper) have assembled, studied, and redescribed all the known crinoids and corals of the Morrow of Oklahoma and Arkansas and of the Marble Falls and Smithwick formations in Texas.

On a basis of the brachiopods, corals, and crinoids, it is thought that the Gibbons conglomerate and Sloan member of the Marble Falls are Morrow in age. Out of eighteen brachiopods identified from the Sloan member, ten occur in the Morrow and several others are very closely related, if not identical. Of the three species of crinoids, two are identical and one is very closely related to forms in the Morrow. Of the corals, according to Moore and Jeffords (following paper), three out of seven occur in the Morrow. Only one ammonite, *Phaneroceras nolinense* (Cox), has been identified from the Sloan member. This species occurs also at the Nolin Iron Works, Edmondson County, Kentucky, in the Pottsville formation.

The following corals have been described and identified in the following paper by Moore and Jeffords from the Sloan member:

Stereocorypha annectans Moore and Jeffords
Lophophyllidium extumidum Moore and Jeffords
Lophophyllidium idonium Moore and Jeffords
Lophophyllidium adapertum Moore and Jeffords
Barytichisma crassum Moore and Jeffords
Barytichisma callosum Moore and Jeffords
Barytichisma repletum Moore and Jeffords
Amplexocarinia corrugata (Mather)
Michelinia referta Moore and Jeffords
Acaciapora venusta Moore and Jeffords
Cladochonus fragilis Mather

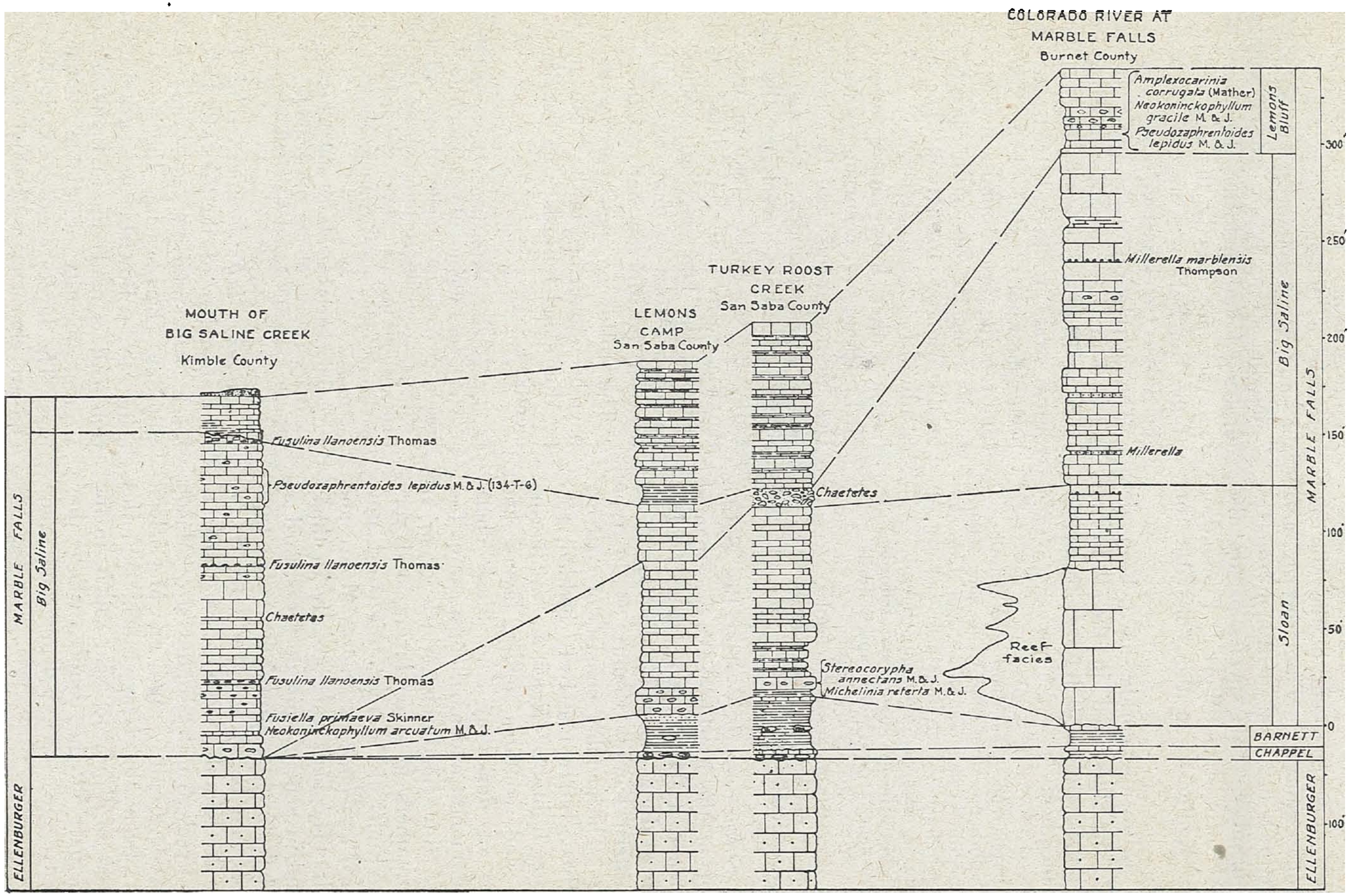
Big Saline member.—The Big Saline member of the Marble Falls was named by Cheney (1940), using the excellent exposures along the Big Saline Creek in northeastern Kimble County as the type locality. The member consists of coarsely crystalline, fairly massively bedded, fossiliferous light-gray limestone weathering white, and contains many layers and nodules of dark-gray and black chert. The commonest and most conspicuous fossils are tiny fusulinids, which occur in great numbers in some layers, and very large cylindrical colonies of a coral, now identified as *Chaetetes favosus* Moore and Jeffords. The beds vary greatly in thickness and in general thin northeastward as the Concho arch is approached. The typical beds can be traced from Big Saline Creek in Kimble County eastward to Honey Creek, 6 miles southwest of Mason in Mason County, and in McCulloch County from the Gray ranch, 5 miles southwest of Brady to Neal ranch, in the eastern part of the county, where they play out against Cavern Ridge and grade into the Lemons Bluff beds. The Big Saline member is thought, also, to be present in the synclinal areas in San Saba and Burnet counties, where it is represented by light-gray, coarse-grained, crinoidal limestone between the Sloan strata and overlying typical Lemons Bluff beds. These middle beds have the same lithologic characteristics as the Big Saline strata, contain the same large fossils and *Chaetetes* colonies, but strangely no fusulinids have so far been found in them; therefore, proof that they are exactly the age equivalent of the Big Saline at its type locality on Big Saline Creek is lacking.

The correlation of the Big Saline member and the intergrading faunally similar Lemons Bluff beds with Lower Pennsylvanian strata in other districts has always been somewhat of a problem. Except for long-ranging brachiopods, few species of fossils from the Big Saline member occur in the Morrow formation. The common fusulinid *Fusulina llanoensis* N. L. Thomas has a rather long range, according to M. L. Thompson, occurring as high as the Des Moines group, and therefore it does not serve as an index. The fauna of the Smithwick shale, overlying the Marble Falls, appears to be Atoka in age. Hence the Big Saline and its related overlying member, the Lemons Bluff member, may be lower Atoka or may represent strata between the Morrow and Atoka.

The following new species of corals have been described in the following paper by Moore and Jeffords from the Big Saline member:

Lophophyllidium extumidum Moore and Jeffords
Barytichisma callosum Moore and Jeffords
Pseudozaphrentoides lepidus Moore and Jeffords
Pseudozaphrentoides spatiosus Moore and Jeffords
Rodophyllum texanum Moore and Jeffords
Neokoninckophyllum arcuatum Moore and Jeffords
Michelinia latebrosa Moore and Jeffords
Chaetetes favosus Moore and Jeffords
Chaetetes subtilis Moore and Jeffords

Lemons Bluff member.—The Lemons Bluff member of the Marble Falls is a black, subcrystalline, uniformly bedded, siliceous, chert-bearing limestone, weathering to yellowish and grayish-brown tints and is made up in many places of a great quantity of minute sponge spicules. The layers are 2 to 12 inches thick and are characterized by flat, smooth surfaces which yield in many places good building blocks and weather to produce a light-weight siliceous rock. The individual layers are commonly separated by



Typical sections of the Marble Falls formation in the Llano region, showing correlation of the subdivisions and locations of some of the fossil zones.

thin partings of shaly limestone, so that a cliff face weathers to give the impression of a masonry wall, each thick layer standing out in relief. The member contains in most places a characteristic fauna. The best index fossils are *Phaneroceras compressum* (Hyatt), *Pharkidonotus bendensis*, n.sp. (MS.), which is a gastropod with large nodes, and *Straparolus savagei* (Knight), a low coiled, smooth-surfaced gastropod. Other common fossils are:

Paralegoceras texanum (Shumard)
Spirifer rockymontanus Marcou
Neospirifer cameratus (Morton)
Bembexia nodomarginata (McChesney)
Straparolus subquadratus Meek and Worthen
Leda bellistriata Stevens

The surfaces of the limestone layers in many places are covered with impressions of the common alga, *Spirophyton caudagalli* (Vanuxem).

This limestone member changes to shale beds eastward and outcrops at McAnelly's Bend along the Colorado River bluffs west of Bend as black fissile shale containing thin layers of dense black limestone. This shale has long been regarded by geologists as typical Smithwick shale. It varies in thickness from a few feet to 125 feet and overlies the Big Saline beds unconformably. The contact in some places is marked by a thin band of small black pebbles and in other places by a bed of gypsum-bearing shale. The change in lithology from the coarsely crystalline light-gray Big Saline beds to the subcrystalline, dense, black siliceous, shaly Lemons Bluff beds is striking and easy to recognize in the field.

The fauna of the Lemons Bluff beds of the Marble Falls formation comprises more species than that of the Big Saline or Sloan members and individual specimens occur in much larger numbers. Spirifers predominate, but in places large gastropods belonging to the genus *Pharkidonotus* are very common. Productids are less common than in the lower beds, yet even hurriedly made collections in some exposures yield more than a dozen species. No fusulinids have been found so far as known, but staffelids and other foraminifera are present and have been found at widely separated localities. The best index fossil is *Phaneroceras compressum* (Hyatt). Fortunately this fossil is fairly common and widespread and has been collected in the black limestones of this upper member from Lampasas County on the east to 11 miles southwest of Mason on the west. This fossil together with its common accompanying assemblage, namely, *Spirifer opimus* Hall, *S. matheri* Dunbar and Condra, *S. rockymontanus* Marcou, *Pharkidonotus bendensis*, n.sp. (MS.), and *Straparolus savagei* (Knight), serve to distinguish this member at once from the two other divisions of the Marble Falls.

The following corals have been identified and described in the following paper by Moore and Jeffords from the Lemons Bluff member:

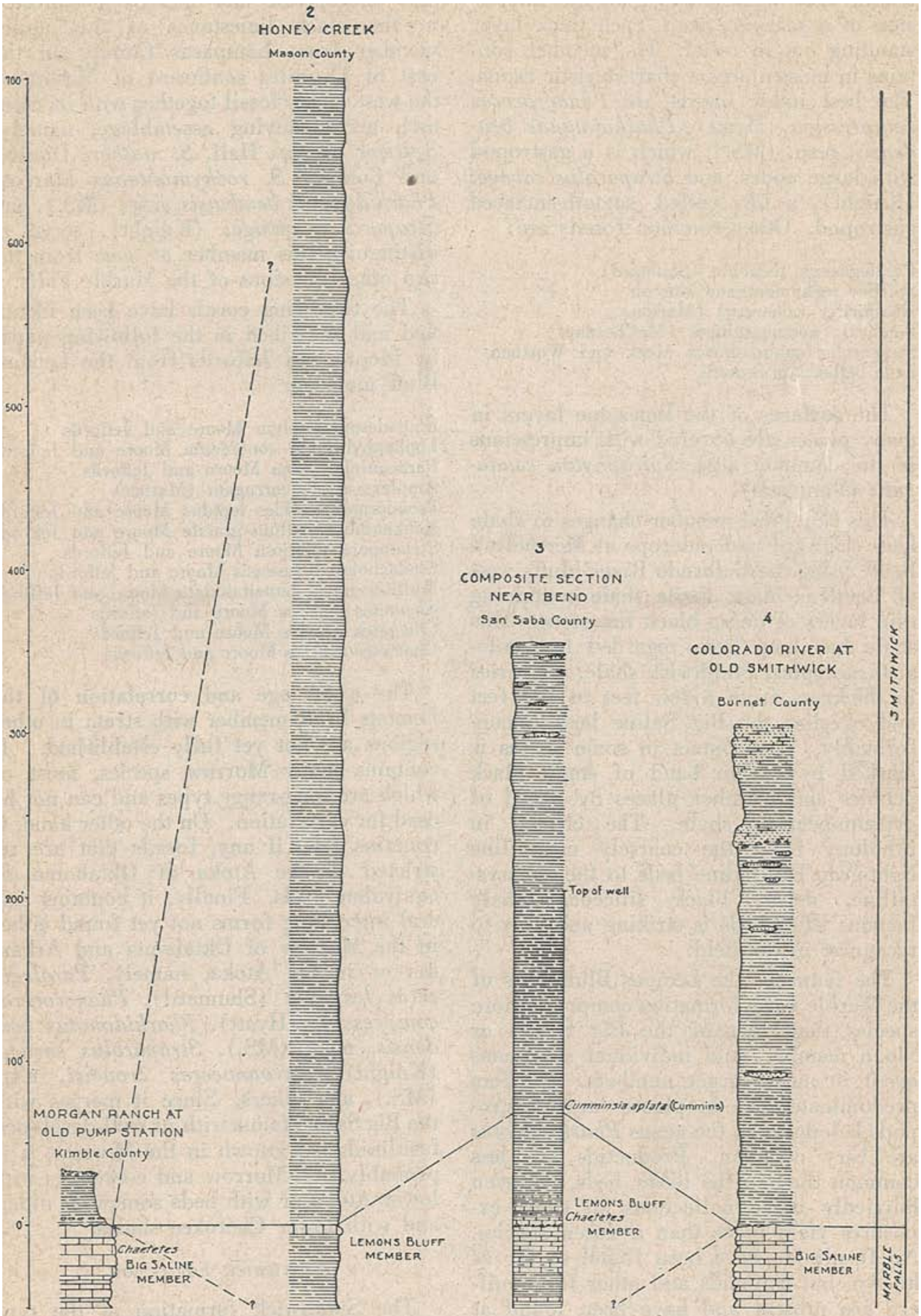
Empodesma imulum Moore and Jeffords
Lophophyllidium conoideum Moore and Jeffords
Paracaninia? sana Moore and Jeffords
Amplexocarinia corrugata (Mather)
Pseudozaphrentoides lepidus Moore and Jeffords
Neokoninckophyllum gracile Moore and Jeffords
Striatopora religiosa Moore and Jeffords
Cladochonus texasensis Moore and Jeffords
Multithecopora paucitabulata Moore and Jeffords
Chaetetes eximius Moore and Jeffords
Chaetetes favosus Moore and Jeffords
Chaetetes subtilis Moore and Jeffords

The exact age and correlation of the Lemons Bluff member with strata in other regions are not yet fully established. It contains many Morrow species, most of which are long-range types and can not be used for correlation. On the other hand, it contains few, if any, fossils that are restricted to the Atoka of Oklahoma or equivalent beds. Finally, it contains several interesting forms not yet found either in the Morrow of Oklahoma and Arkansas or in the Atoka, namely, *Paralegoceras texanum* (Shumard), *Phaneroceras compressum* (Hyatt), *Pharkidonotus bendensis*, n.sp. (MS.), *Straparolus savagei* (Knight), *Rayonnoceras croneisi*, n.sp. (MS.), and others. Since it merges with the Big Saline fauna with its well-developed fusulinids not known in the Morrow, it is probably post-Morrow and correlates with lower Atoka or with beds somewhat older, and with lower Cherokee shales.

Smithwick Formation

The Smithwick formation at the type locality, as now defined, includes the strata above the Lemons Bluff beds, with

The University of Texas Bulletin 4401 **Plate 13**



Typical sections of the Smithwick formation in the Llano region showing variations in thickness and position of the *Cumminsia aplata* zone.

their typical *Phaneroceras compressum* fauna, and below typical Strawn beds, which carry in some places a Des Moines fauna. Through west and central San Saba County it includes all the shale below the Strawn group and above the black Marble Falls limestone. In eastern San Saba County, near Bend, the basal Smithwick is 60 feet above the top of the limestone, and the base is marked by the lowest occurrence of the coral "*Hadrophyllum*" *aplatum*, now named *Cumminsia aplata* by Moore and Jeffords.

The Smithwick formation is best exposed on the southeast side of the region for nearly a mile along the Colorado River bluffs 6 miles east-southeast of Marble Falls at the abandoned town of Smithwick, Burnet County. On the north side of the region (map, Pl. 11) it is well expressed in Cherokee, San Saba, and Wallace Creek valleys and Long Valley. It appears to be absent in McCulloch County west of Long Valley and between Rochelle and Brady. Around Brady it is overlapped by Strawn and Canyon beds. It is present in Honey Creek valley southwest of Mason and in Kimble County southeast of London. In subsurface it is thought to be present in most wells drilled north of the region, except perhaps in some of the holes drilled on tops of the highest structures. No Smithwick has been found, for example, on the structure southwest of Lampasas. Its thickness varies from a few feet to 700 feet (Pl. 13). It has been stated by Jones (1929) and others that the Smithwick thickens markedly in subsurface sections east and northeast of the region. Some of the apparent thickening, at least, is due probably to change in facies of the Marble Falls from limestone to shale east of the region. Some of the recorded thick Smithwick shale section may be due to inability to distinguish the similar overlying Strawn shale from the Smithwick. The Smithwick shale is thickest in the structural synclines and thinnest on the anticlines and over buried ridges. It appears that deformation and faulting in this region commenced before the end of the Marble Falls epoch and that the Smithwick accumulated in greater amounts in the troughs and grabens during and following the deformation. The shales overlap the buried ridges and occur around the rims of the troughs, exemplified by Cherokee Valley and Long Valley. In several places the transgression of black shale strata is marked by an angular unconformity and basal conglomerate.

The Smithwick shale is typically a black, fissile, siliceous shale that in most places is unfossiliferous, but at a few places contains an ammonoid and gastropod fauna quite unlike the Marble Falls and similiar to the Atoka formation of Oklahoma. At the type locality on Colorado River the shale contains small specimens of *Ambocoelia*, *Lingula*, *Orbiculoidea*, and other minute fossils found in black shale near its base. Above, it is made up of a thick section of black, soft slightly ferruginous and gypsiferous, unfossiliferous shale containing thin lentils of firmly cemented, hard siltstone marked on the surfaces by impressions of plant leaves, stems, animal tracks and trails. West of Bend, along the Colorado River bluffs in San Saba County, the lower few feet of beds of the Smithwick are fossiliferous, soft, very thinly laminated, black shale. These are overlain by nonfossiliferous shale containing at the top thin, hard beds of siltstone 2 to 12 inches thick, marked by tracks and trails. In Wallace Creek valley southwest of San Saba, the shale is dense, black, soft, and contains numerous ferruginous concretions but less siltstone. Three miles west of Rochelle (locality 6 in McCulloch County, Pl. 11) along the bluff east of the Rochelle conglomerate escarpment, the soft black gypsiferous shale contains many limonitic concretions and is abundantly fossiliferous. The fossils are characterized by the well-known ammonoid, *Gastrioceras smithwickense* Plummer and Scott. Along Honey Creek southwest of Mason, south of the highway, the shale is black, fissile, ferruginous, and the lower 50 feet is fossiliferous.

The Smithwick shale has not been subdivided into members. The lower 50 to 75 feet of the Smithwick contains marine fossils and was certainly laid down in marine waters. The upper portion appears to have been deposited in shallow littoral waters where fine silts were spread over the black mud, and where ripple marks, plants, and tracks of marine animals have been preserved and fossilized.

Chart showing distribution of coral species in correlative formations in Texas, Oklahoma, and Arkansas.

Species	Texas				Oklahoma	Arkansas	
	Smithwick	Lemons Bluff	Big Saline	Sloan	Morrow	Hale	Brentwood
Stereocorypha annectans Moore & Jeffords				x			
Empodesma imulum Moore & Jeffords		x					
Lophophyllidium extumidum Moore & Jeffords				x			
Lophophyllidium idonium Moore & Jeffords				x			
Lophophyllidium conoideum Moore & Jeffords		x					x
Lophophyllidium adapertum Moore & Jeffords				x			
Hapsiphyllum tumidum Moore & Jeffords	x						
Hapsiphyllum retusum Moore & Jeffords	x						
Zaphrentoides excentricus Moore & Jeffords	x						
Barytichisma crassum Moore & Jeffords				x			
Barytichisma repletum Moore & Jeffords				x			
Barytichisma callosum Moore & Jeffords			x	x			x
Paracaninia? sana Moore & Jeffords		x					
Amplexocarinia corrugata (Mather)		x		x		x	
Pseudozaphrentoides lepidus Moore & Jeffords		x	x				
Pseudozaphrentoides spatiosus Moore & Jeffords			x				
Rodophyllum texanum Moore & Jeffords			x				
Neokoninckophyllum arcuatum Moore & Jeffords			x				
Neokoninckophyllum gracile Moore & Jeffords		x					
Cumminsia aplata (Cummins)	x						
Michelinia latebrosa Moore & Jeffords			x				
Michelinia referta Moore and Jeffords	x			x			
Striatopora religiosa Moore & Jeffords		x					
Acaciapora venusta Moore & Jeffords				x			
Cladochonus fragilis Mather				x		x	
Cladochonus texasensis Moore & Jeffords		x					
Multithecopora paucitabulata Moore & Jeffords		x					
Chaetetes eximius Moore & Jeffords		x				x	
Chaetetes favosus Moore & Jeffords		x	x				
Chaetetes subtilis Moore & Jeffords		x	x				
Palaeacis walcotti Moore & Jeffords	x						
Palaeacis testata Moore & Jeffords	x						

Three facies in the Smithwick sediments can be recognized as follows:

Siltstone facies
Fissile black shale facies
Conglomerate facies

The conglomerate is found between the black shale and Marble Falls limestone where upper black shale overlaps onto anticlinal structures and buried ridges. The black shale facies is the normal facies and makes up 90 per cent of the formation. The siltstone facies occurs in most places near the top of the formation, rarely near the middle, and it probably represents a shallowing of the Smithwick sea and the emergence of mud flats toward the end of the Smithwick epoch.

The fauna of the Smithwick is less well known than that of almost any other Carboniferous formation in the Midcontinent. With the exception of the ammonoids (Plummer and Scott, 1937), chonetids (King, 1938), crinoids (Moore and Plummer, 1939), and corals (Moore and Jeffords, following paper), no detailed paleontologic studies have been undertaken, and many of the species are new to science. The fauna in general is that which belongs in a black carbonaceous shale facies. Thin-shelled gastropods (bellerophons, euomphalids, etc.) and pelecypods (*Leda, Yoldia,* etc.) predominate; brachiopods are in the minority; ammonoids, frequently preserved as pyrite or hematite casts, are found at a few localities. Corals are represented by only a few species. The greater part of the shale section is barren of mollusks or other animal remains.

Two different fossil assemblages occur within the Smithwick formation. Both are found within 75 feet of the top of the Marble Falls limestone. The two assemblages, however, have never been found in the same section, and since the Smithwick sediments transgress and overlap structural ridges of older rock, the lower beds of Smithwick shale in different sections do not represent the same age. Accordingly these two different assemblages undoubtedly are from different zones and represent different time units. They are as follows:

1. *Cumminsia aplata* zone.—Found in the lower part of the Smithwick shale across northern San Saba County, occurring in the lower 25 feet above the Marble Falls formation. This zone contains the following corals:

   Hapsiphyllum tumidum Moore and Jeffords
   Hapsiphyllum retusum Moore and Jeffords
   Michelinia referta Moore and Jeffords
   Palaeacis testata Moore and Jeffords
   Cumminsia aplata (Cummins)

2. *Gastrioceras smithwickense* zone.—This has been found at only a few localities and is thought to belong, when present, about 60 to 75 feet above the base of the formation. It occurs at Bend on Colorado River (locality 13 in San Saba County, Pl. 11) and at a locality 3 miles east of Rochelle (locality 6 in McCulloch County, Pl. 11) at a horizon thought to be about 50 feet above the top of the Marble Falls formation. Unfortunately exposures in the Smithwick are generally poor, and this zone has been found at only two or three localities. This zone contains the coral *Zaphrentoides excentricus* Moore and Jeffords.

SUMMARY

The classification of the Lower Pennsylvanian formations shown in the accompanying table has long been in use by the Bureau of Economic Geology (Sellards, 1932) and by the U. S. Geological Survey (Darton and others, 1937). The names of the upper and lower members of the Marble Falls are new. The middle member was named by Cheney (1940) but used by him in the rank of a

Classification of the coral-bearing beds of the Lower Pennsylvanian strata in central Texas.

SERIES	FORMATION	MEMBERS	CORAL ZONES
Bend	Smithwick		*Cumminsia aplata*
	Upper Marble Falls	Lemons Bluff	*Neokoninckophyllum gracile*
		Big Saline	*Rodophyllum texanum*
Morrow	Lower Marble Falls	Sloan	*Stereocorypha annectans*

Chart showing distribution of coral species in the Smithwick and Marble Falls formations in Texas.
(Locality numbers are those used by the Bureau of Economic Geology, The University of Texas; see map, Pl. 11, and locality descriptions in following paper by Moore and Jeffords.)

Species	Localities*																												
	27-T-10	27-T-16	134-T-2	134-T-6	134-T-8	153-T-6	153-T-81	153-T-85	159-T-1	159-T-17	205-T-1	205-T-4	205-T-13	205-T-16	205-T-40	205-T-43	205-T-49	205-T-50	205-T-65	205-T-71	205-T-79	205-T-84	205-T-87	205-T-92	205-T-102	205-T-165	"Nautilus 1st" San Saba Co.	Honey Creek, Llano Co.	USGS-2429 Lampasas Co.
SMITHWICK																													
Hapsiphyllum tumidum Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—
Hapsiphyllum retusum Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—
Zaphrentoides excentricus Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	x	—	—	—	—	—	—	—	—
Cumminsia aplata (Cummins)	—	—	—	—	—	x†	—	—	—	—	—	—	x	—	—	—	—	x	—	x	—	—	—	—	—	—	—	x	—
Michelinia referta Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—
Palaeacis testata Moore & Jeffords	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Palaeacis walcotti Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—
MARBLE FALLS																													
Lemons Bluff member																													
Empodesma imulum Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x‡	—	x
Lophophyllidium conoideum Moore & Jeffords	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Paracaninia? sana Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Amplexocarinia corrugata (Mather)	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pseudozaphrentoides lepidus Moore & Jeffords	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Neokoninckophyllum gracile Moore & Jeffords	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Striatopora religiosa Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—
Cladochonus texasensis Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Multithecopora paucitabulata Moore & Jeffords	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chaetetes eximius Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—

Chaetetes favosus Moore & Jeffords	—	—	—	—	—	—	—	—	—	x	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chaetetes subtilis Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Big Saline member																													
Lophophyllidium extumidum Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
Barytichisma callosum Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pseudozaphrentoides lepidus Moore & Jeffords	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pseudozaphrentoides spatiosus Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
Rodophyllum texanum Moore & Jeffords	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Neokoninckophyllum arcuatum Moore & Jeffords	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Michelinia latebrosa Moore & Jeffords	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chaetetes favosus Moore & Jeffords	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chaetetes subtilis Moore & Jeffords	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sloan member																													
Stereocorypha annectans Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	x	—	—	—	—	—	—	—
Lophophyllidium extumidum Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lophophyllidium idonium Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lophophyllidium adapertum Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—
Barytichisma crassum Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—
Barytichisma callosum Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—
Barytichisma repletum Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Amplexocarinia corrugata (Mather)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	x	—	—	—	—	—	—	—	—	—	—
Michelinia referta Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	x	—	—	—	—	—	—	—
Acaciapora venusta Moore & Jeffords	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—
Cladochonus fragilis Mather	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—

*Designations used by The University of Texas, Bureau of Economic Geology, for fossiliferous outcrops. Descriptions of these localities are included in the following paper by Moore and Jeffords.

†Exceedingly rare at this well-known exposure.

‡"*Nautilus* limestone" is undoubtedly the prominent ledge on Colorado River southwest of Bend (205-T-1).

formation. The name Lampasas has been applied by Cheney (1940) in place of restricted Bend, and this term has received some acceptance. Cheney, however, designated as the type locality of the Lampasas the outcrops along the Colorado west of Lampasas. These outcrops are the same as those near Bend, the type locality for the Bend, and it seems to introduce confusion into the nomenclature to substitute a new name for one long in good usage by the State and Government surveys.

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DESCRIPTION OF LOWER PENNSYLVANIAN CORALS FROM TEXAS AND ADJACENT STATES

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ABSTRACT

Fossil corals are widely distributed and locally abundant in marine Pennsylvanian rocks of Texas and adjacent parts of the central United States. They are varied in form and represent many genera and species. Study of these fossils is specially desirable because of the promise of their usefulness in stratigraphic paleontology and because of the need to fill in the considerable gap now separating the large coral faunas of Lower Carboniferous and Permian rocks that have been described.

This paper gives the results of investigations on corals obtained from the Lower Pennsylvanian rocks of Texas called Marble Falls limestone and Smithwick shale. These formations crop out on the flanks and over part of the summit area of the Llano uplift, especially in San Saba, Burnet, Kimble, Mason, and McCulloch counties. Corals from rocks of approximately equivalent age in Oklahoma and Arkansas are also described; a single species is identified from New Mexico.

The Lower Pennsylvanian corals here described are assigned to 22 genera, of which 6 (*Stereocorypha, Empodesma, Lophotichium, Barytichisma, Cumminsia, Acaciapora)* are new and 7 *(Zaphrentoides, Paracaninia, Amplexocarinia, Pseudozaphrentoides, Rodophyllum, Neokoninckophyllum,* and *Multithecopora)* have not previously been recognized in North America. A total of 62 species of corals is described. This number includes 5 unnamed species, 7 previously described forms, and 50 new species. The assemblage is classified by grouping in 11 families, of which 3 (Lophophyllidiidae, Porpitidae, Palaeacidae) are new, and 1 (Zaphrenthidae) is given a new name.

INTRODUCTION

Purpose and scope of study.—To a much larger extent than is generally realized by geologists, marine Pennsylvanian deposits of the Midcontinent contain a varied assemblage of fossil corals. In some strata of this age they are very abundant. Little work, however, has been done on late Paleozoic corals in this country and most published records consist of identifications that recognize only a few species. These include such forms as *Chaetetes milleporaceus* Edwards and Haime, *Michelinia eugeneae* White, *Syringopora multattenuata* McChesney, *Lophophyllum profundum* (Edwards and Haime), *Campophyllum torquium* (Owen), and *Aulopora prosseri* Beede—using the names that commonly have been applied to them. Excepting the first-mentioned fossil, which may not be a coral, specimens from almost any horizon from oldest to youngest Pennsylvanian have been referred to these species. Accordingly, they have come to be regarded as very long-ranging and as having little value for stratigraphic paleontology. This conclusion is not supported by a critical examination of large collections of Pennsylvanian corals, in which internal structural features are determined by means of transverse and longitudinal sections. Actually there are many genera and species of American late Paleozoic corals, most of which can not be identified on the basis of external characters that seemed sufficient to earlier workers. Not only are the true stratigraphic ranges of the commonly known Pennsylvanian corals very incompletely ascertained, but reliable identification of most of them is not now possible owing to lack of essential information concerning their internal structure.

This paper gives results of our studies on available Lower Pennsylvanian corals from Texas and adjacent states. Its object is to show the nature of the known kinds of fossil corals from strata occurring between the Mississippian-Pennsylvanian boundary and the base of the Strawn (Des Moinesian) series, that is, rocks belonging to the divisions currently classed as Morrowan series and Lampasan series by many geologists of the Midcontinent region. Recent work by F. B.

Plummer (see foregoing paper) has shown that Lampasan is equivalent to Bendian (restricted) and the older name is here retained. Another purpose of the report is to indicate the degree of similarity or of difference between the observed coral assemblages of the north-central Texas area of Lower Pennsylvanian outcrops and those in near-by districts. Chiefly important for comparison with Texas are the exposures of Morrowan and Bendian rocks in southern and northeastern Oklahoma and in northwestern Arkansas. The latter region contains the type section of Morrowan deposits, although rocks of this age are not so thick here as in some other places. Lower Pennsylvanian strata, equivalent in age to pre-Strawn deposits of the Llano region in north-central Texas, occur in Trans-Pecos Texas and New Mexico, but almost no basis for comparative study of fossil corals from these areas now exists in collections available to us. A single Morrowan coral is to be reported from a locality in southern New Mexico.

The stratigraphic relations of the Lower Pennsylvanian corals from Texas are indicated in the preceding paper, by F. B. Plummer, and there is no occasion to make additions here to his description of the occurrence of the fossils. All the fossils described in this paper from areas outside of Texas are from rocks of Morrowan age.

Previous work.[1]—A number of writers have noted the occurrence of fossil corals in the Marble Falls limestone and lower Smithwick shale, of early Pennsylvanian age, in north-central Texas and in approximately equivalent strata of Oklahoma and Arkansas; but barely more than a half-dozen reports contain descriptions or illustrations of these fossils. W. F. Cummins in 1891 (p. 552) described an interesting discoid species of rugose coral that is common in the Smithwick shale near Bend, Texas, designating it as *Hadrophyllum aplatus* [sic], n.sp. This coral, which occurs in other Smithwick outcrops but is not yet known outside north-central Texas, is established in the present paper as genotype of the new genus *Cumminsia.* No other publication contains descriptions of Lower Pennsylvanian corals from Texas as new species, but Plummer and Moore (1922) reported some forms, identified in the Marble Falls and Smithwick formations, and published illustrations; also, Bassler (1937) has redescribed and figured *Hadrophyllum aplatum* Cummins. Several types of corals from Morrowan strata of northwestern Arkansas and northeastern Oklahoma were described and illustrated by Mather (1915). Corals identified in this work include species called by Mather as follows: *Zaphrentis gibsoni* White, *Lophophyllum profundum* (Edwards and Haime), *Campophyllum torquium* (Owen), *Michelinia eugeneae* White, *Chaetetes milleporaceous* [sic] Edwards and Haime, *Aulopora* sp., *Amplexus corrugatus*, n.sp., *Pachypora carbonaria*, n. sp., *Michelinia exilimura.* n.sp., *M. subcylindrica*, n.sp., and *Cladochonus fragilis*, n.sp. Croneis (1930, pl. 21) illustrated three of these Morrowan species, from the Brentwood limestone of Arkansas but did not add to description of their characters. One of the corals described and figured from the "Mayes formation," presumed to be of Chester, Upper Mississipian age, by L. C. Snider (1915) is *Pachypora oklahomensis*, n.sp.; this fossil seems almost unquestionably to have been obtained from Morrowan beds in northeastern Oklahoma. Finally, mention is to be made of Morgan's (1924) report on the Stonewall quadrangle in southern Oklahoma, which contains descriptions and figures of a new Lower Pennsylvanian coral, named *Pachypora caneyana;* this paper also contains illustrations of a few other corals from Morrowan beds of southern Oklahoma, identified as *Cyathaxonia* sp. [= *Lophophyllidium* sp.], *Cladochonus fragilis* Mather, *Michelenia* [sic] *exilimura* Mather, and *M. eugeneae* White.

[1]Since the submission of the manuscript of this paper in 1942, several articles on Carboniferous corals by R. G. S. Hudson, J. W. Wells, W. H. Easton, and others have been published. These papers deal largely with revision of concepts regarding the morphology of genera and species that have been understood incompletely and they contribute to clarification of many confusing taxonomic problems. Brief footnote reference is made to the more important observations that are pertinent to study of corals described in this paper. Analysis of some recently described new genera and species is difficult, because adequate longitudinal sections of the corals are lacking.

Methods of study.—All lots of corals in the collections were examined and classified as well as possible, first, on the basis of external features. Then, specimens were chosen for sectioning and these were sawed transversely at selected places with a thin-bladed diamond saw or a band saw using carborundum carried to the cutting edge by water. Experience in the work of sectioning and exercise of reasonable care commonly yield sections of corals that do not need smooth grinding and polishing of the cut surface in order satisfactorily to reveal structural features of these fossils. The sections were photographed, mostly at x5 magnification, and then one or more segments of the coral were sectioned longitudinally in a plane perpendicular to the counter and cardinal septa whenever possible to identify these septa. The longitudinal sections were photographed and the several illustrations belonging to one specimen were mounted together for study. Two dozen or more specimens of some lots were sectioned and photographed, and, in aggregate, hundreds of corals were thus prepared. Many peel sections, which require polishing and slight etching of the surface to be represented by the peel, were made and a number of thin sections were sliced and ground; but, generally, the cut sections showed structures clearly, especially when coated with a light oil. A binocular microscope was used constantly in studying the sections, supplementing work with the photographs.

The technique in inking and bleaching selected photographs for published illustrations of coral sections has been described in some detail by us in earlier papers (Moore and Jeffords, 1941, p. 72; Jeffords, 1942, p. 190) and need not be repeated here. This treatment gives accurate and clear representation of observed structures and, because reproduction is relatively inexpensive as compared to half-tone or full-tone figures, more adequate illustration of a species can be offered under a specified limit of cost.

An invaluable tool for study of Paleozoic corals is an illustrated card catalog of genera and species based on an extended survey of world literature on the subject. This catalog, financed by the State Geological Survey of Kansas and by grants from the Graduate Research Committee of the University of Kansas, has been organized very largely by Mr. Jeffords.

Collections studied.—Corals from the Lower Pennsylvanian formations of north-central Texas that have been available for our study are chiefly from three sources. The Bureau of Economic Geology, The University of Texas, has a large and representative collection of these fossils, obtained mainly during field studies by F. B. Plummer and assistants; an especially rich assemblage of the Smithwick coral, here named *Cumminsia aplata*, showing the range of its variation, is contained in the Plummer collection. Numerous specimens belonging to the U. S. Geological Survey, mostly from unspecified horizons in the Marble Falls limestone, were loaned to R. C. Moore some years ago for study; work on these corals was intended to have been part of a collaborative investigation of invertebrate fossils of the Marble Falls and Smithwick strata by George H. Girty and R. C. Moore, but the carrying out of plans was prevented by attention on the part of both to other work and by the untimely death of Doctor Girty in 1939. Numerous specimens from north-central Texas in the collections of the University of Kansas, obtained in the course of field work by R. C. Moore beginning in 1918, have been available for this study.

Specimens of Lower Pennsylvanian corals from Oklahoma and Arkansas that have been used in preparing the present paper belong to The University of Texas and the University of Kansas. Collections in the type Morrow region, northwestern Arkansas, were made by F. B. Plummer and R. C. Moore. Large numbers of well-preserved corals from the Hale formation in northeastern Oklahoma have been collected by L. R. Laudon, A. L. Bowsher, R. H. King, R. C. Moore and students of paleontology classes at the University of Kansas; these fossils have been obtained chiefly at localities about 8 miles northeast and 12 miles southeast of Muskogee, Oklahoma. Southern Oklahoma specimens in our collection are from Morrowan strata of the Ardmore basin, south of the

Arbuckle Mountains, and from the Wapanucka limestone, also Morrowan, north of the Ouachita Mountains; these were found on various trips in the field by R. C. Moore.

Sectioned and polished specimens of a distinctive lophophyllidid coral, from beds near the base of the Pennsylvanian section in Searcy County, northwestern Arkansas, were kindly furnished to us by W. H. Easton, of the Illinois Geological Survey.

A single specimen of a Morrowan coral from southern New Mexico was collected by A. L. Bowsher, of the University of Kansas, in the course of work with L. R. Laudon in the summer of 1942; this coral is identified as *Striatopora oklahomensis* (Snider).

It is reasonable to estimate that the materials studied by us in making the present report represent a majority of the kinds of Lower Pennsylvanian corals occurring in the north-central Texas and Oklahoma-Arkansas regions, but this does not mean that many additional types of solitary and colonial corals are not to be discovered in rocks of this age, especially in areas that have not yet been searched for fossils. Noteworthy variation in the constitution of local assemblages of corals is shown by our investigations, and this is expectable if the stratigraphic horizons represented by the fossils are somewhat discordant, if conditions of sedimentation affected the distribution of early Pennsylvanian corals, and if regional differences of provincial nature due to such partial barriers as the southern Oklahoma mountain uplifts of early Pennsylvanian time prevailed in life of the shallow seas. Thus, it is desirable to specify the ground on which we have worked. Although the number of genera and species of Upper Carboniferous corals reported from rocks of North America is augmented appreciably by the forms described in this paper, we are sure that the field is only partially explored.

Acknowledgments.—We express thanks to the several geologists, mentioned in discussion of the collection studied, who have contributed to the results of our work by making specimens obtained by them available to us. Especially, such expression of appreciation is due to F. B. Plummer, at whose instance this research has been pressed to the state of readiness for publication. It seemed to him very desirable to expedite a study of the north-central Texas Lower Pennsylvanian corals because of their bearing on detailed stratigraphic studies that he has been making for some time in the Llano region.

Some of the drawings of the exterior of fossil corals [illegible] by Wayne Gallentine an[illegible]graphic assistance was given by Owen C. Bingham, both of the University of Kansas. Miss Ann Hill, of Lawrence, assisted in bibliographic work and other parts of the study. Harold and Frances Williams have given highly valued assistance in bibliographic work, checking the records of occurrence, labeling specimens, and other tasks. James Steele Williams, of the U. S. Geological Survey, made search for locality data on collections that had been loaned by G. H. Girty. A letter received during preparation of this manuscript calls attention to our regrettable oversight in publishing acknowledgment of aid given to us in translating from the Russian a diagnosis of one of Soschkina's coral genera. Dr. M. K. Elias, of the Nebraska Geological Survey, very kindly performed this much-appreciated service. We are glad to acknowlege this aid. We express thanks also to the State Geological Survey of Kansas and the Graduate Research Committee of the University of Kansas for financial support.

CLASSIFICATION OF PALEOZOIC CORALS

The problem of constructing a classification of fossil corals that expresses significant similarities of structure on the one hand and contrasts in morphologic features on the other, reflecting with reasonable precision the phylogenetic relations of the many forms known, is exceedingly difficult. This is especially true of Paleozoic corals, the vast majority of which belong to extinct major groups. Studies by many workers are leading to general recognition of the nature of several evolutionary trends among the older corals (Lang, 1923; Jeffords, 1942, p. 200); but because these may affect stocks of different origin so as to produce various sorts and degrees of homeomorphy, they are not easily or directly applicable to solution of questions of classification. It is not our intention to review the subject of classification of corals even cursorily but only to make explanation of the grouping of genera in the systematic part of this paper. Recently published contributions to the taxonomy of Paleozoic corals include articles by Gerth (1919), Lang (1923), Grabau (1928), Hill (1935, 1938, 1939, 1940), Huang (1932), Sanford (1939), and Jones and Hill (1940).

The Lower Pennsylvanian corals from Texas and adjacent areas comprise representatives of three distinct major groups. (1) The most important of these from the standpoint of numbers of individuals and of genera and species is characterized by the presence of well-developed septa; these radially disposed walls extend to the axis of the coral or reach only part way to the axis, and commonly they are divisible into distinct quadrants. The names Tetracoralla and Tetraseptata, which denote the four-fold grouping of the septa in these corals, have been used, but an older and much more generally adopted term is Rugosa, which refers to the uneven character of the surface of most specimens. We recognize the Rugosa and designate the group as a suborder of the order Madreporaria, subclass Zoantharia, class Anthozoa. The Rugosa include solitary and colonial corals, which are characterized essentially by a bilateral symmetry resulting from insertion of the major septa in four positions arranged in pairs. (2) Another group of Lower Pennsylvanian corals that is also abundant in other Paleozoic rocks is distinguished by the absence or extreme shortness of radially disposed walls and the presence in all but a few genera of numerous platforms called tabulae. This assemblage has come to be known as the Tabulata, but almost certainly it is not a natural phylogenetic division. All representatives of the Tabulata are colonial. (3) A third group of corals that is represented by a single rather uncommon genus *(Palaeacis)* cannot be assigned to either of the previously indicated divisions, and it has been referred tentatively by some authors to a place among the Mesozoic-Cenozoic modern type corals called Hexacoralla. Possibly it is not a coral but belongs with the sponges or with fossils like the Archaeocyathidae that may be intermediate between sponges and corals.

The definition and diagnosis of families among the Rugosa and Tabulata are very considerably influenced by subjective factors. Accordingly, Lang, Smith, and Thomas (1940) did not undertake to incorporate an outline of the organization of Paleozoic coral families in their invaluable index of genera. Although the existence of many problems as to assignment of Paleozoic genera in families is recognized, there are good grounds for differentiating numerous family assemblages. It may be granted that the basis for establishment of some groups is insecure, phylogenetically; but, lacking proof of significant lines of evolutionary differentiation, it seems best to segregate genera having like structural characters and belonging generally to a somewhat restricted segment of geologic time. The International Rules do not provide regulations concerning the nomenclature of families except for specifying addition of -idae to the name of the family type genus in making the designation for the family. Widely recognized among zoologists, however, is the good practice of extending to nomenclature of families the essential features of rules for the valid names of genera. Thus, the acceptable name for a family is that based on the first-chosen genus included in the family assemblage, whether or not this family type first published is deemed to be wholly representative of the entire assemblage.

TERMINOLOGY

The names applied to the various structural features of fossil corals are not altogether uniform, and the terminology of some workers is needlessly technical and complicated. Descriptive adjectives, such as phaceloid, rhopaloid, reptant, adnate, utricular, and many others, are perhaps advantageous from the standpoint of avoiding circumlocution, but it must be confessed that they are sufficiently unfamiliar to most students to make use of them in combination with necessary morphologic terms undesirable. The specialist in study of the corals knows the distinction between fossula and pseudofossula, between carinae, synapticulae, trabeculae and dissepiments, and between different types of axial columnar structures; one who has not undertaken research on fossil corals is likely to have forgotten. or not to know, the meaning of some terms. For the sake of defining our usage of morphologic terms and as a convenience to readers, we introduce an alphabetically arranged list of words, commonly used in description of corals, and brief explanations of them. Much more detailed accounts of coral morphology and terminology are given by Grabau (1922), Hill (1935), and Sanford (1939).

Acceleration is the more rapid introduction of septa in certain parts (quadrants) of a coral than in others, giving rise to a greater number of septa in these parts at a given growth stage.

Alar is a term applied to two primary septa (protosepta) on opposite sides of a rugose coral and to more or less defined wide spaces (pseudofossulae) that may border the alar septa on the side facing the counter septum. One of the four insertion points of newly formed major septa adjoins each alar septum on the counter side and this relationship commonly serves for identification of the alar septa. On diagrams and in septal formulae the alar septa are indicated by the symbol A.

Apical indicates the immature lowermost part of a corallite, near the apex of cone-shaped forms.

Axial refers to the mid-line of the upwardly growing coral; this term may be applied to a centrally located columnar structure or to designate a region in the coral skeleton.

Brevisepta are much-shortened radial partitions of a coral that extend inward only part way from the periphery to the axis.

Calyx is the more or less deep cuplike hollow at the top of a coral skeleton to which the living polyp is attached.

Cardinal is a term that applies first to one of the four main earliest-formed septa of a rugose coral; it lies in the plane of bilateral symmetry, and insertion points of newly formed major septa adjoin it on both sides. Secondarily, the name cardinal is applied to the depression (fossula) that is formed by the partial or complete abortion of the cardinal septum, and it is used also to designate the quadrants of septa that lie contiguous to the cardinal septum. On diagrams and in septal formulae the cardinal septum is commonly indicated by the symbol C (or H, for Hauptseptum, in German). Transverse sections of rugose corals illustrated in this paper are oriented with the cardinal septum directed downward.

Carinae are keel-like ridges on the sides of septa; they are straight or curved and run more or less longitudinally.

Column is a term applicable to varied sorts of axial structures of corals (including *columella* and *pseudocolumella* of authors), ranging from dense rodlike growths to delicate open meshwork.

Compound corals are colonial forms consisting of a number of individual corallites attached to one another.

Corallite is the name used for the hard parts of a coral individual.

Corallum refers collectively to the hard parts of a coral colony.

Counter (meaning opposite) is the name given to one of the four first-formed septa of rugose corals, lying in the plane of bilateral symmetry opposite to the cardinal septum; it is also applied to the quadrants of septa contiguous to it. On diagrams and in septal formulae the counter septum is indicated by the symbol K (or G, for Gegenseptum, in German). Transverse sections of rugose corals figured in this paper are oriented with the counter septum directed upward.

Dissepiments are small curved plates built one on another so as to form vesicles; their convex surfaces are directed toward the interior of the coral and more or less upward. Dissepiments occur only in some rugose corals and commonly they are restricted to the peripheral region. Intercepts of tabulae in transverse sections of corals may simulate those of dissepiments and several authors have erroneously reported occurrence of dissepiments in genera that lack them.

Fossula is a depression in the floor of a rugose coral calyx formed by the partial or complete abortion of a protoseptum, in virtually all cases the cardinal septum. The presence of a fossula may be revealed in transverse sections of a corallite by a distinct open space extending peripherally between some of the septa.

Inner wall is a term most commonly employed to designate a thickened wall-like structure at the inner edge of a zone of dissepiments; it is also applied to a curved wall that is formed in some rugose corals by union of the inner extremities of some of the septa.

Interseptal ridges are longitudinal elevations on the exterior of some rugose corals that mark slight outward bulges of the enclosing wall (theca) of the coral.

Lamellae are subvertical plates of the axial region of some rugose corals, generally not confluent with septa; they may be discontinuous longitudinally. Some corals, like *Dibunophyllum*, have an axial column that is characterized by a prominent *median lamella* in the plane of the cardinal and counter septa and by *radiating lamellae*, which intersect the median lamella at different points.

Lonsdaleoid structure refers to the peripheral disappearance of septa in a dissepimental zone, as in the genus *Lonsdaleia*, so that the septa do not reach the theca.

Major septa are the relatively long septa of rugose corals that comprise the four first-formed protosepta and subsequently inserted pairs of septa (metasepta) appearing in definite order in the different quadrants.

Metasepta are major septa other than the protosepta.

Minor septa are secondarily introduced septa, generally short, that appear nearly simultaneously between major septa of some rugose corals.

√*Mural pores* are tubular passageways that perforate the walls of many tabulate corals, serving to permit connection of the soft parts of adjacent polyps of a colony.

Peripheral refers to the outer zone of a corallite.

Protosepta are the four first-formed septa of rugose corals (cardinal, counter, two alar) that are introduced nearly simultaneously very early in the growth of the corallite and that define the tetrameral development and bilateral symmetry of these fossils. Except the counter, they are the septa next to which insertion points of newly formed major septa are located. According to some investigators, an additional pair of septa (counter-laterals), which adjoin the counter septum, are classifiable as protosepta but these do not affect the four-fold arrangement of the septa.

Pseudofossula is a depression or space between septa on the floor of the calyx of some rugose corals, not formed by the partial or complete suppression of a septum. Pseudofossulae are developed on the counter side of the alar septa in many corals and are termed alar pseudofossulae.

Quadrant, not necessarily an exact one-fourth, is the term given to areas of the corallite in the Rugosa lying between any two adjacent protosepta: these areas are designated, respectively, as cardinal quadrants (adjoining the cardinal septum) and counter quadrants (adjoining the counter septum).

Rejuvenation is a renewal of immature structural characters during the growth of a corallite after maturity has been attained.

Rhopaloid is a descriptive term, meaning club-shaped, that refers to the thickened inner edges of septa, as developed in some rugose corals.

Septa are the radial partitions that partly or completely divide the interior of rugose corallites into compartments; they are the most characteristic structural feature of most rugose corals.

Septal formula designates the relative position of protosepta and the number of metasepta in respective quadrants in a consistent abbreviated manner. As employed in this paper, the formula begins with the counter septum, proceeds clockwise around the corallite, and ends at the counter septum—for example, counter septum (K), 9 metasepta, alar septum (A), 4 metasepta, cardinal septum (C), 3 metasepta, alar septum (A), 9 metasepta, and the counter septum again. Expressed as a formula, the septal arrangement of this corallite may be given as follows:

K 9 A 4 C 3 A 9 K.

Septal grooves are longitudinal depressions on the exterior of some corals that mark inbending of the outer wall along lines at the edges of the septa.

Solitary corals are individuals that grow unattached to other corallites, as in a colony.

Stereoplasm consists of organically deposited calcium carbonate and this term is especially used in referring to secondary thickening of various coral structures.

Stereozone is a convenient term for the designation of a band or zone in the interior of a corallite that is made dense by deposits of stereoplasm. Such a zone may be formed by thickening of skeletal elements or by the partial or complete filling of spaces between them.

Tabellae are more or less strongly arched platforms of the axial region that in some corals are seemingly differentiated from tabulae, but this distinction in nomenclature has dubious value.

Tabulae are subhorizontal, arched, or upwardly concave platforms that are not limited by the septa and that extend at least partly across the axial region of the corallite. Complete tabulae are those that reach across the axial area without intersecting an axial structure and that join the outer wall or a zone of dissepiments peripherally. Other tabulae are incomplete or anastomosing.

Theca is the term given to the outer wall of Paleozoic corals.

SYSTEMATIC DESCRIPTIONS

Phylum COELENTERATA
Subphylum CNIDARIA
Class ANTHOZOA
Subclass ZOANTHARIA
Order MADREPORARIA
Suborder RUGOSA Edwards

The suborder Rugosa includes solitary and colonial corals having typically a well-defined theca and more or less elongate septa grouped in four quadrants defined by protosepta. In a few genera the theca is very thin or largely lacking. The septa are disposed in a bilaterally symmetrical manner, owing to distribution of the four insertion points of successively added major septa in pairs; the respective pairs are located next to the alar septa on the counter side and adjoining opposite sides of the cardinal septum. Tabulae are commonly present, dissepiments occur in many genera, and an axial column is present or absent. Range, Ordovician to Permian.

Family STREPTELASMAIDAE Nicholson and Lydekker, 1889

Solitary corallites of conical to cylindrical form comprise this family; they have a strong theca that commonly bears longitudinal grooves and ridges on the exterior, and they are marked internally by numerous bilaterally arranged septa. A more or less distinct axial column may be present but this is not a solid rodlike structure. Tabulae are few to numerous, but dissepiments are lacking. Range, Ordovician to Permian.

Discussion.—The differentiation of this family assemblage, especially as regards the inclusion or exclusion of several genera that have been referred to it by authors, is not satisfactorily established. One may observe, however, that this statement applies also to several other proposed coral families. Most of the difficulties in classification have origin not only in uncertainties concerning the evolution and taxonomic importance of different structural features, but in lack of knowledge of the characters of corals themselves. This paper is not at all directed toward consideration of general problems in classification of the corals, and so, in general, no discussion of the composition or phylogeny of families is undertaken. We seek merely to allocate the Lower Pennsylvanian genera here described in assemblages where they seem most naturally to belong.

The Streptelasmaidae are seemingly related to the Lindströmiidae (Pocta, 1902) and Lophophyllidiidae, n.fam., both of which have tabulae and solid axial structures but lack dissepiments. The Streptelasmaidae do not have a definite column.

The Cyathaxonidae (Edwards and Haime, 1850), which have a dense axial column and possess tabulae but no dissepiments (Carruthers, 1913, p. 54), are distinguished from the Streptelasmaidae by the manner of insertion of major and minor septa (Hill, 1935, p. 503), which differs markedly from that of streptelasmaid genera.

The Streptelasmaidae are distinguished from the Hapsiphyllidae by differences in structure of the axial region of the corallites and by general absence or weak development of fossulae in the former, as contrasted to the well-defined fossulae in the latter. The Streptelasmaidae are not open in the axial region, and inner margins of the septa do not join to make a wall, as in some of the Hapsiphyllidae; a fairly distinct, though not solid, axial column may occur in streptelasmaid genera, but such a structure is not developed among the hapsiphyllids.

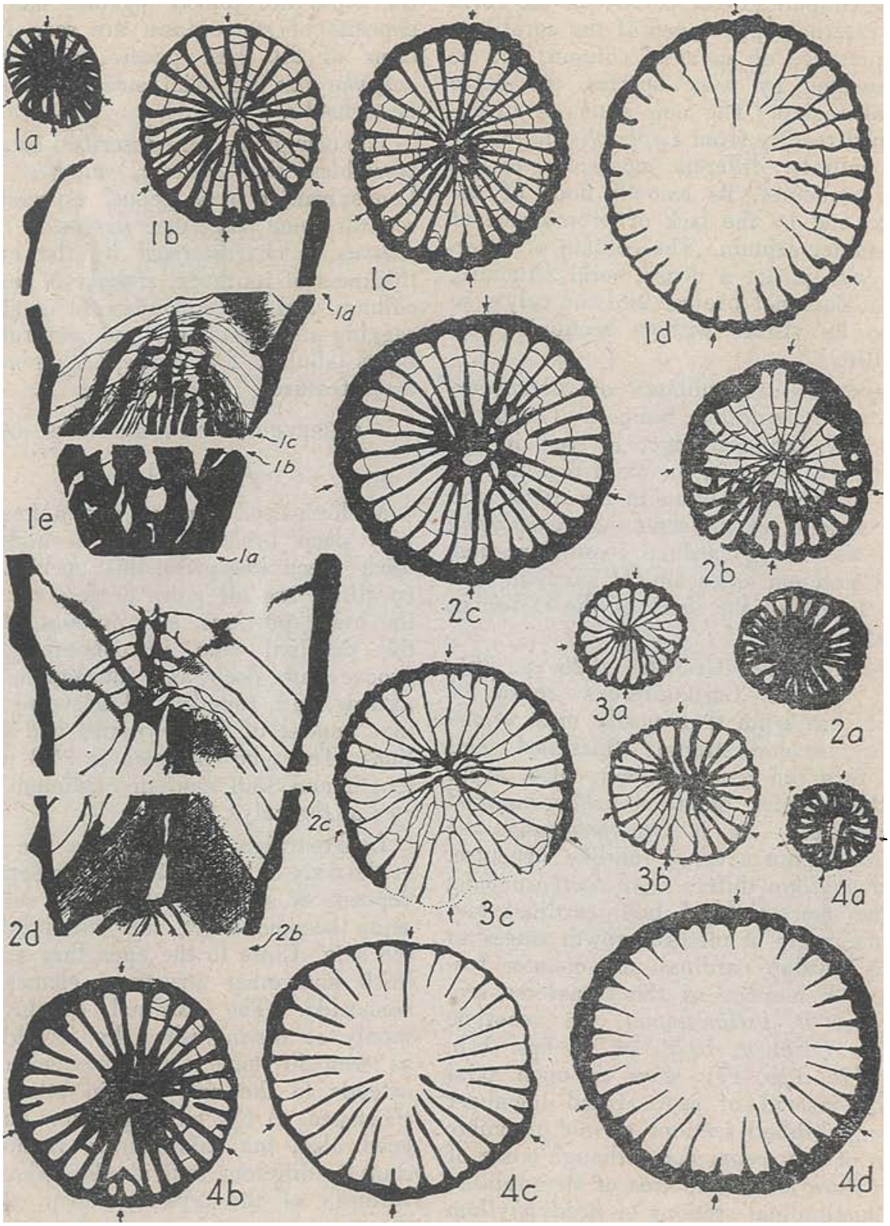
The Zaphrenthidae, Clisiophyllidae, and other families differ from the Streptelasmaidae in having more or less abundant dissepiments.

Genus STEREOCORYPHA, n.gen.

Solitary corallites of small to medium size, having a slightly curved conical form, are included in this genus. The theca is moderate in thickness, and its exterior is marked by septal grooves, transverse wrinkles, and growth lines. The calyx is deep, its bottom part broad and nearly flat, and its sides very steep; in the genotype species the depth of the calyx may equal its diameter. About 20 to 30 long straight septa are evenly disposed around the corallite, most of them or all of them reaching to the axis where they are joined together by thickening of the septa and deposits of stereoplasm. The shortened nature of some septa is sporadic. The cardinal septum lies in an obscurely marked fossula; it is commonly thinner than the other septa and joined to the axis in the lower parts of the corallite, and it is distinctly shortened and not joined to the axis near the floor of the calyx. Alar pseudofossulae are identifiable in some transverse sections but are not prominent. The arrangement of the septa shows distinct acceleration of the counter quadrants. Minor septa are lacking. There are fairly numerous arched tabulae, some of them anastomosing, but dissepiments are absent. The apical portion of all studied specimens is characterized by its almost solid nature, due to deposits of stereoplasm.

Genotype.—*Stereocorypha annectans*, n. sp., base of Marble Falls limestone, Morrowan, Lower Pennsylvanian (Upper Carboniferous), southwest of San Saba, Texas.

Discussion.—This genus is distinguished mainly by the arrangement of its septa, especially their union in the axial region so as to form an irregular column, and the dense nature of the apical region. Other characters, such as the lack of strongly marked cardinal, counter, and alar septa, as seen in transverse sections, the rather steeply arched tabulae, absence of minor septa, and very deep calyx, aid in identification of the genotype species, but probably they have less value for generic diagnosis.



Figs. 1–4. Sections of Marble Falls streptelasmaid corals, x3, all belonging to *Stereocorypha annectans,* n.gen., n.sp., from the base of the Marble Falls limestone on Wallace Creek about 10 miles southwest of San Saba, Texas (loc. 205–T–43). Transverse sections are oriented with the cardinal septum at bottom; protosepta indicated by small arrows. Longitudinal sections are mostly at right angles to the plane of the cardinal and counter septa; positions of the transverse sections shown by small italic figures. (1) Type specimen, no. P11931c. (2) Specimen no. P11913a. (3) Specimen no. P11229a. (4) Specimen no. P11931d.

Stereocorypha resembles *Lophophyllidium* Grabau (1928, p. 98) in the form and external appearance of the corallites, the presence of an axial column, and as represented by some species, the dense apical region. The new genus is distinguished readily from *Lophophyllidium* by the entirely different character of its axial structure, its smooth floor of the calyx, and by the lack of prominence of its counter septum. The column of *Stereocorypha* is not a dense, solid structure, and it does not project into the calyx, so as to be visible without sectioning the corallite.

Superficial resemblance of *Stereocorypha* to *Stereolasma* Simpson (1900, p. 205), of Devonian age, is seen in the junction of septa in the axial region, lack of a projecting column in the calyx, and even spacing of the septa. *Stereocorypha* lacks the strong cardinal fossula, regular axial column, open apical portion, and even length of the septa of the Devonian genus.

Bradyphyllum Grabau (1928, p. 35), from Middle Carboniferous rocks of China, has septa that mostly meet at the center, become strongly thickened, and thus form an axial column; also, septa of the counter quadrants show marked acceleration. As in *Stereocorypha*, the column is not a dense rod-like structure. *Bradyphyllum* differs from *Stereocorypha* in the shortening of both cardinal and counter septa at mature growth stages so as to develop cardinal and counter fossulae. A number of the transverse sections of *B. bellicostatum*, the genotype species (Grabau, 1928, pl. 2, figs. 11b, 11d, 11e, 12b, 17), show an open axial region instead of septa fused together; other published sections do not resemble those of *Stereocorypha*, although some of them show a circular area of stereoplasm. No longitudinal sections of *Bradyphyllum* showing the axial region are given.

Distinction between *Stereocorypha* and hapsiphyllid genera, such as *Zaphrentoides* Stuckenberg (1895, p. 191), *Hapsiphyllum* Simpson (1900, p. 203), and *Euryphyllum* Hill (1936, p. 50), is readily made on the basis of transverse sections showing the arrangement of septa and the well-defined fossulae of the three last-mentioned genera. Although some of the septa are joined together and axial deposits of stereoplasm are seen in sections of all these genera, only *Stereocorypha* has an axial structure that can be termed a column.

The new genus here described somewhat resembles *Barytichisma*, another Lower Pennsylvanian new genus, especially as regards some transverse sections. *Barytichisma* is characterized by the unusual thickness of its theca, absence of an axial column, and the subhorizontal or slightly sagging attitude of the broad central parts of its tabulae. *Stereocorypha* has none of these features.

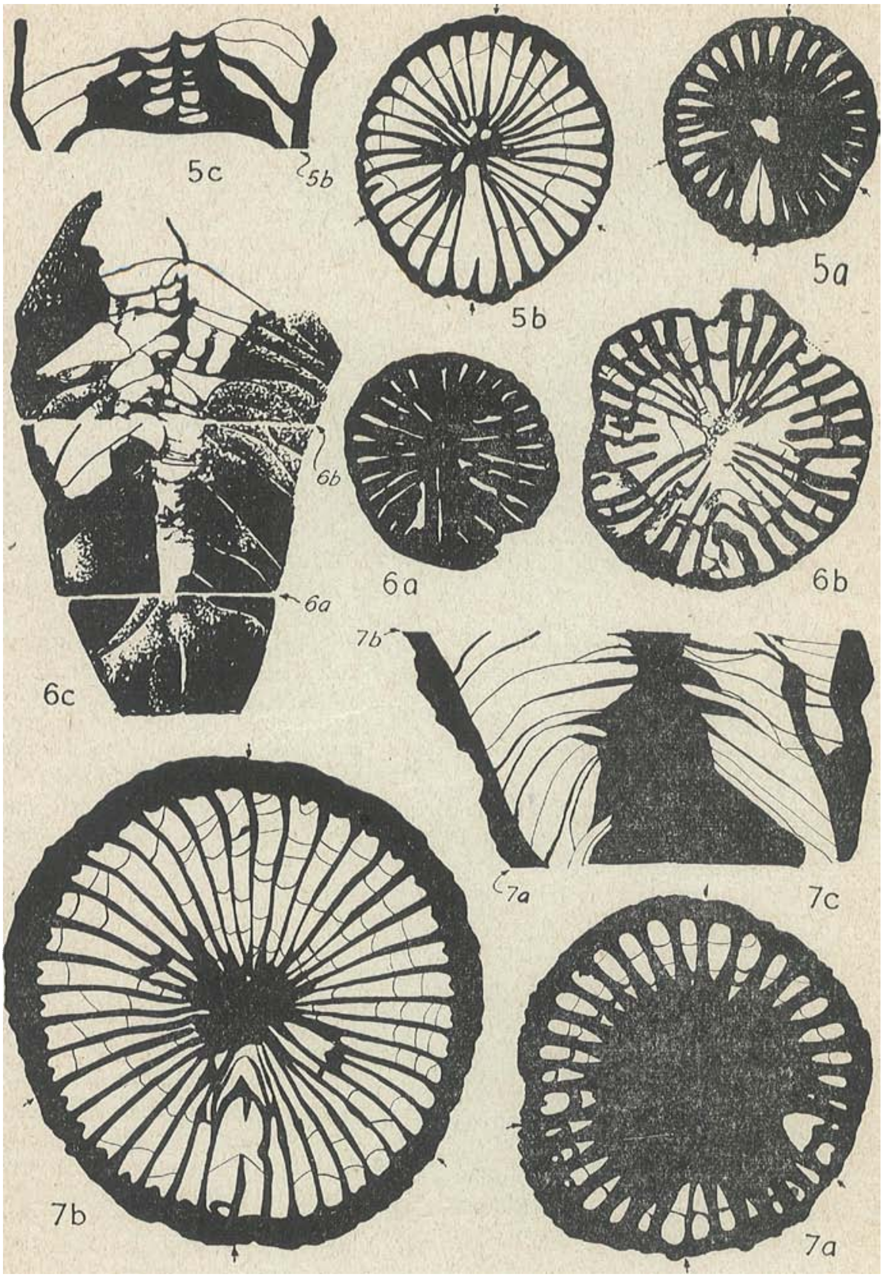
STEREOCORYPHA ANNECTANS, n.sp.

Text figs. 1–6, 9

Medium-sized conical corals having a very deep broad calyx and moderately thick theca comprise this species. The corallites are all more or less curved in the lower portions, and in most of them the cardinal side is concave. Septal grooves are deep and interseptal ridges narrow and rounded. Transverse markings consist of low wrinkles and growth lines. The type specimen is 24.3 mm. in length and 13.8 mm. in maximum diameter at the calyx.

Long straight major stepta are joined at the axis by thickening of the septa and deposits of stereoplasm. In the calyx the septa become short and withdraw from the axis. Close to the apex they are very thick and other structural elements are concealed. The cardinal septum commonly is distinguished by its thinness; as seen in some transverse sections, it extends to the axis but in others it is shortened. A few metasepta may be shortened also, but this feature is not constant in different individuals. The septal formula of the type specimen, showing the very strong counter acceleration, is as follows: K 9 A 3 C 4 A 9 K.

Numerous slightly anastomosing tabulae rise steeply from the periphery to the column. Dissepiments are lacking. The junction of the axial ends of the septa and arched tabulae is thickened with stereoplasm to form a more or less open column. The cardinal septum lies



Figs. 5-7. Sections of Marble Falls and Wapanucka streptelasmaid corals, x3, belonging to *Stereocorypha*, n.gen. Transverse sections are oriented with the cardinal septum at bottom; protosepta indicated by small arrows. Longitudinal sections are mostly at right angles to the plane of the cardinal and counter septa; positions of the transverse sections indicated by small italic figures. (5) *Stereocorypha annectans*, n.sp., specimen no. P11914a, from the base of the Marble Falls limestone on Wallace Creek about 10 miles southwest of San Saba, Texas (loc. 205-T-43); (6) specimen no. KU7511-24c, from the Marble Falls limestone 1.3 miles south of Maxwell Crossing, San Saba County, Texas (loc. 205-T-84). (7) *Stereocorypha spissata*, n.sp., the type specimen, no. KU7060-22a, from the Wapanucka limestone near Limestone Gap, Atoka County, Oklahoma.

in an inconspicuous but definite fossula which is crossed by numerous tabulae. Alar pseudofossulae are present but well defined in middle periods of growth only.

Discussion.—This new genus and species resembles Mississippian corals described by Grove (1935) as *Triplophyllum welleri* Grove, *T. dalii* (Edwards and Haime)?, and *Hapsiphyllum cassedayi* (Edwards and Haime) in the characters of the cardinal fossula, the union of the major septa at the axis, presence of rudimentary minor septa, and lack of dissepiments. The Marble Falls corals have a distinctly longer cardinal septum than any of these species, however. *Stereocorypha annectans* differs from *Hapsiphyllum cassedayi* also in the lack of definite minor septa and of a wall about the fossula, and in the more conical shape of the corallite. *S. annectans* is distinguished from *T. dalii* by the small size of the corallite and inconspicuous cardinal fossula. *S. spissata*, n.sp., has a septal arrangement somewhat similar to that of *S. annectans*, but the latter can be separated by the smaller size, thinner theca, and fewer, more irregular tabulae.

Occurrence.—Marble Falls limestone, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by F. B. Plummer and R. C. Moore, near Wallace Creek road, 10 miles southwest of San Saba, San Saba County, Texas (loc. 205–T–43); collected by R. C. Moore from 1.3 miles south of Maxwell Crossing on San Saba River (loc. 205–T–84 or Univ. Kansas loc. 7511).

Material studied.—Several hundred well-preserved corallites are available for study, and about 25 representative specimens have been sectioned.

Type.—The University of Texas, Bureau of Economic Geology, specimen no. P–11931c from 10 miles southwest of San Saba, Texas.

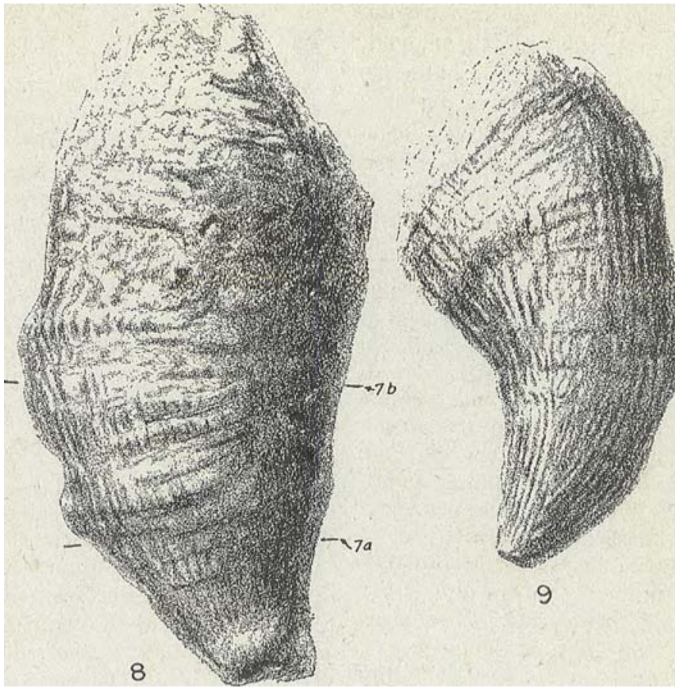
STEREOCORYPHA SPISSATA, n.sp.

Text figs. 7, 8

Large conical corals having a deep calyx and thick theca comprise this species. The counter septum is located on the concave side of the corallite in one of our specimens and on the convex side in another. The surface is marked by prominent septal grooves and rounded ridges, which are crossed by growth lines and a few low wrinkles. The type specimen is 44 mm. in length and 23.5 mm. in diameter at the calyx.

Long major septa extend to the axis, except in the calyx. In early periods of growth they are thick and joined together at the axis by stereoplasm so that septa are separate only in the peripheral third of the corallite. The septa become thinner throughout their entire length in mature parts of the corallite, but continue to the axis where they are loosely joined by stereoplasm. The cardinal septum is thin in youthful stages and much shortened in advanced portions. Other major septa are equal in length and thickness. The septal formula in the upper part of the type specimen is as follows: K 12 A 6 C 6 A 12 K. This arrangement indicates a strong counter acceleration, twice as many septa occurring in the counter quadrants as in the cardinal quadrants. Minor septa are present near the calyx as rudimentary ridges. The cardinal side of the coral is indicated in youth by the thin cardinal septum and large cardinal pseudofossulae and in sections of adult forms by the shortened cardinal septum and closed fossula. Alar pseudofossulae are present in immature parts of the corallite. The deposition of stereoplasm about the axial edges of the septa and filling up much of the lower parts of the corallites produces an irregular axial structure. Numerous regularly spaced thin tabulae rise from the periphery, level out abruptly and continue to the axis. Dissepiments are lacking.

Discussion.—This species is characterized by its large size, long septa, and thickened lower portions. It can be distinguished from *Stereocorypha annectans*, n.sp., by the larger size of the corallite, thick deposit of stereoplasm at the axis, and more regular tabulae. In both these species the septa are long and more or less joined at the axis and the lower portions filled with stereoplasm. *S. spissata* is separated from *Barytichisma* by its continuous axial column, the lack of a distinct closed cardinal fossula and alar pseudofossulae in youthful stages, as well as in the thinner theca and arched tabulae.



Figs. 8, 9. Exterior views of specimens of *Stereocorypha*, n.gen., x2. (8) *S. spissata*, n.sp., type specimen, no. KU7060–22a, from Wapanucka limestone near Limestone Gap, Atoka County, Oklahoma. (9) *S. annectans*, n.sp., specimen no. KU7171–21i, from the base of the Marble Falls limestone on Wallace Creek about 10 miles southwest of San Saba, Texas (205–T–43).

Occurrence. — Wapanucka limestone, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore at Gap, Oklahoma (Univ. Kansas loc. 7060).

Material studied.—Two well-preserved specimens were available for sectioning.

Type.—University of Kansas, specimen no. 7060–22a.

Genus EMPODESMA, n.gen.

Conical solitary corallites of very slight curvature having a very oblique calyx and characterized by the prominence of the protosepta in the apical region, the cardinal and counter septa being joined together for some distance vertically from the apex, are assigned to the new genus *Empodesma*. Primitive septal patterns persist during early growth longer than is ordinarily observed in late Paleozoic rugose corals.

The theca is moderately thin and its outer surface is marked only by fine concentric growth lines and coarser wrinkles, except in one observed specimen that shows faint longitudinal markings near the apex. The calyx has a broad, comparatively even floor and a thin encircling wall about equal to the radius in height or less; commonly the wall is broken away. Owing to the obliquity of the calyx, the long side of the corallite has about twice the length of the short side. The protosepta are long and thick in the apical region, the cardinal and counter septa being joined together firmly; other major septa are shorter but just above a tabula they may form a virtually solid mass extending to the axial region. The major septa are not fused together in places where they are crowded. In the upper part of the corallite the septa become thinner and the interspaces wider, the cardinal septum is partially aborted and a fossula is produced. No minor septa are known to occur in corals belonging to this genus. Tabulae are common but not closely crowded. They rise slightly from the theca and sag in crossing the axial region or they are subhorizontal throughout. Most of the tabulae are complete but some are incomplete. Dissepiments are lacking.

Genotype.—*Empodesma imulum*, n.sp., Marble Falls limestone, Bendian, Lower Pennsylvanian, north-central Texas.

Discussion.—This genus differs from *Lophophyllidium* Grabau and other column-bearing corals in the entire absence of a column, even though the axial region is shown by some transverse sections to be dense or to be characterized by prominence of coalesced cardinal and counter septa. The thick closely crowded septa that are seen in some sections and the strong acceleration of the counter quadrants are characters suggestive of *Euryphyllum* Hill, described from Permian rocks of Australia, but these are merely superficial resemblances; in *Empodesma* the septa become thin near the calyx, there are no considerable deposits of stereoplasm in any part of the corallite, and the internal structure generally is fairly open. *Stereocorypha* lacks the strongly defined bilateral symmetry that is produced by the arrangement of septa in the apical region of *Empodesma*, and it has an irregular sort of axial column. Some species of *Barytichisma* have thickened and axially joined septa in the immature region and a well defined cardinal fossula in the calyx, but this genus is distinguished from *Empodesma* by its greatly thickened theca, more numerous, regularly arranged septa, the lack of obliquity of the calyx, and especially its dissimilar apical region.

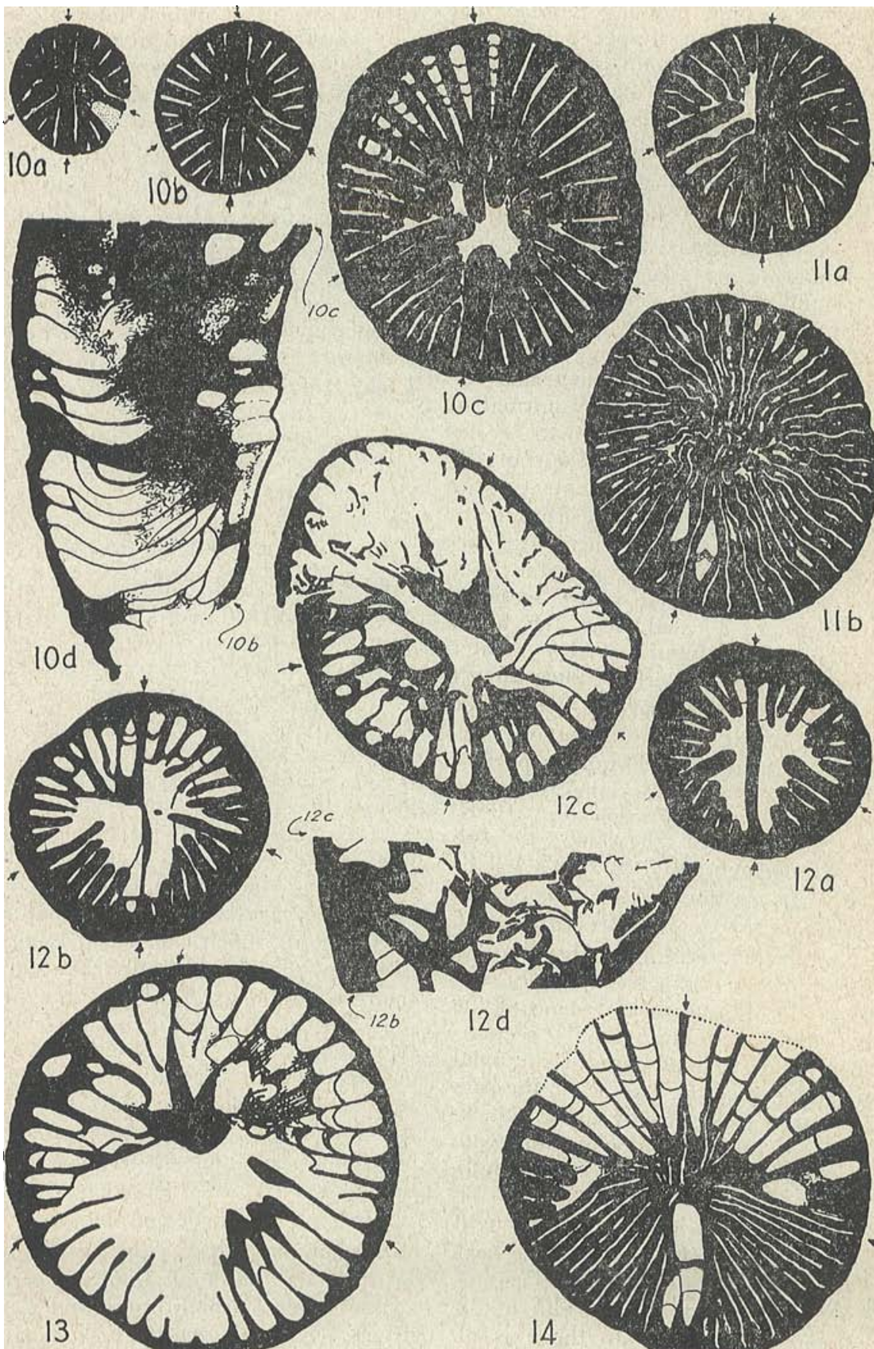
Occurrence.—Marble Falls limestone, north-central Texas.

EMPODESMA IMULUM, n.sp.

Text figs. 10–14

Description of this species is based on well-preserved specimens from three localities in the Marble Falls limestone of the Llano region, Texas; eight of the specimens were sectioned for study. The theca is thin, or only moderately thick—that is, about 0.3 to 0.8 mm. and generally less than 0.5 mm. Its outer surface bears numerous fine concentric growth lines and some irregular coarse wrinkles; longitudinal markings are not evident, except near the apex of one specimen, where faint septal grooves can be discerned. The apex of the corallite is slightly rounded to sharply pointed, the sides diverging at an angle of about 60 degrees. The calyx is characterized by a strongly oblique position, its floor lying at an angle of 30 to 40 degrees from the axis of the corallite, instead of about 90 degrees, as in a great number of solitary corals. The walls of the calyx are broken away in most of the specimens available for study, but one having this part embedded in matrix was sectioned longitudinally, and it shows an upward projection of the theca and very short marginal parts of the septa to a height of 10 or 12 mm. above the broad, comparatively even floor of the calyx. A cardinal fossula is well shown on some specimens but it is not constant in position; commonly, it is on the convex, long side of the corallite, but in some specimens, including the type, it is about halfway between the convex and concave sides. Inasmuch as almost no curvature is seen in some of these corals, it is more accurate to refer to the long and short sides of the corallite, between the margin of the inclined calyx and the apex.

Figs. 10–14. Sections of Marble Falls streptelasmaid corals, x3, all belonging to *Empodesma imulum*, n.gen., n.sp., from localities USGS-2419 (probably same as 205-T-1) and USGS-2429, San Saba quadrangle, San Saba and Lampasas counties, Texas. Transverse sections are oriented with the cardinal septum at bottom; protosepta indicated by small arrows. Longitudinal sections are mostly at right angles to the plane of the cardinal and counter septa; positions of the transverse sections indicated by small italic figures. (10) Type specimen, no. USGS2429aa, showing the dense structure of the apical region of the corallite, the united cardinal and counter septa, and the strongly marked acceleration of the counter quadrants. (11) Specimen no. USGS2419c. (12) Specimen no. USGS2429ab. (13) Specimen no. USGS2419h, a section near the floor of the calyx. (14) Specimen no. USGS2419b, a transverse section near the calyx showing the well-defined cardinal fossula.


10a
10b
10c
10c
11a
10d
10b
11b
12c
12c
12a
12b
12b
12d
13
14

Internal structural features, as revealed by transverse sections at different distances from the apex, are bisymmetrically arranged septa and inclined tabulae that intersect them. In the upper part of the corallite the septa are thin and somewhat shortened; some of them reach to the axial region at or near their contact with subjacent tabulae, but just beneath a tabula even the longer septa generally do not extend to the axis. Transverse sections very close to the floor of the calyx (fig. 12c) show long septa on one side of the corallite and short ones on the other; in each case the side having long septa is located on the convex, or long, side of the corallite, and the plane of the transverse section, which is approximately normal to the axis of the specimen, is 50 to 60 degrees from the plane of the floor of the calyx. At lower levels the septa appear much thicker and more uniform; commonly, the spaces between them are narrow. The cardinal, counter, and alar septa are readily identified in most sections, especially those located near the apex, for they are distinguished by greater length and by the pattern of successively inserted septa of the various quadrants. The counter quadrants are distinctively accelerated. A section of the upper part of the type (fig. 10c) shows the following septal formulae: K 9 A 6 C 6 A 10 K. Another section (fig. 12b) shows the following arrangement: K 8 A 5 C 5 A 9 K. Sections near the apex (figs. 10a, b, 11a, 12a, b) show the coalesced cardinal and counter septa that form a bar dividing the corallite into two symmetrical halves; the alar septa lie oblique to the plane of the cardinal-counter. Longitudinal sections (fig. 10d) show the absence of an axial column and reveal the nature of the tabulae; the pattern formed by locally thickened parts of tabulae and edges of septa of one specimen (fig. 12d) is strikingly irregular.

The type specimen has a greatest length of 40 mm. and a length along the short side of the corallite of 20 mm. The obliquely disposed calyx has a width of 22 mm., measured transverse to the axis of the corallite, and about 28 mm. at right angles to this direction.

Discussion.—Inasmuch as only one species is now known that seems assignable to *Empodesma*, comparison must be made with representatives of other genera, if at all. The obliquity of the calyx and especially the described internal features serve best to distinguish *E. imulum* from other Marble Falls corals of generally similar form and size, *Stereocorypha annectans*, n.sp.

Occurrence.—Marble Falls limestone, Bendian, Lower Pennsylvanian, U. S. Geological Survey localities 2419 (San Saba quadrangle, "Nautilus limestone," lot 46a, locality? coll. by G. H. Girty, 1910) and 2429 (Lampasas quadrangle, in creek bottom, 2.5 miles west of Nix on road to Bend, coll. by J. A. Taff, E. O. Ulrich, and J. W. Beede), Lampasas County, Texas.

Type.—U. S. Geological Survey, specimen no. 2429aa, from the Lampasas County outcrop.

Family LOPHOPHYLLIDIIDAE, n.fam.

Corals assigned to this family are conical to cylindrical in form and of solitary habit; they have a strong theca and well-developed calyx that centrally bears a projecting boss. The septa are continuous, of one or two orders, not joined together axially, except in the apical region; commonly they show distinct tetrameral development and bilateral symmetry, with acceleration of the counter quadrants; the counter septum may be joined to a rodlike axial column through most of its length, but the cardinal septum is commonly much shortened, lying in an open fossula. A well-defined, dense or relatively solid axial column that projects into the calyx is a diagnostic feature of these corals; it may show traces of a median lamina, radiating laminae, and superposed concentric layers, but the structure is compact. Tabulae are present or absent. Dissepiments are not observed. Range, Lower Carboniferous to Permian.

Discussion.—The combination of structural characters that is presented in diagnosis of the Lophophyllidiidae embraces a number of Carboniferous and Permian genera, such as *Lophophyllidium* Grabau, *Sinophyllum* Grabau, *Malonophyllum* Okulitch and Albritton, *Fasciculophyllum* Thomson, *Lophamplexus* Moore and Jeffords, and others. Some of these genera have been referred to the Lophophyllidae Grabau, and some have not been given even tentative family assignment. Uncertainty as to the evolutionary significance of observed characters of the axial column augments the difficulties of determining phylogenetic relationships of these corals and of establishing a reasonably demonstrable natural grouping. The column of *Sochkineophyllum* Grabau, for example, is not essentially different from axial structures seen in some species of *Lophophyllidium*. The Lophophyllidiidae are distinguished from the Cyathaxonidae Edwards and Haime by difference in the mode of insertion of the septa. Column-bearing corals that have dissepiments do not belong in the Lophophyllidiidae, and accordingly such corals as *Lophophyllum* Edwards and Haime and *Koninckophyllum* Nicholson and Thomson, which were assigned by Grabau to the family Lophophyllidae, are excluded from the Lophophyllidiidae.

Genus LOPHOPHYLLIDIUM Grabau, 1928

Solitary corallites of medium size having gently curved or straight conical form and characterized by the presence of a dense axial column are included in this genus. The theca is plainly marked by septal grooves, and there are transverse wrinkles and growth lines of varying prominence. The calyx, which generally is deep, bears a spikelike column that projects from the central part of the floor. The major septa of mature parts of the corallite are straight, thin, and moderately long, but they are not joined to the column. In the immature region the septa may be slightly curved and thickened at their inner edges; they do not reach to the column, although deposits of stereoplasm may join them and the column. The counter septum is more elongate than the other septa, and its inner part is strongly thickened so as to form part or all of the axial column. The cardinal septum is distinctly shortened and lies in a fossula. Alar pseudofossulae are mostly inconspicuous or absent. Minor septa are well developed or lacking. Tabulae are more or less numerous, or slightly anastomosing, and they slope upward rather steeply from the periphery to the column. Dissepiments are not present.

Genotype.—*Cyathaxonia prolifera* McChesney, Missourian, Pennsylvanian (Upper Carboniferous), near Springfield, Illinois.

Discussion.—The generic characters and relationships of *Lophophyllidium* have been reviewed recently at some length in other papers by us (Moore and Jeffords, 1941, pp. 78–83; Jeffords, 1942, pp. 201–213) and comparisons already given are not repeated here.

Lophophyllidium differs from *Lophotichium*, n.gen., in the greater regularity and simplicity of structure in the immature region and in the lack of septa-like peripheral extensions of tabulae.

Occurrence.—Pennsylvanian (Morrowan to Virgilian) (Upper Carboniferous) and Permian; world-wide.

LOPHOPHYLLIDIUM EXTUMIDUM, n.sp.

Text figs. 15–22, 33

Small solitary conical slightly curved corallites characterize this species. The surface is marked by fine septal grooves and low broad ridges crossed by growth lines and low wrinkles. The walls of the calyx are not preserved but a large axial column rises in the center. The type specimen is 13.5 mm. in length and 17.8 mm. in maximum diameter at the calyx.

Immature parts of the corals show the septa to be long and much thickened at their axial edges so as to be laterally in contact or joined to each other and to the column by stereoplasm. During subsequent growth the septa gradually withdraw a short distance from the column and are only irregularly in contact with each other at their axial edges. The cardinal septum is short and thin. The counter septum is thick only at the axis where it forms a large solid column. The septal formula of the type specimen is as follows: K 9 A 5 C 5 A 8 K. That of a similar specimen is as follows: K 7 A 3 C 3 A 7 K. The counter quadrants are strongly accelerated. Minor septa are lacking.

Numerous tabulae rise in a gentle arch from the periphery to the thickened axial


15a
15b
15c
15b
16a
16b
16c
17a
17b
17b
17c
17a
18a
18a
18b
19a
19b
19b
19c
20
21a
21a
21b

portions of the septa, and then sag somewhat between the margins of the septa and the column. In transverse sections, tabulae are seen to occur at regular intervals between the septa. The cardinal septum lies in a conspicuous fossula in all periods of growth. Alar pseudofossulae are small. The large column is formed by the thickened axial portions of the counter septum and ascending tabulae thickened by stereoplasm. In longitudinal and transverse sections the column seems to consist of numerous superposed cones of varying thickness.

Discussion. — The distinct rhopaloid thickening of the septa, very large column, and numerous tabulae serve to distinguish this coral. It can be separated from *Lophophyllidium minutum* Jeffords (1942, p. 246) by the numerous tabulae and rhopaloid septa. *L. extumidum* is distinguished from *L. metum*, n.sp., by the broad conical shape of the corallite, larger column, inner wall formed by the rhopaloid septa, and more numerous tabulae. The Texas corals are separated from *L. blandum*, n.sp., by the extreme rhopaloid nature of the septa, large axial column, and thickened lower portions of the corallite. *L. newelli* Jeffords (1942, p. 242) resembles *L. extumidum* in having a similar conical shape, rhopaloid septa and thickened immature region, but differs in its less numerous tabulae, more strongly developed alar pseudofossulae, and smaller column.

Occurrence.—Marble Falls limestone, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by F. B. Plummer, 4 miles south of San Saba on the Llano highway, San Saba County, Texas (loc. 205–T–4). Bendian, collected by P. V. Roundy from middle or upper member of the formation, just south of Simpson Creek Crossing on Llano road (loc. USGS–2606); collected by K. C. Heald from middle beds 1.7 miles south and 0.3 mile east of San Saba (loc. USGS–2689), San Saba County, Texas.

Material studied.—Three well-preserved specimens of this species were sectioned for study.

Type.—The University of Texas, Bureau of Economic Geology, specimen no. P–9536a, from 4 miles south of San Saba, Texas.

LOPHOPHYLLIDIUM CONOIDEUM, n.sp.

Text figs. 23, 24, 31

Solitary conical corallites that have a deep calyx and moderately thick theca comprise this species. The exterior of the type specimen is concealed by matrix, but a specimen from Texas shows sharp narrow septal grooves and broad rounded ridges. The type specimen is 23 mm. in length and 11.1 mm. in maximum diameter at the calyx.

Major septa are long and straight. In youth they are rhopaloid and united to the axis by a dense deposit of stereoplasm, whereas they are thin and of unequal length in upper sections. The axially thickened counter septum is extended to form a column, but the cardinal septum is thin and short. The septal arrangement of the type specimen, determined by tracing the protosepta and fossula upward along the corallite, is as follows: K 6 A 5 C 4 A 6 K. Minor septa are rudimentary.

Figs. 15–21. Sections of Marble Falls lophophyllidid corals, x3, all belonging to *Lophophyllidium extumidum*, n.sp., from near San Saba, Texas. Transverse sections are oriented with the cardinal septum at bottom; protosepta indicated by small arrows. Longitudinal sections are mostly at right angles to the plane of the cardinal and counter septa; positions of the transverse sections shown by small italic figures. (15) Specimen no. P7856c, from the lower Marble Falls limestone, 4 miles south of San Saba on Llano road (loc. 205–T–4). (16) Specimen no. USGS2689b, from the middle Marble Falls limestone on Simpson Creek, 1.7 miles south and 0.3 of a mile east of San Saba (loc. USGS–2689 or 205–T–165). (17) Specimen no. USGS2606a, from middle or upper Marble Falls limestone just south of Simpson Creek on San Saba-Llano road. (18) Specimen no. P7857a, from loc. 205–T–4. (19) Type specimen, no. P9536a, from loc. 205–T–4. (20) Specimen no. USGS2689a, from the locality of fig. 16. (21) Specimen no. USGS2606c, from the locality of fig. 17.

A few thin tabulae rise evenly from the periphery; they flatten out at about the inner edges of the septa, and then rise gently to form the column. The axial column is relatively small throughout and is attached to the counter septum, even into the lower part of the calyx. The cardinal fossula is distinct in both youthful and mature regions, but alar pseudofossulae are recognizable only in the apical portion.

Discussion.—The unequal development of the major septa in the mature portion of the corallite, as seen in *Lophophyllidium conoideum*, is a feature shown in other late Paleozoic genera such as *Tachylasma* (Grabau, 1922), *Rhopalolasma* (Hudson, 1936), *Sochkineophyllum* (Grabau, 1928), and *Plerophyllum* (Hinde, 1890). The other features of this coral, as well as the relatively slight accent of this septal pattern, justifies assignment to *Lophophyllidium.*

This species resembles *Lophophyllidium blandum*, n.sp., in its elongate conical form, long septa, and nature of the column which is closely joined to the counter septum. *L. conoideum* is distinguished by unequal length of the major septa in the mature portion, a more stereoplasm-filled apical region, and a closer junction of the septa and column. *L. conoideum* is separated from *L. idonium*, n.sp., *L. extumidum*, n.sp., and *L. metum*, n.sp., by a lesser amount of stereoplasm in the corallite and the nature of the septa.

Occurrence.—Upper part of Marble Falls limestone, Bendian, Lower Pennsylvanian (Upper Carboniferous); collected by F. B. Plummer, 2 miles southeast of Brady, McCulloch County, Texas (loc. 153–T–81); Brentwood limestone member, Bloyd shale, Morrowan, collected by F. B. Plummer, along U. S. highway No. 71, one-quarter of a mile east of Brentwood, Arkansas.

Material studied.—One sectioned specimen from each of the above localities was available for study.

Type.—The University of Texas, Bureau of Economic Geology, specimen no. P–10500a, from the Arkansas locality.

LOPHOPHYLLIDIUM IDONIUM, n.sp.

Text figs. 25–28, 32

Small, solitary, steeply conical corallites, that are straight to slightly curved and seemingly have a relatively shallow calyx containing the spikelike axial column, are included in this species. The theca is relatively thick and bears distinct septal grooves and cross markings. The type specimen is 23 mm. in length and 9.2 mm. in maximum diameter just below the base of the calyx.

Major septa are long and seem to remain connected to the column, even into the calyx. The cardinal septum is short, whereas the counter septum is extended to the axis and thickened to form a column. Other major septa reach close to the column and are joined to it and to each other by a dense deposit of stereoplasm. The septa are distinctly separated into quadrants by the cardinal fossula, alar pseudofossulae, and the counter septum. A characteristic feature of the transverse

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Figs. 22–30. Sections of Marble Falls, Brentwood. and Wapanucka lophophyllidid corals, x3, belonging to the genus *Lophophyllidium* Grabau. Transverse sections are oriented with the cardinal septum at bottom; protosepta indicated by small arrows. Longitudinal sections are mostly at right angles to the plane of the cardinal and counter septa; positions of the transverse sections shown by small italic figures. (22) *L. extumidum*, n.sp., specimen no. P7856c, from the upper Marble Falls limestone, 4 miles south of San Saba, Texas, on the Llano road (loc. 205–T–4). (23) *L. conoideum*, n.sp., specimen no. P9923, from the upper Marble Falls limestone near Brady Creek, 2 miles southeast of Brady, Texas (loc. 153–T–81); (24) type specimen, no. P10500a, from the Brentwood limestone, one-fourth mile east of Brentwood, Arkansas. (25) *L. idonium*, n.sp., the type specimen, no. KU7151–21a, from the Wapanucka limestone, 1 mile west of Wapanucka, Oklahoma; (26) specimen no. P7856a, from the same locality as fig. 22; (27) specimen no. KU7151–21c, from the same locality as fig. 25; (28) specimen no. KU7151–21b, from the same locality as fig. 25. (29) *L. adapertum*, n.sp., specimen no. USGS2415x, from the ?Marble Falls limestone, San Saba quadrangle, Texas; (30) specimen no. USGS2415z, from the same locality as fig. 29.


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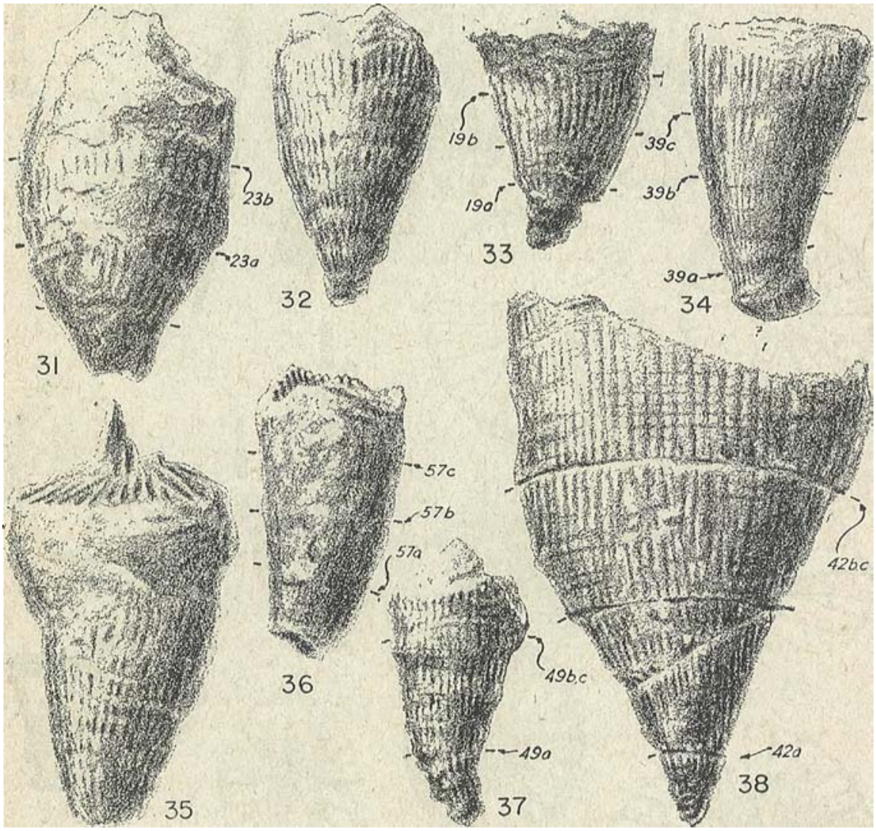
27a
27b
28a
28b
29
30

sections is the wide space on either side of the counter septum. The septal arrangement of the type specimen is indicated by the formula K 7 A 4 C 5 A 6 K, and that of another specimen from the type locality by K 7 A 4 C 4 A 7 K. Minor septa are lacking.

Relatively few thin tabulae rise evenly from the periphery to join the column, and they are only rarely indicated in transverse sections. The axial column is formed by the thickened edge of the counter septum, supplemented by the thick edges of other septa and stereoplasm. Some transverse sections show a faint but distinct concentric layering of this column. Large alar pseudofossulae and a deep closed fossula that contains the cardinal septum persist throughout the corallite.

Discussion.—The corals here called *Lophophyllidium idonium* have a pattern



Figs. 31–38. Exterior views of species of *Lophophyllidium* Grabau from the Marble Falls, Brentwood, Hale, and Wapanucka formations, x2. (31) *L. conoideum*, n.sp., no. P9923, from the upper Marble Falls limestone near Brady Creek, 2 miles southeast of Brady, Texas (loc. 153–T–81). (32) *L. idonium*, n.sp., no. KU6885–21, from the basal Marble Falls limestone, 4 miles south of San Saba, Texas, on the Llano road (loc. 205–T–4). (33) *L. extumidum*, n.sp., type specimen, P9536a, from the same locality as fig. 32. (34) *L. blandum*, n.sp., type specimen, no. KU5564–21a, from the Hale formation at Keough quarry, 2½ miles north of Fort Gibson, Oklahoma. (35) *L. eastoni*, n.sp., Univ. Chicago, Walker Mus., no. 47237, from lowermost Pennsylvanian beds 1 mile east of Leslie, Searcy County, Arkansas. (36) *L. ignotum*, n.sp., type specimen, no. KU7134–21b, from the Wapanucka limestone, 1 mile south and 1 mile east of Hartshorne, Oklahoma. (37) *L. metum*, n.sp., type specimen, no. KU4520–21a, from the same locality as fig. 34. (38) *L. adapertum*, n.sp., type specimen, no. USGS2415y, from the ?Marble Falls limestone, San Saba quadrangle, Texas.

of the fossula and pseudofossulae similar to that of *L. distinctum* Jeffords (1942, p. 243), but they differ in character of the tabulae, the rhopaloid septa of mature regions, and more elongate form. *L. idonium* is separated from *L. confertum* Jeffords (1942, p. 221) by its short cardinal septum, larger fossula and pseudofossulae, and the wide space on each side of the counter septum; this new species differs from *L. conoideum*, n.sp., *L. extumidum*, n.sp., and *L. blandum*, n.sp., in having strong alar pseudofossulae. The broad axial column and well-developed fossula and pseudofossulae of *L. idonium* are similar to those of *L. minutum* Jeffords (1942, p. 246). *L. idonium* can be distinguished, however, by the presence of few, but well-defined, tabulae, the large spaces adjoining the counter septum, and its more slender, elongate form.

Occurrence. — Wapanucka limestone, Morrowan, Lower Pennsylvanian (Upper Carboniferous). The type and other specimens were collected by R. C. Moore along State highway No. 61, 1 mile west of Wapanucka, Oklahoma (Univ. Kansas loc. 7151). Other specimens were collected by F. B. Plummer from the basal Marble Falls limestone, 4 miles south of San Saba, Texas (loc. 205–T–4).

Material studied. — Three sectioned specimens from the type locality and three from the Texas locality were available for study of this species.

Type.—University of Kansas, specimen no. 7151–21a, from the Wapanucka limestone.

LOPHOPHYLLIDIUM ADAPERTUM, n.sp.

Text figs. 29, 30, 38, 42, 43

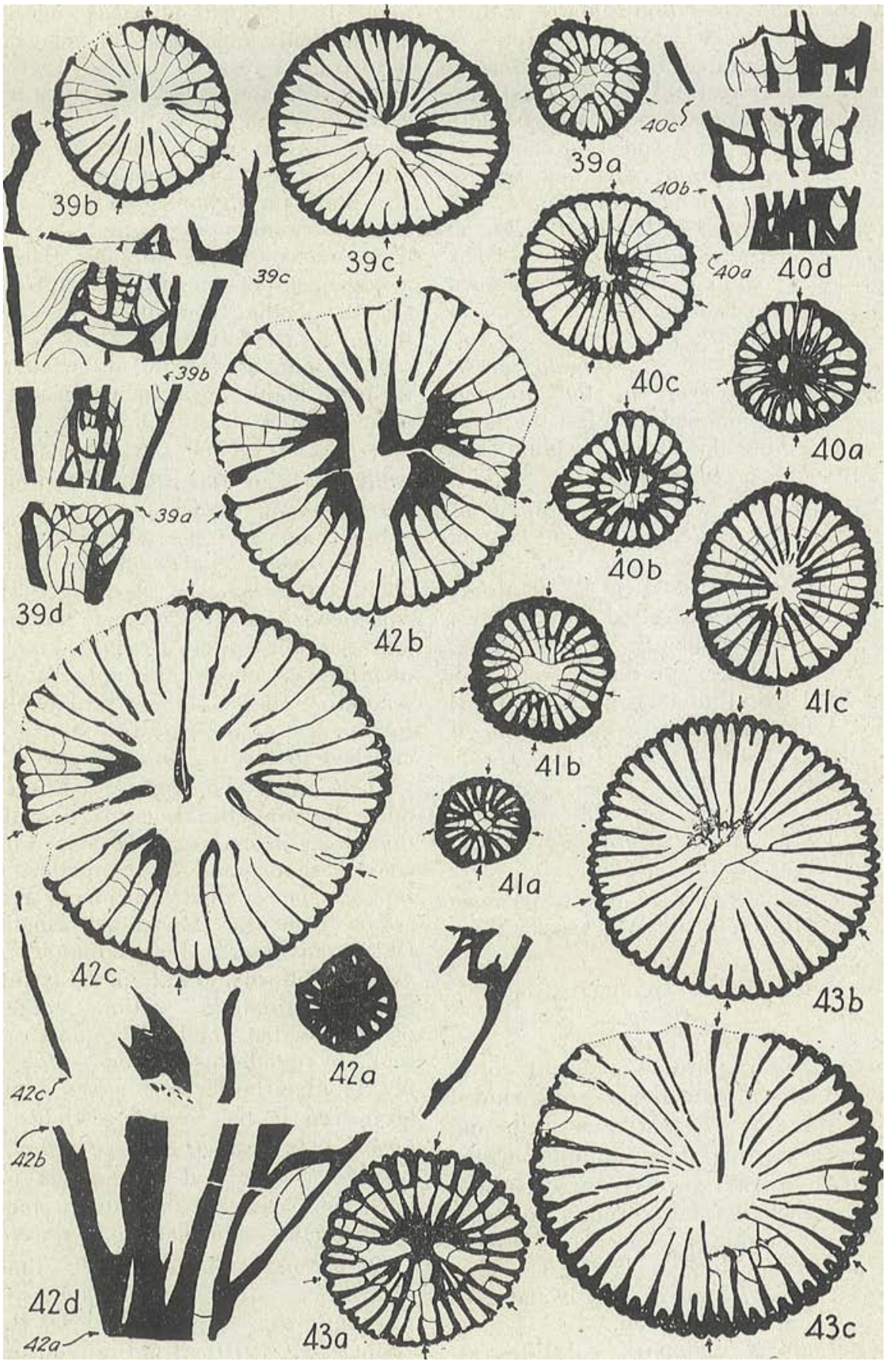
Large, solitary, broadly conical corallites, that have a thin theca, are included in this species. The calyx is deep and contains a narrow axial column in the lower part. Septal grooves are sharp and deep and the alternating ridges rounded. Transverse markings consist of growth lines and a few low wrinkles. The type specimen is 43.7 mm. in length and 28.0 mm. in diameter at the top.

In the apical region of corallites assigned to this species, the septa and stereoplasm fill the interior except for small spaces between peripheral edges of the septa. In middle portions of the corallites, the long septa of each quadrant are joined together by deposits of stereoplasm about their rhopaloid axial edges. They are distinctly separated into quadrants by the cardinal fossula, alar pseudofossulae, and the counter septum. Sections near the calyx show long septa that are thin except at the swollen axial edges, and nearly all are separated. The cardinal septum is very short throughout growth, whereas the counter septum is long and thickened at the axis to form a column. The septal arrangement of the uppermost transverse section of the type specimen is as follows: K 10 A 6 C 6 A 10 K. Minor septa occur as sharp ridges alternating with the major septa in uppermost transverse sections.

A few tabulae are indicated in the transverse and longitudinal sections, but the dominant structures are the septa, column, and an inner wall that is formed by the fused axial edges of the septa about the axis. The cardinal fossula is conspicuous in all transverse sections and alar pseudofossulae are large and easily identified except in the upper transverse sections. The column is relatively thin for the size of the corallites and is firmly attached to the counter septum.

Discussion.—This species differs from other lophophyllidid corals described in this paper in its larger size, more broadly conical shape, and in the pattern of its septa. The studied specimens resemble corals from the Savanna formation of Oklahoma described as *Lophophyllidium newelli* Jeffords (1942, p. 242) in their open longitudinal section, large alar pseudofossulae, and the union of the septa by quadrants. *L. adapertum* has a few tabulae, however, whereas none have been seen in the several sectioned specimens of *L. newelli*. *L. adapertum* has a few more septa and a somewhat broader open space between the column and fused edges of the septa than in *L. newelli*.

Occurrence.—Marble Falls limestone, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by G. H. Girty (Sept. 30, 1910) from an unspecified locality in the San Saba quadrangle, Texas. Near base of Marble Falls limestone, collected by F. B. Plummer and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R. C. Moore, about one-fourth mile northeast of Jack Sloan's ranch house, 6.8 miles due south of Richland Springs, San Saba County, Texas (loc. 205–T–92 or Univ. Kansas loc. 7085).

Material studied.—The well-preserved type specimen and three other specimens were sectioned for study.

Type.—U. S. Geological Survey, specimen no. 2415y (locality unknown).

LOPHOPHYLLIDIUM BLANDUM, n.sp.

Text figs. 34, 39–41

This species consists of medium-sized conical corallites that are curved only near the apex. The moderately thick theca is marked externally by well-developed sharp septal grooves and broad rounded interseptal ridges, which are intersected by very fine growth lines and a few low rounded wrinkles. The floor of the deep calyx is broad and nearly flat except for the column protruding at the axis. The type specimen is 12.1 mm. in maximum diameter at the calyx and 20.4 mm. in length.

The major septa are long and approximately equal in length. In transverse sections of the immature region the septa reach close to the axis but do not join it. In high sections they become rhopaloid, laterally joined to each other about the axial area, and a few may be extended as fine lamellae reaching to the column. Near the calyx the septa are long and thin, except for the slight thickening of the axial edges of some. The cardinal septum remains thin and short throughout, whereas the counter septum is extended to the axis and thickened to form a column. The septal formula of the type specimen is as follows: K 7 A 4 C 4 A 7 K. The development of the minor septa first in the counter quadrants, as well as the greater number of septa in these quadrants, indicates the strong counter acceleration. Minor septa, which are present only near the calyx, remain short.

A few thin tabulae rise from the periphery towards the axis and the inner wall formed about the thickened axial edges of the septa. The even arch of the tabulae is indicated by the approximately continuous intersection of the tabulae between the septa seen in transverse sections. A conspicuous open cardinal fossula persists throughout the corallite, but alar pseudofossulae are prominent only in sections of the immature region. A narrow axial column is formed by the thickened counter septum. As this septum shortens in the mature region, the column also decreases in size and does not persist as an independent structure at the axis.

Discussion.—The corals called *Lophophyllidium blandum* differ from *L. metum*, n.sp., in the broader form of the corallite, thin septa, and open apical region. The septa of *L. blandum* are not nearly as rhopaloid as those of *L. extumidum*, n.sp.; and the more or less open axial area in the youthful region of the former separates it from *L. conoideum*, n.sp., and *L. angustifolium*, n.sp. *L. blandum* resembles *L. dunbari* Moore and Jeffords (1941, p. 83) and *L. yakovlevi* Fomitchev (1938, p. 220) in the distant septal grooves and fine growth lines, thin septa, irregular tabulae, and strong cardinal fossula. The column of the Morrowan corals, however, is not so large nor does it persist in the calyx as an independent structure.

Occurrence. — Hale formation, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore at

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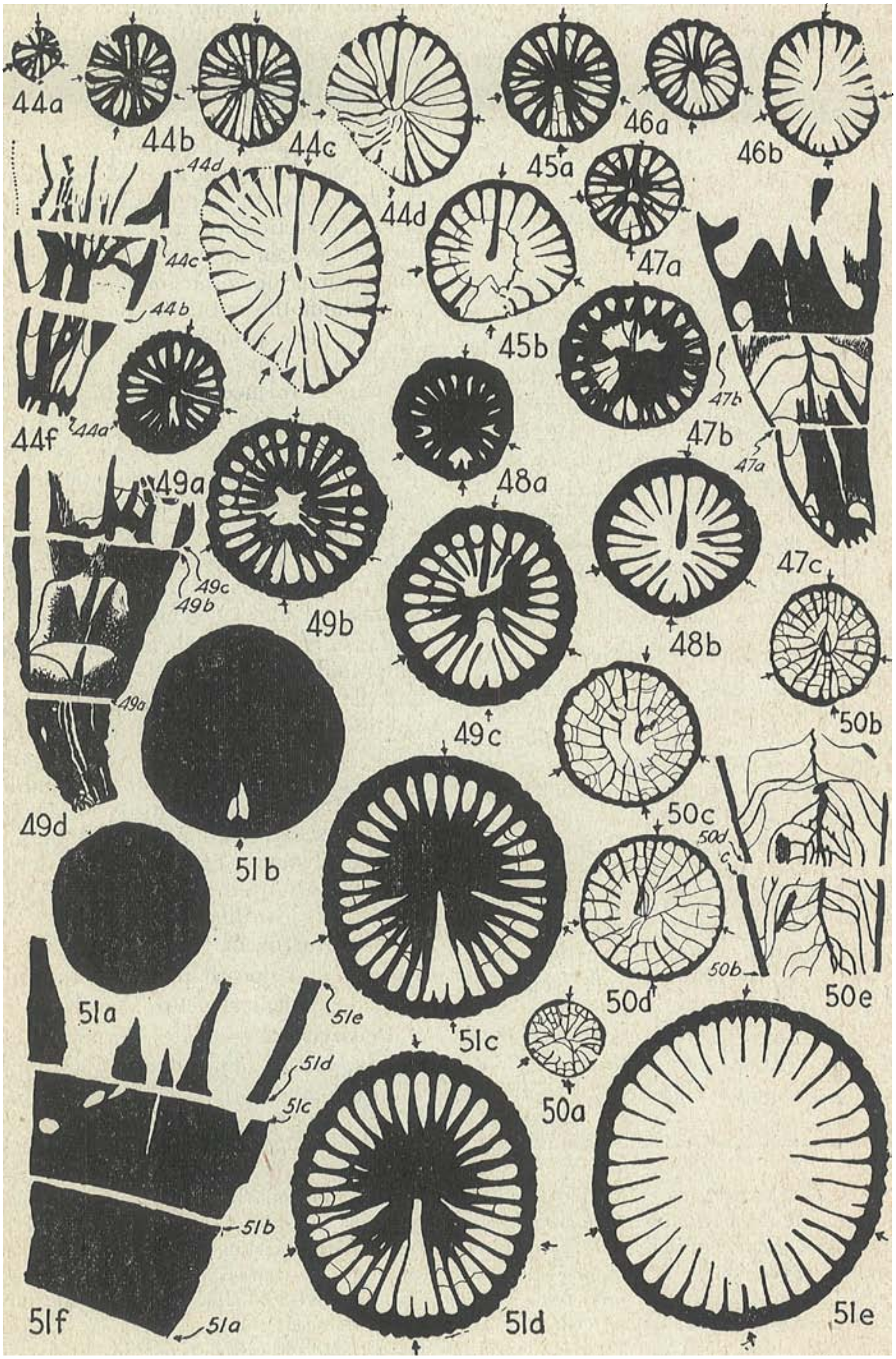
Figs. 39–43. Sections of Marble Falls and Brentwood lophophyllidid corals, x3, belonging to the genus *Lophophyllidium* Grabau. Transverse sections are oriented with the cardinal septum at bottom; protosepta indicated by small arrows. Longitudinal sections are mostly at right angles to the plane of the cardinal and counter septa; positions of transverse sections shown by small italic figures. (39) *L. blandum*, n.sp., type specimen, no. KU5564–21a, from the Hale formation at Keough quarry, 2½ miles north of Fort Gibson, Oklahoma; (40) specimen no. KU5564–21c, from same locality as fig. 39; (41) specimen no. KU5564–21b, from same locality as fig. 39. (42) *L. adapertum*, n.sp., type specimen, no. USGS2415y, from the ?Marble Falls limestone, San Saba quadrangle, Texas; (43) specimen no. KU7085–21a, from the lower Marble Falls limestone, Sloan ranch, 13 miles southwest of San Saba, Texas (loc. 205–T–92).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Keough quarry, about 2½ miles north of Fort Gibson, Oklahoma (Univ. Kansas loc. 5564).

Material studied.—Three of the four available well-preserved specimens of this species were sectioned for study.

Type.—University of Kansas, specimen no. 5564–21a.

LOPHOPHYLLIDIUM ANGUSTIFOLIUM, n.sp.

Text figs. 44–46

Solitary, straight or slightly bent corallites that have a deep calyx comprise this species. The moderately thick theca is marked by low septal grooves and fine growth lines. The type specimen is 22.1 mm. in length and 9.6 mm. in maximum diameter at the calyx.

In youthful parts of the corallites, long major septa reach close to the axis and are united to it. The axial edges of the septa of each of the quadrants seem to unite and to be connected to the column by a narrow extension. In sections of the mature parts, straight slender major septa are long but do not join with each other. The cardinal septum is short, whereas the counter septum is extended to the axis and thickens to form a column. The arrangement of the septa in the middle part of the type specimen is shown by the formula K 6 A 5 C 4 A 6 K. Minor septa are indicated only by low rounded ridges between the major septa in the uppermost transverse section of the type.

A few thin, incomplete tabulae rise steeply from the theca towards the axial structure. The cardinal fossula persists throughout growth, and the strong alar pseudofossulae of the youthful part become concealed only in uppermost sections. The axial column is formed by the somewhat thickened axial part of the counter septum and persists into the calyx.

Discussion.—Transverse sections of the mature part of this species resemble those of *Lophophyllidium mundulum* Jeffords (1942, p. 223) in the nature of the septa and fossula, but they show the absence of a thickened column. *L. angustifolium* differs from *L. minutum* Jeffords (1942, p. 246) in its more abundant tabulae, thinner theca, and in the more open apical part of the corallite. *L. idonium*, n.sp., has similarly well-developed alar pseudofossulae, but *L. angustifolium* lacks the thickening at the axis shown in the first-mentioned species. The nature of the septa, conspicuous alar pseudofossulae, and lack of structures that are thickened by stereoplasm separate *L. angustifolium* from *L. extumidum*, n.sp., *L. metum*, and *L. conoideum*, n.sp.

Occurrence.—Hale formation, Morrowan, Lower Pennsylvanian (Upper Carboniferous). The type specimen was collected by R. C. Moore on Hale Mountain, 1 mile south of Morrow, Arkansas, and other specimens were collected by R. C. Moore and University of Kansas students at the east end of the dam, Greenleaf Lake, cen. sec. 10, T. 13 N., R. 20 E., southeast of Braggs, Oklahoma (Univ. Kansas loc. 5441).

Material studied.—Three sectioned corallites from these localities are included in this species. Other specimens from the Oklahoma locality seem to belong here

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Figs. 44–51. Sections of Brentwood and Hale lophophyllidid corals, x3, belonging to the genus *Lophophyllidium* Grabau. Transverse sections are oriented with the cardinal septum at bottom; protosepta indicated by small arrows. Longitudinal sections are mostly at right angles to the plane of the cardinal and counter septa; positions of the transverse sections shown by small italic figures. (44) *L. angustifolium*, n.sp., type specimen, no. KU5441–21a, from the Hale formation on Hale Mountain, 1 mile south of Morrow, Arkansas; (45) specimen no. KU7385–24e, from the Hale formation at Greenleaf Lake, southeast of Braggs, Oklahoma; (46) specimen no. KU7385–24g, from same locality as fig. 45. (47) *L. metum*, n.sp., specimen no. KU7206–21a, from the Brentwood limestone near Woolsey, Arkansas; (48) specimen no. KU7206–21b, from same locality as fig. 47; (49) type specimen, no. KU4520–21a, from the Hale formation at Keough quarry, about 2½ miles north of Fort Gibson, Oklahoma. (50) *L. exile*, n.sp., type specimen, no. KU7385–21i, from the same locality as fig. 45. (51) *L. coaptum*, n.sp., type specimen, no. KU4625–21a, from the Brentwood limestone in NE. ¼ sec. 21, T. 14 N., R. 30 W., Arkansas.

also, but their characters are not well indicated by the sections.

Type.—University of Kansas, specimen no. 5441–21a, from the Greenleaf Lake locality.

LOPHOPHYLLIDIUM METUM, n.sp.

Text figs. 37, 47–49

Small steeply conical corals that are slightly bent in the alar plane, characterized by a deep calyx, and enclosed by a moderately thick theca comprise this species. The septal grooves are sharp and deep, and interseptal ridges are low and rounded. A few irregularly spaced growth lines are present. The type specimen, which is about average size, is 18.5 mm. in length and 9.1 mm. in diameter at the calyx.

The major septa are long and straight. In immature stages they are united at the axis by stereoplasm, but they become progressively shorter during subsequent development. The slightly thickened counter septum is long, whereas the cardinal septum is very short in all growth stages. Other major septa are approximately equal in length. The septal arrangement of the type specimen, showing the strong counter acceleration, is as follows: K 7 A 3 C 3 A 7 K. Minor septa are lacking.

The elongated counter septum, supplemented by parts of the tabulae and deposits of stereoplasm, forms the axial column. Regularly spaced tabulae, which make an angle of about 45 degrees with the theca, become horizontal halfway to the axis, and then rise again adjacent to the column. The cardinal fossula is large in all growth stages and open only in the calyx. Alar pseudofossulae are indicated by the poorly developed last-inserted septa in the counter quadrants.

Discussion.—This species is characterized by its very short cardinal septum, moderately thickened counter septum, and deposits about the tabulae. It can be distinguished readily from *Lophophyllidium extumidum*, n.sp., by the narrow conical shape, non-rhopaloid septa, and nature of the tabulae. The thick deposits of stereoplasm and thickened lower portions of the corallite separate *L. metum* from *L. conoideum*, n.sp., *L. angustifolium*, n.sp., *L. blandum*, n.sp., and *L. complexum* Jeffords (1942, p. 227).

Occurrence. — Brentwood limestone member, Bloyd shale, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore along U. S. highway No. 71, near Woolsey, Arkansas. (Univ. Kansas loc. 7206). Hale formation, Morrowan; collected by R. C. Moore at Keough quarry, about 2½ miles north of Fort Gibson, Oklahoma (Univ. Kansas loc. 4520).

Material studied.—Four well-preserved specimens were sectioned.

Type.—University of Kansas, specimen no. 4520–21a, from the locality north of Fort Gibson, Oklahoma.

LOPHOPHYLLIDIUM EXILE, n.sp.

Text figs. 50a-c

Solitary, slender, conical corallites, that are bent only close to the apex, comprise

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Figs. 52–60. Sections of Brentwood and Wapanucka lophophyllidid corals, x3, belonging to the genus *Lophophyllidium* Grabau. Transverse sections are oriented with the cardinal septum at bottom; protosepta indicated by small arrows. Longitudinal sections are mostly at right angles to the plane of the cardinal and counter septa; positions of the transverse sections shown by small italic figures. (52) *L. coaptum*, n.sp., specimen no. KU4625–21b, from the Brentwood limestone in NE. ¼ sec. 21, T. 14 N., R. 30 W., Arkansas; (53) specimen no. P10500b, from the Brentwood limestone one-fourth mile east of Brentwood, Arkansas. (54) *L. minutum* Jeffords, type specimen, no. KU7385–21c, from the Hale formation at Greenleaf Lake southeast of Braggs, Oklahoma; (55) specimen no. KU1221–21a, from the Wapanucka limestone just west of Clarita, Oklahoma; (56) specimen no. KU7060–21a, from the Wapanucka limestone near Limestone Gap, Oklahoma. (57) *L. ignotum*, n.sp., type specimen, no. KU7134–21b, from the Wapanucka limestone 1 mile south and 1 mile east of Hartshorne, Oklahoma; (58) specimen no. KU7134–21c, from the same locality as fig. 57. (59) *L. eastoni*, n.sp., type specimen, Univ. Chicago, Walker Mus., no. 47236, from lowermost Pennsylvanian 1 mile east of Leslie, Searcy County, Arkansas; (60) Walker Mus. specimen no. 47237, from same locality as fig. 59.


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59a.

this species. The thin theca bears faint septal grooves and a few fine transverse growth lines. The walls of the calyx are not well preserved, but the axial column projects as a thin spine in the center of the calyx. The type species is 22.8 mm. in length and 8.5 mm. in maximum diameter at the base of the calyx.

The long slender major septa are extended nearly or entirely to the axis in youthful portions of the corallite, but in higher sections they shorten somewhat and reach two-thirds the distance to the axis. The septa are not rhopaloid, but the axial ends of some unite or are connected by tabulae. The thin cardinal septum is shortened, whereas the counter septum reaches the axis and is thickened slightly. Minor septa are very rudimentary. The cardinal fossula is not prominent, and alar pseudofossulae are not identified.

Numerous thin anastomosing tabulae rise steeply from the periphery, flatten out slightly, and then join the column. The axial column, which is formed by the thickened counter septum joined by the tabulae, is not large but it persists into the calyx.

Discussion.—This species is characterized by the delicate nature of the septa, theca, tabulae, and axial column. These features readily separate *Lophophyllidium exile* from the other corals in the collection now available, such as *L. idonium,* n.sp., *L. blandum,* n.sp., *L. metum,* n.sp., and *L. extumidum,* n.sp., and the species referred to *Lophophyllidium* by Jeffords (1942). The lack of thickening of the column and septa is a feature seen commonly in some undescribed species from the Kansas City group.

Occurrence.—Hale formation, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore at the east end of the dam, Greenleaf Lake, cen. sec. 10, T. 13 S., R. 20 E., southeast of Braggs, Oklahoma (Univ. Kansas loc. 7385).

Material studied.—One very well-preserved, sectioned corallite from the abundant material collected at Greenleaf Lake has been the basis for description of this species. Numerous other unsectioned corallites may belong here also.

Type.—University of Kansas, specimen no. 7385-21i.

LOPHOPHYLLIDIUM COAPTUM, n.sp.

Text figs. 51–53

This species comprises solitary medium-sized conical corallites that are straight or only slightly bent. The moderately thick theca bears very narrow but distinct septal grooves and broad rounded interseptal ridges. Fine growth lines run transverse to the septal markings. The deep calyx contains the projection of the column in lower portions only. The type specimen, the largest of the corallites identified as belonging to this species, is 25.4 mm. in length and 15.8 mm. in maximum diameter at the upper part of the calyx.

In the lowermost transverse section, the septa are long and so solidly fused with stereoplasm that rarely can individual septa be traced to the axis. Higher sections show that the septa are thickened at their axial edges (rhopaloid) and solidly fused to each other and to the column by stereoplasm. Under the microscope the individual septa can be identified by differences in color between the septa and contiguous filling of stereoplasm. Only in the calyx do the septa shorten and withdraw from the column. The cardinal septum is short throughout, whereas the counter septum is long. The septal formula of the type specimen, showing the strong counter acceleration, is as follows: K 10 A 5 C 6 A 10 K. Minor septa are identified in the uppermost section of the type specimen only between the counter septum and the adjacent counter laterals, but the exterior shows strong grooves in the position of the minor septa.

The solidly filled nature of the interior of the corallite conceals tabulae in longitudinal sections, but transverse sections indicate the presence of a few regularly arched tabulae. The cardinal fossula is large throughout growth and alar pseudofossulae are prominent.

Discussion. — The thickened internal structures give *Lophophyllidium coaptum* a general similarity to *L. extumidum,* n.sp., *L. idonium,* n.sp., *L. minutum* Jeffords (1942, p. 246), and *L.* sp. A. The large alar pseudofossulae and few tabulae separate *L. coaptum* from *L. extumidum*, *L. minutum*, and *L.* sp. A; and the more numerous septa, more solid lower portion, and lack of distinctly larger spaces between the counter septum and the counter laterals distinguish *L. coaptum* from *L. idonium.*

Occurrence.—Brentwood limestone, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore from NE. 1/4 sec. 21, T. 14 N., R. 30 W., Winslow quadrangle, Arkansas (Univ. Kansas loc. 4625). Another specimen was collected by F. B. Plummer along U. S. highway No. 71, one-fourth of a mile east of Brentwood, Arkansas.

Material studied.—Two sectioned corallites from University of Kansas loc. 4625 and one other sectioned specimen were the available representatives of this species.

Type.—University of Kansas, specimen no. 4625-21a, from the first locality mentioned above.

LOPHOPHYLLIDIUM MINUTUM Jeffords

Text figs. 54-56

Lophophyllidium minutum JEFFORDS, 1942, Kansas Geol. Survey, Bull. 41, pt. 5, p. 246, pl. 7, figs. 2-4.

This species includes small solitary conico-cylindrical corallites that have only a very slight curvature near the apical end. The relatively thick theca bears deep narrow septal grooves and moderately broad interseptal ridges. Transverse growth lines and wrinkles are low and inconspicuous. The calyx is not well preserved but seems to be of moderate depth.

The type specimen has 21 major septa in the uppermost part of the corallite and about the same number of septa occur in the other specimens studied. The cardinal septum, which is very short, lies in a prominent fossula, whereas the counter septum is prolonged and attached to the column in all growth stages, although it shows a tendency to become separate close to the calyx. The arrangement of the septa in the uppermost section of the type specimen, showing the strong counter acceleration, is as follows: K 5 A 3 C 3 A 6 K.

Major septa are joined to the axial column in early stages of growth by thick deposits of stereoplasm, but they tend to become more distinct in upper parts of the corallite. The highest section of the type specimen shows septa that have a distinct axial swelling but are still united to the column. Another section (figure 55b) shows a more advanced stage having distinct minor septa and separate rhopaloid major septa. In nearly all specimens it is possible to recognize the elements of the septa and the column and to see that the union of the septa with the column is not a primary structural feature. The closed alar pseudofossulae and cardinal fossula are large and persist throughout. The laterally compressed column, produced by the thickened end of the counter septum, is increased in size by the close approach of the axial ends of the septa and the stereoplasm deposited between the septa and the column. In the calyx (figures 54a, 55b), a definite median lamella and straight radiating lamellae can be identified within the thickened column. No tabulae are recognized.

Discussion.—The small size, large alar pseudofossulae, and thickened axial region characterize this species. It is distinguished from *Lophophyllidium idonium*, n.sp., by its broader form, seeming lack of tabulae, and uniform spaces between septa, except for alar pseudofossulae and the cardinal fossula, and from *L. confertum* Jeffords (1942, p. 221) by the two characters last mentioned. Lamellae within the septa and axial column and outer edges of the septa in the region of thick deposits of stereoplasm are seen in this species quite distinctly, whereas in *L. idonium* and *L. confertum* these structures are difficult to identify.

Occurrence.—Hale formation, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore and University of Kansas students, at the east end of the dam, Greenleaf Lake, cen. sec. 10, T. 13 N., R. 20 E., southeast of Braggs, Oklahoma (Univ. Kansas loc. 7385). Other specimens were collected by R. C. Moore in the Otterville limestone, north of Berwyn, Oklahoma, and from the Wapanucka limestone at Coal Creek, sec. 15, T. 1 N., R. 7 E., Oklahoma, Gap, Oklahoma, and west of Clarita, Oklahoma.

Material studied. — Seven sectioned specimens from the preceding localities were studied to determine the characteristics of this species.

Type.—University of Kansas, specimen no. 7385–21c. from the Greenleaf Lake locality, Oklahoma.

LOPHOPHYLLIDIUM IGNOTUM, n.sp.

Text figs. 36, 57, 58

The solitary medium-sized slightly bent corallites comprising this species have a deep calyx that contains the high projection of the axial column. The thick theca bears very low rounded septal grooves, but lacks conspicuous transverse markings. The type specimen is 19.5 mm. in length and 11.4 mm. in maximum diameter at the calyx.

Major septa are thick but not rhopaloid and in the immature region many are joined to each other laterally and to the column. Near the calyx they become shortened and are evenly reduced in thickness away from the periphery. The counter septum is elongated and thickened at the axis to form a column in the lower portion of the corallite, but it becomes short in the upper part. The cardinal septum remains distinctly shortened throughout growth. The septal formula of the type specimen, indicating the counter acceleration, is as follows: K 7 A 3 C 3 A 7 K. Minor septa, present only in the mature region, are rudimentary.

Longitudinal sections of these corals do not show the tabulae clearly, but intersections of regularly arched tabulae can be seen in the transverse sections. Dissepiments are lacking. The column is formed by the thickened axial part of the counter septum in the immature region; it projects as an independent structure near the top of the corallite. Sections indicate that the axial column has an irregular transverse outline and that it consists of several thickened, curved radiating lamellae, connected by a few tabulae and made comparatively solid by addition of stereoplasm. The cardinal fossula persists throughout the corallite but alar pseudofossulae are observed only near the apex.

Discussion.—The solid column, strong counter acceleration, form of the corallite, nature of the septa, and lack of dissepiments are features of *Lophophyllidium ignotum* seen also in several other typical species of *Lophophyllidium.* The strongly radiating appearance of the column in transverse sections, however, distinguishes this coral. The species from the Marmaton group called *Lophophyllidium murale* Jeffords (1942, p. 224) also has an irregularly radiating column in the mature region, but it differs from *L. ignotum* in having a distinctly larger size, thin rhopaloid septa, and a relatively thin theca.

It is possible that corals such as the species here described should be assigned to a genus other than *Lophophyllidium.* The axial column, of distinctive appearance, differs from that of the genotype of *Lophophyllidium* in having an accentuated radial pattern. Sufficient evidence of the importance of this character is not now seen to warrant separation of *L. ignotum* from *Lophophyllidium.*

Occurrence. — Wapanucka limestone, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore in a quarry, 1 mile south and 1 mile east of Hartshorne, Oklahoma (Univ. Kansas loc 7134).

Material studied.—Two well-preserved corallites were sectioned for study of this species.

Type.—University of Kansas, specimen no. 7134–21b.

LOPHOPHYLLIDIUM EASTONI, n.sp.

Text figs. 35, 59, 60, 80

Relatively large, nearly straight conical corallites having an unusually thick, prominent axial column are included in this species. The theca is thick. The type specimen has an excessively thickened periphery that consists mainly of evenly deposited stereoplasm on the inner side of the theca. A transverse section of this specimen near the floor of the calyx (fig. 59b) shows that the outer wall of the corallite has a thickness equal to about one-half of the length of the major septa in the plane of the section, and the thickness is greater than the length of minor septa, existence of which is shown only by the pattern of laminated tissue in the peripheral stereozone. At mid-height of the coral, stereoplasm fills interspaces of the major septa to their inner margins, or nearly so; yet each septum can be distinguished clearly by reason of difference in the color of the calcite in respective areas. The outer surface of the theca is marked by shallow septal grooves and intervening low, rounded ridges; these are crossed by growth lines and small transverse wrinkles. The depth of the calyx is not determinable from the specimens, but one of them shows the prominent elevation of the column in the calyx. The length of the corallites belonging to this species is about 40 to 50 mm.; the diameter of the type specimen near the floor of the calyx is 20 mm.

The major septa are nearly uniform in length and thickness; none of them are expanded near the axial margin so as to give a club-shaped or rhopaloid appearance in cross section. The counter septum is joined to the massive axial column, but unlike the structure seen in most species of *Lophophyllidium*, the midline of the counter septum is not extended as a median lamina of the column; the axial edge of the counter septum merely impinges on the column, even though the contact is firmly welded by stereoplasm. The cardinal septum is much shorter than the other major septa and it remains short throughout growth of the corallite; an open cardinal fossula is readily recognized in transverse sections. Alar septa are identifiable but there are no alar pseudofossulae. The number and distribution of major septa in the type specimen are shown by the formula K 10 A 5 C 5 A 9 K. The counter quadrants are strongly accelerated. Minor septa are introduced in the upper part of the corallite.

The axial column is ovoid to subtrigonal in outline, as seen in transverse section, and its diameter is nearly one-third that of the corallite. The structure is dense, but variation in the colors of successive growth laminae shows a concentric arrangement of the layers in transverse sections and steeply sloping lamination in longitudinal sections. The column is seemingly not formed by closely packed, sharply upbent portions of tabulae, sealed together by stereoplasm, as judged by the definiteness of the sides of the column and the open nature of the area around it, which is crossed by outwardly down-sloping tabulae. On the other hand, the tabulae are seen to thicken very abruptly close to the column and to bend parallel to the lamination of the column. Some tabulae are anastomosing. Dissepiments are lacking.

Discussion.—The described characters of *Lophophyllidium eastoni*, including especially the massive, concentrically layered axial column, thick peripheral stereozone, and features of the septa, set this species widely apart from most others assigned to the genus. *L. extumidum*, n.sp., from the Marble Falls limestone of Texas, has a similar laminated column, though less stout, but it is characterized by strongly rhopaloid septa and a thin theca, which are not seen in *L. eastoni*. A lophophyllidid from Utah, described as *Lophophyllum proliferum* var. *sauridens* White (1877, p. 101, pl. 6, figs. 4a–d), closely resembles *Lophophyllidium eastoni* in the relatively large size, subcircular cross section, and concentric lamination of the column, but White's species is a much longer, more slender and curved coral that has a relatively thin theca. Specimens of the genotype of *Lophophyllidium*, which is *L. proliferum* (McChesney), also show resemblance to *L. eastoni* in the structure, shape, and general proportions of the column. One of the corallites figured by Jeffords (1942, pl. 1, figs. 1 a-c), showing internal structure of *L. proliferum*, especially suggests features of *L. eastoni*, although the latter is readily distinguished by characters of the septa and stereozone.

The evolutionary significance and classificatory importance of structural characters observed in the axial column, septa, and other parts of cyathaxonid and lophophyllidid corals are by no means clearly understood at the present time. For example, the genus *Sinophyllum* Grabau (1928, p. 98), which is considered by some students of the rugose corals to be validly separated from *Lophophyllidium*, but which is not accepted by others, is characterized by a greatly thickened, dense, concentrically laminated column, like that of *L. eastoni*, and by a so-called inner wall formed by junction of the axial edges of most of the major septa. Several species that have been assigned to *Lophophyllidium*, perhaps ill-advisedly, possess one or the other of these attributes of *Sinophyllum*, or both of them. The laterally compressed type of column bearing a clearly marked median lamina, such as occurs in most described species of *Lophophyllidium*, and the column of stellate cross section having radially placed laminae, such as distinguishes *L. murale* Jeffords (1942, p. 228) and *L. ignotum*, n.sp., seem to have little in common with the axial structure of *L. eastoni* and *Sinophyllum*. Until work on corals of this whole group has been considerably extended, however, we hold the opinion that it is unwise to attempt further generic differentiation.

This species is named for W. H. Easton, of the Illinois Geological Survey, who obtained and prepared excellent sections of the specimens studied by us. Doctor Easton is, himself, a student of fossil corals who has contributed ably to knowledge of late Mississippian and other fossil groups. We appreciate his kindness in aiding our investigation by permission to describe and figure this interesting species.

Occurrence.—Shale of Morrowan or Bendian (Atoka) age, near the base of the Pennsylvanian section exposed just north of road, 1 mile east of Leslie, Searcy County, Arkansas (SE. 1/4 sec. 23, T. 14 N., R. 15 W.).

Studied material.—The specimens available to us include one large corallite sectioned transversely and polished, the apical and calycinal parts lost or destroyed in grinding, and one specimen sectioned longitudinally. The latter shows the distal extremity of the column but walls of the calyx are broken away. Internal features of both specimens are excellently preserved. Dr. Easton has reported that additional specimens of this coral are in the collections at Walker Museum, University of Chicago, but they could not be located for study by us.

Type.—University of Chicago, Walker Museum, specimen no. 47236.

LOPHOPHYLLIDIUM sp. A

Text figs. 78, 79

The corals comprising this assemblage have a relatively slender conical form and are characterized by their greatly thickened interior. The theca is thick and bears fine septal markings and growth lines. The calyx is not well preserved, but seemingly it is deep and contains a broad, solid axial column. The largest specimen (Univ. Kansas, no. 7134–21a) is 27.4 mm. in length and 10.9 mm. in maximum diameter at the calyx.

The axial edges of the stout septa are thickened and united by stereoplasm so that septa are separated by open spaces only for a short distance from the theca. The median laminae of the septa can be traced under the microscope and do not join that of the elongate counter septum. The cardinal septum is thin and the counter septum extends to the axis; other major septa are of equal length. Transverse sections in the lower part of the corallities show an almost complete filling with stereoplasm. The structures of the longitudinal section are nearly completely concealed, but a few tabulae are seen to rise toward the axial region. Minor septa and dissepiments are lacking. The thickened counter septum is not distinctly separable from the axial ends of the septa and therefore the column seems to be very large, occupying the axial one-third of the corallite. The cardinal fossula is conspicuous, but alar pseudofossulae are not identified.

Discussion.—The thick deposit of stereoplasm of these corals distinguishes them from other species, but it also makes recognition of significant structures difficult. The corallites are even more solidly filled with stereoplasm than specimens of *Lophophyllidium confertum* Jeffords (1942, p. 221), and the thickened axial column is broader. *L.* sp. A can be distinguished from other described species of this genus by its well-developed cardinal fossula, thickened corallite, indistinct alar pseudofossulae, and thick theca.

Occurrence.—Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore from the Wapanucka limestone at a quarry, 1 mile south and 1 mile east of Hartshorne, Oklahoma (Univ. Kansas loc. 7134), and from the Hale formation, at the east end of the dam, Greenleaf Lake, cen. sec. 10, T. 13 N., R. 20 E., southeast of Braggs, Oklahoma (Univ. Kansas loc. 7385).

Material studied.—One sectioned specimen from each of the localities was available for study (Univ. Kansas, specimen nos. 7134–21a and 7385–21n).

Genus LOPHOTICHIUM, n.gen.

Moderately small conical solitary corallites having more or less curvature longitudinally, distinguished by internal structure that generally resembles the interior of *Lophophyllidium,* are included in this new genus. The theca, which is relatively thick, bears very shallow septal grooves, clearly marked in some specimens but indistinct in others, and it is crossed by transverse growth lines and small wrinkles. The septa unite at the axis in the immature region, and near the apex the corallites may be almost solid; numerous septa are visible but the protosepta are not readily identifiable. The middle and upper parts of the corallite show a strongly differentiated counter septum, which is longer than the others and thickened near its inner edge to form an axial column that is continuous with the column of the immature region below and that projects above the floor of the calyx. The cardinal septum tends to become shortened in the mature region, but a fossula is not distinct.

A diagnostic feature of the genus is the seeming greater number of septa near the apex of the corallite than in the upper part. Many radially disposed subvertical walls, indistinguishable from septa, in the immature part of the corallite undergo noteworthy change in appearance and structural relationship as they are traced to the mature region of the corallite. These septa-like structures terminate abruptly or curve to join steeply inclined peripheral parts of tabulae, and some of them reappear in sections above a tabula. The nonpersistent "septa" mostly alternate with radial partitions that persist upward and that, accordingly, are identifiable as true metasepta. The intercalated walls, which are not thus accounted for, are interpreted as steeply inflected portions of tabulae. Transverse sections of the lower and upper parts of a corallite are thus notably dissimilar, the septa shown in upper sections being fewer than septa and septa-like structures in the lower ones. Tabulae are fairly numerous; they are complete or somewhat anastomosing and slope upward from the theca toward the column. Dissepiments are lacking.

Genotype.—*Lophotichium vescum,* n.sp., Morrowan, Lower Pennsylvanian (Upper Carboniferous), eastern Oklahoma.

Discussion.—This new genus is evidently like *Lophophyllidium* in the nature of the column, formed by the thickened inner part of the elongate counter septum, arched tabulae, and characters of the metasepta in the mature region. The shortened cardinal septum that is seen in the upper part of corallites belonging to the genotype of *Lophotichium* is a commonly developed feature in *Lophophyllidium.* These similarities of the mature zone are not matched by likeness of the immature region in these two genera. Transverse sections near the apex of *Lophophyllidium proliferum,* which is the genotype, and of several other species belonging to this genus (Jeffords, 1942) show a comparatively simple structure consisting of a small number of short straight septa joined to the enlarged counter septum by stereoplasm that lies between and around the ends of the septa. Both counter and cardinal septa are distinguishable definitely not far from the apex. In *Lophotichium,* septa and septa-like structures of the immature zone are numerous and irregular; they join one another so as to form groups of twos, threes and fours, and the solid axial area is produced by actual junction of their extremities, not by intercalated stereoplasm between and around the ends of the septa. The median laminae and the borders of individual septa can be traced by examination under a microscope. The number of septa increases upward toward the calyx in *Lophophyllidium* and their arrangement is regular. The number of septa seemingly decreases upward in *Lophotichium;* their arrangement is irregular and commonly they are joined together in the immature region. The anomalies of the internal structure of *Lophotichium* are explained as a simulation of septa by portions of the tabulae.

Occurrence.—Morrowan, Lower Pennsylvanian (Upper Carboniferous); Oklahoma.

LOPHOTICHIUM VESCUM, n.sp.

Text figs. 61–74, 90

This species is characterized by its small size, conical to cylindrical shape, moderately thick theca, and very deep calyx that contains a sharply projecting axial column. The exterior is not well preserved on most examples, but some specimens show narrow septal grooves, rounded alternating ridges, and a few low transverse wrinkles. Many of the specimens exhibit abrupt constrictions due to rejuvenation. The incomplete type specimen is 13.9 mm. in length and 7 mm. in maximum diameter; other specimens reach a maximum diameter of about 10 mm.

The septa of this coral are long and thin; in lower and middle regions of growth they are united to the thickened counter septum at the axis, or joined in groups of two or three and continued to the axis as a single structure. Septa are not rhopaloid in any period of growth, but near the calyx they gradually shorten and withdraw from the column. In many specimens (figs. 64b, 65b, 70a) the septa of the cardinal quadrants shorten earlier than those of the opposite quadrants. The counter septum is long and thickened at the axis except at a late stage of growth, when it is only slightly longer than other septa. The thin cardinal septum reaches the column during early growth, but in the calyx it is short. The septal arrangement of the type specimen is indicated by the formula K 6 A 3 C 2 A 7 K. The greater number of the septa in the counter quadrants indicates them to be accelerated, although the development of the breviseptal stage first in the cardinal quadrants is not expected in forms having strong counter acceleration.

Thin irregularly inosculating tabulae rise steeply from the periphery or from other tabulae and join the axial column. Portions of numerous tabulae are not only subvertical near the theca but they are disposed radially so as to resemble septa; they are joined to the septa in a manner that produces a simulated bifurcation of the septa, as indicated both in tangential and transverse sections of the corallite. Close to the column the tabulae may be almost cystlike. Dissepiments are lacking. A cardinal fossula is indicated by the thin cardinal septum that is shortened in maturity, and alar pseudofossulae are recognizable in transverse sections up to the breviseptal stage. The column is formed by the thickened axial part of the counter septum, ascending tabulae, and axial edges of the other septa, except in the mature region where the counter septum is the last to be shortened, and projects into the calyx as a tall spine.

The internal structure of *Lophotichium vescum* is shown by the numerous transverse and longitudinal sections (figs. 62–74). A special study that was made of one specimen is illustrated by the drawings in figure 61. This specimen was cut transversely at four places distributed at intervals of about 5 mm.; the uppermost section was located a short distance below the floor of the calyx and the lowermost about 4 mm. from the apex. The theca was removed by grinding so as to reveal the outer edges of septa and tabulae. Camera lucida drawings of the segments give information that enables one better to understand

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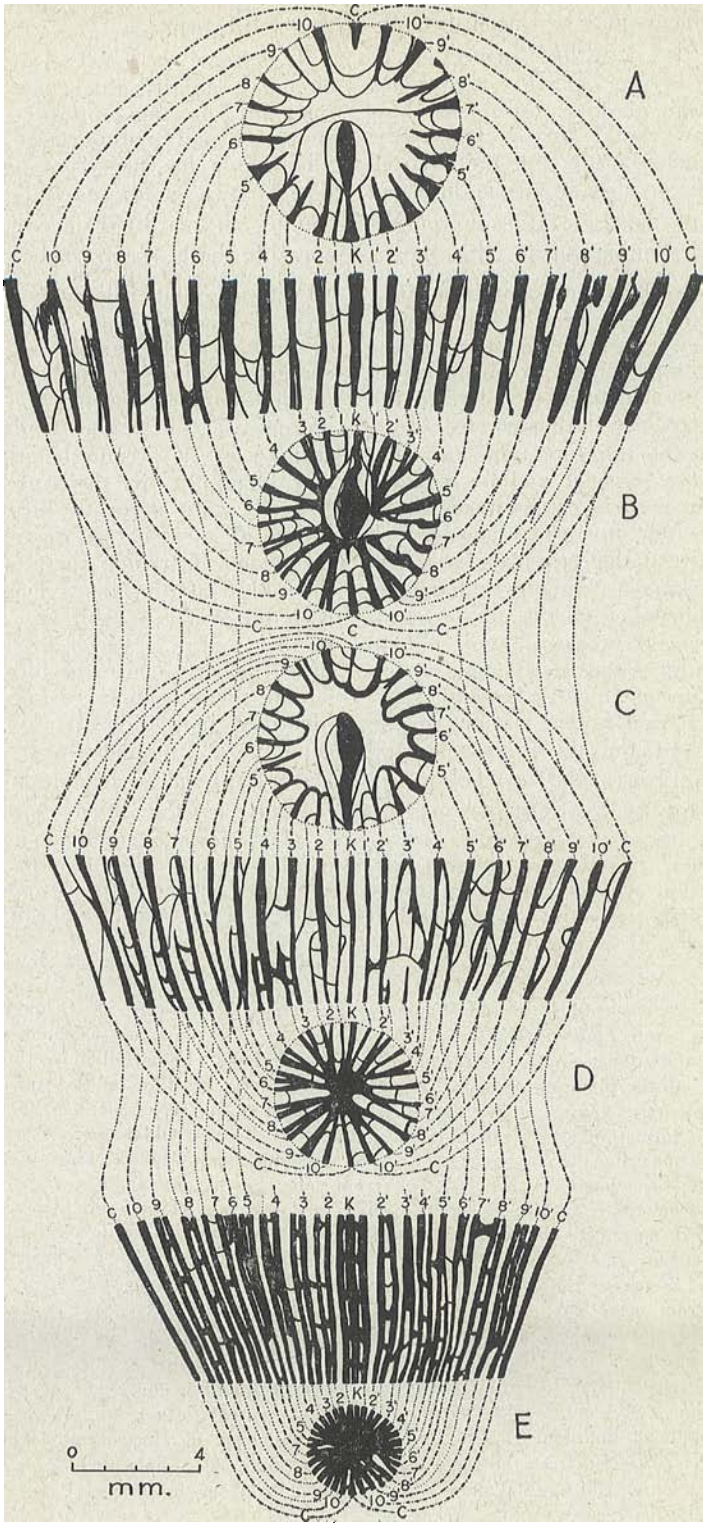
Fig. 61. Camera lucida drawings showing the arrangement of septa and tabulae in a specimen (KU7744–22c) of *Lophotichium vescum*, n.gen., n.sp. The theca was removed by grinding in order to show the peripheral edges of septa and tabulae, and the specimen was sawed transversely in four places. The top of the second segment, next below that containing the calyx, is shown in *A* and the bottom of this segment in *B;* the structural elements exposed on the sides of this segment are shown between *A* and *B.* The top, base, and sides of the third segment are shown in *C, D.* and between. The sides and base of the fourth segment are indicated in *E* and above. The septa are designated by numbers and by the letters C (cardinal) and K (counter); other elements are interpreted as tabulae.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mm.

the transverse sections, inasmuch as many structural elements may be traced throughout most of the corallite. Inspection of this specimen before removal of the theca and examination of other specimens show that a shallow septal furrow marks the position of each septum, but the furrows are too poorly defined on the middle and upper parts of most corallites to permit satisfactory determination by this means of the spacing of septa at the periphery.

The uppermost segment of the de-thecated sectioned specimen, containing the calyx, is not represented by drawings in figure 61. The structural elements of the second segment are indicated by transverse sections at the top (A) and bottom (B) of the segment and by a drawing of the outer surface, arranged in the manner of a Mercator projection, which is placed between the two transverse sections. A thickness of about 1 mm. between each pair of segments of the corallite was destroyed in sawing and polishing. Accordingly, the transverse section (C) at the top of the third segment belongs about 1 mm. below section B; the outer surface of the third segment and its base (D) are arranged just below section C. The top of the fourth segment is so similar to transverse section D that it was not drawn; the bottom of this segment is given in section E and the outer surface is shown just above E. The fifth segment, containing the apex of the coral, was not drawn.

Transverse section A clearly reveals the elongate, axially thickened counter septum and, in an opposite position, the short cardinal septum; alar septa are not identifiable by inspection of this section, but the two quadrants lying between the counter and cardinal on either side of the corallite both seem to be composed of 10 major septa. Intercepts of tabulae are seen as curved lines between the septa or crossing the axial region; a cone-shaped tabula surrounds the inner part of the counter septum. Section B, at the bottom of this segment, differs notably from A in the greater length of the septa and seemingly in their greater number. Several septa seem to bifurcate. Correlation of elements in sections A and B by means of tracing their outer edges on the sides of the theca-denuded segment is definite. The irregularity and generally thinner nature of several septa-like structures that are seen to be introduced differentiate them from extensions of the septa identified in section A. All elements except the 22 numbered or lettered septa are interpreted to be tabulae.

Study of the third corallite segment (C–D) shows characters similar to those of the second, just pointed out, but the contrast between the upper and lower faces is even greater. Transverse section

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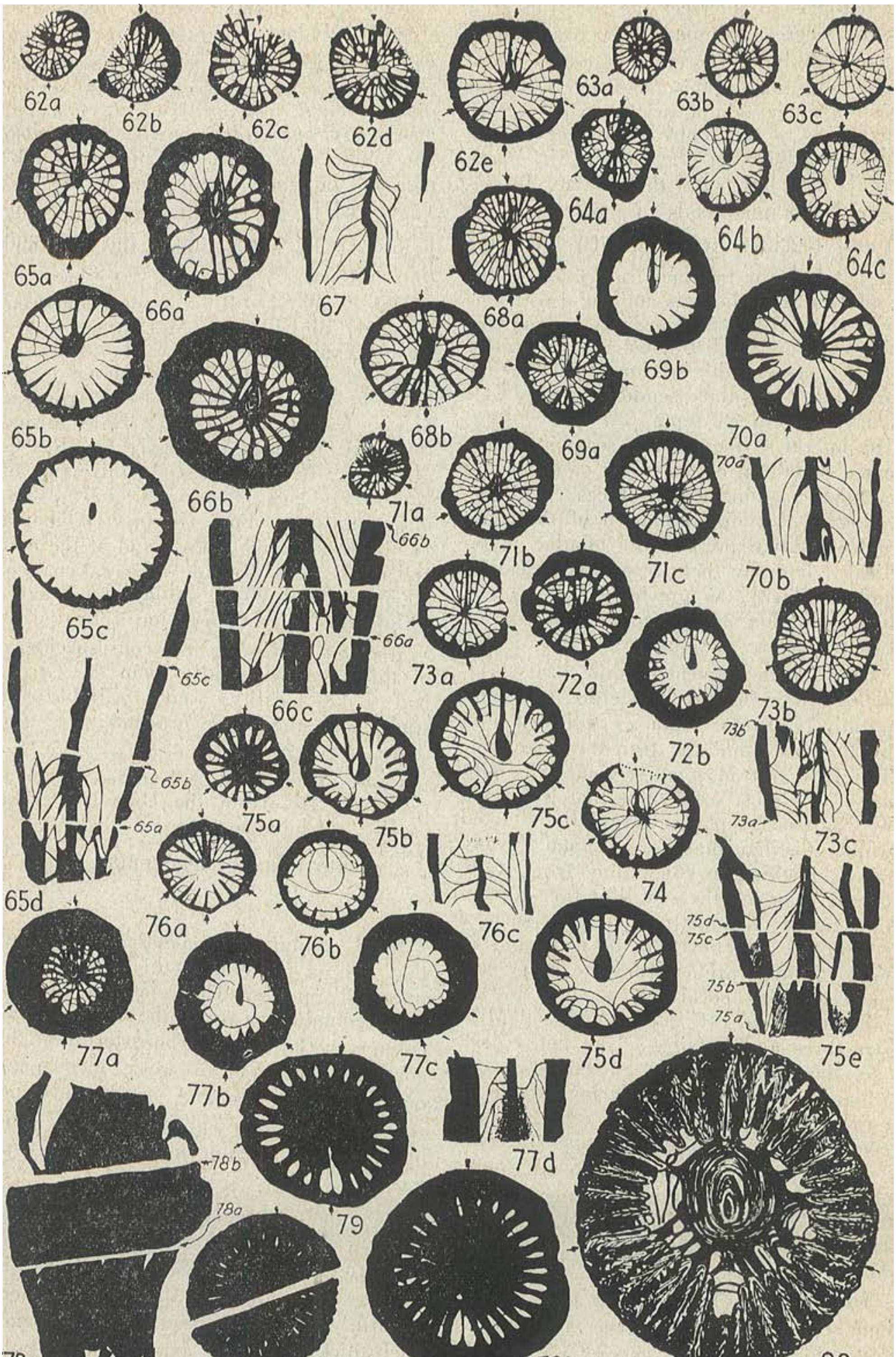
Figs. 62–80. Sections of Hale and Wapanucka lophophyllidid corals, x3, belonging to *Lophotichium*, n.gen., and *Lophophyllidium* Grabau. Transverse sections are oriented with the cardinal septum at bottom; protosepta indicated by small arrows. Longitudinal sections are mostly at right angles to the plane of the cardinal and counter septa; positions of the transverse sections shown by small italic figures. (62) *Lophotichium vescum*, n.sp., type specimen, no. KU7385–24s, from the Hale formation at Greenleaf Lake southeast of Braggs, Oklahoma; (63) specimen no. KU7385–23n, from same locality as fig. 62; (64) specimen no. KU7385–21o, from same locality as fig. 62; (65) specimen no. KU7385–21d, from same locality as fig. 62; (66) specimen no. KU7385–21u, from same locality as fig. 62; (67) specimen no. KU7385–24h, from same locality as fig. 62; (68) specimen no. KU7385–24w, from same locality as fig. 62; (69) specimen no. KU7385–24m, from same locality as fig. 62; (70) specimen no. KU7385-24i, from same locality as fig. 62; (71) specimen no. KU7385–24u, from same locality as fig. 62; (72) specimen no. KU7385–24r, from same locality as fig. 62; (73) specimen no. KU7583–21v, from same locality as fig. 62; (74) specimen no. KU7385–24t, from same locality as fig. 62. (75) *Lophotichium improcerum*, n.sp.. type specimen, no. KU7385–21q, from same locality as fig. 62; (76) specimen no. KU7385–24j, from same locality as fig. 62. (77) *Lophotichium densum*, n.sp., type specimen, no. KU7385–21L, from same locality as fig. 62. (78) *Lophophyllidium*, sp., A, no. KU7134–21a, from the Wapanucka limestone, 1 mile south and 1 mile east of Hartshorne, Oklahoma; (79) specimen no. KU7385–21n, from the same locality as fig. 62. (80) *Lophophyllidium eastoni*, n.sp., type specimen, Univ. Chicago, Walker Mus., no. 47236, from lowermost Pennsylvanian beds 1 mile east of Leslie, Searcy County, Arkansas.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C happens to intersect the corallite at a plane where a comparatively broad open space adjoins the prominent counter septum; presumably this condition is found just below a tabula in the axial region, inasmuch as the septa are longer on the upper surfaces of the tabulae in many corals than just below the tabulae. In section C the inner ends of most septa are joined together by the curved intercepts of a tabula or tabulae. In section D the septa reach to the axis and unite with one another; neither the cardinal septum nor the counter is distinguishable definitely on the basis of this section alone, but the position of the alar pseudofossulae is well marked (between septa 6–7 and 7′–8′). The lateral surface of this segment, showing distribution of the edges of septa and tabulae just inside the theca, is interesting in that differentiation of the septa and septa-like portions of tabulae is indicated both by their respective thickness and regularity, as previously noted, and by correlation of elements shown in the two transverse sections.

The fourth segment of this coral specimen shows seemingly numerous and comparatively regular septa, as indicated both by the sides and the transverse sections. The bottom transverse section (E) indicates an almost solid mass that is formed by coalesced septa and radially situated walls indistinguishable from septa. Surely one is justified in concluding from study of this part of the corallite that it contains more than 30 septa; yet such a conclusion is believed to be erroneous in view of observations from the other segments of this coral which point to the tabulate nature of intercalated septa-like structures and in view of an entire lack of other coral genera known to us in which septa are aborted during growth so as to reduce the number of septa in proceeding from youthful to mature stages.

The arrangement of septa in the specimen represented by figure 61 is concluded to be as follows: K 6 A 3 C 2 A 7 K. The alar septa are nos. 7 and 8′, as shown on the diagrams.

Discussion.—The relatively thick theca, long septa, and nature of the tabulae separate this coral from species of *Lophophyllidium.* The smaller size, much less distinct alar pseudofossulae, and more erratic tabulae separate *Lophotichium vescum* from *L. amoenum,* n.sp. The thinner theca and more open apical region distinguish *L. vescum* from *L. densum,* n.sp., *Lophophyllidium exile,* n.sp., also has unthickened septa and numerous tabulae, but *Lophotichium vescum* can be distinguished by the peculiar nature of the tabulae, septa which join at the axis, and thicker theca.

Occurrence. — Brentwood limestone member, Bloyd shale, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore along U. S. highway No. 71 near Woolsey, Arkansas (Univ. Kansas loc. 7206). Hale formation, Morrowan; collected by R. C. Moore, L. R. Laudon, and University of Kansas students at Keough quarry, 2½ miles north of Fort Gibson, Oklahoma (Univ. Kansas loc. 4520), and at the east end of the dam, Greenleaf Lake, cen. sec. 10, T. 13 N., R. 20 E., southeast of Braggs, Oklahoma (Univ. Kansas loc. 7385).

Material studied.—Numerous specimens of this coral, especially from the Greenleaf Lake locality, were available for study, and about 25 corallites were sectioned.

Type.—University of Kansas, specimen no. 7385–24s, from the Greenleaf Lake locality, Oklahoma.

LOPHOTICHIUM IMPROCERUM, n.sp.

Text figs. 75, 76, 92

Small solitary conico-cylindrical corals that have a moderately thick theca comprise this species. The relatively shallow calyx contains the tip of the large pointed column in the center. The exterior of the corallite is marked by weak, inconspicuous septal grooves and small transverse wrinkles. The type specimen is 19.7 mm. in length and 9.9 mm. in maximum diameter at the calyx.

In immature regions the septa reach close to the axis, where their edges are fused to the column. Sections higher in the corallite show that the septa shorten upward. The counter septum is long and much thickened at the axis to form a column, whereas the cardinal septum is short.

The septal arrangement of the type specimen, showing the strong counter acceleration, is as follows: K 6 A 2 C 2 A 6 K.

Numerous anastomosing tabulae rise from the periphery to join the column at the axis. They may be so nearly vertical as to simulate septa when seen in transverse sections, but are thinner than the normal septa. Dissepiments are lacking. The cardinal septum is somewhat thinner and shorter than other septa, but the cardinal fossula is not conspicuous. Alar pseudofossulae are identified only in sections close to the apex.

Discussion.—This species differs from *Lophotichium vescum*, n.sp., and *L. amoenum*, n.sp., in the smaller number and stouter nature of the septa. Also, tabulae are more regular in longitudinal sections and the counter septum is more distinctly thickened at the axis. *L. improcerum* is easily separated from *Lophophyllidium exile*, n.sp., by its much thicker column, theca, and septa.

Occurrence.—Hale formation, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore and University of Kansas students at east end of the dam, Greenleaf Lake, cen. sec. 10, T. 13 N., R. 20 E., southeast of Braggs, Oklahoma (Univ. Kansas loc. 7385).

Material studied.—The well-preserved type specimen and three other sectioned specimens of this species were available for study.

Type.—University of Kansas, specimen no. 7385–21q.

LOPHOTICHIUM DENSUM, n.sp.

Text figs. 77a-d

Solitary medium-sized conical corallites that have a thick theca and completely solid apical portion are assigned to this species. The calyx is very deep and surrounded by the thick thecal wall. Broad rounded septal grooves are separated by sharp narrow interseptal ridges. Transverse markings consist of growth lines and low sharp wrinkles. The type specimen is 20.8 mm. in length and 7.9 mm. in diameter at the upper part of the calyx.

Septa are long and strongly fused together at the axis in lower and middle regions. Near the apex the interior is so solidly filled with swollen septa and stereoplasm that septal characters are concealed. Near the calyx the septa are shortened so as to leave a broad axial area, which contains the column. The cardinal septum is distinctly weaker than other septa throughout the length of the corallite, whereas the counter septum is long and thickened to form a column. The alar septa are not positively determined, but the septal formula seemingly is K 6 A 2 C 2 A 6 K. Minor septa are lacking.

Numerous thin tabulae rise steeply to the column. They are similar in general nature to those of *Lophotichium vescum*, n.sp., but do not simulate septa to such a degree as in the genotype species. Dissepiments are lacking. The thickened counter septum forms a distinct column, opposite which lies the weak cardinal septum in a poorly defined fossula. Alar pseudofossulae are inconspicuous.

Discussion.—The very thick theca and excessively filled apical region separate this species from other corals here described as *Lophotichium vescum*, n.sp., and *L. amoenum*, n.sp. The transverse sections of the mature part are similar to those of typical representatives of *Lophophyllidium*, except for the very thick theca. The nature of the tabulae as seen in transverse sections of the immature region and in longitudinal sections, however, indicates closer affinity to *Lophotichium*.

Occurrence.—Hale formation, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore and L. R. Laudon at the east end of the dam, Greenleaf Lake, cen. sec. 10, T. 13 N., R. 20 E., southeast of Braggs, Oklahoma (Univ. Kansas loc. 7385).

Material studied.—One sectioned specimen only was found in the collections available for study, but this is so distinctive and well characterized by the material as to merit description.

Type.—University of Kansas, specimen no. 7385–21L.

LOPHOTICHIUM AMOENUM, n.sp.

Text figs. 81a-g

This species comprises solitary slightly bent elongated conical corallites that have a thick theca and a moderately deep calyx. The narrow incised septal grooves are separated by broad rounded ridges and crossed transversely by fine growth lines. The type specimen is 24.3 mm. in length and 9.6 mm. in maximum diameter at the base of the calyx.

The major septa unite at the axis except close to the calyx, where they extend only half the distance to the center. The cardinal septum is distinctly thinner than other septa, whereas the counter septum is long and thickened at the axis. In upper sections, where the other septa shorten, the counter septum remains long. The septal arrangement in the uppermost section of the type specimen is indicated by the formula K 8 A 4 C 4 A 7 K. Seemingly, minor septa are not developed.

Tabulae are numerous, steeply inclined or vertical, and highly anastomosing. In transverse sections they are seen as curved bars transverse to the septa or more or less parallel to the septa. Dissepiments are lacking. The cardinal fossula is only weakly shown, but alar pseudofossulae are very strongly accented even in mature regions. The axial column in the apical part is formed by the thickened counter septum and by the axial edges of the other septa. In advanced stages the column is formed by the elongate counter septum only.

Discussion.—The many anastomosing steep tabulae and long septa of this species indicate affinity with *Lophotichium vescum*, n.sp., but *L. amoenum* differs from *L. vescum* in having a larger size, more persistent septa, a stronger counter septum, and somewhat more conspicuous alar pseudofossulae. *L. amoenum* is separated from *L. densum*, n.sp., by its larger size and especially its relatively thinner theca and more open apical portion.

Occurrence.—Hale formation, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore at Keough quarry, 2½ miles north of Fort Gibson, Oklahoma (Univ. Kansas loc. 7744).

Material studied.—The single available specimen is a well-preserved corallite that has been sectioned sufficiently to show internal features clearly.

Type.—University of Kansas, specimen no. 7744–22a).

LOPHOTICHIUM sp. A

Text figs. 82a-c

This form is represented by a single elongate, evenly conical corallite that has a thick theca and a deep calyx. Very indistinct, longitudinal markings on the exterior are crossed by small transverse wrinkles. The figured specimen, which is somewhat incomplete at the apex, is 31.5 mm. in length and 10.9 mm. in maximum diameter.

Transverse sections of this coral show long relatively thick septa that join the thickened counter septum at the axis. The counter septum is long and thickened, but the cardinal septum is only slightly weaker than other metasepta. The septal arrangement seems to be as follows:

Figs. 81–89. Sections of Hale and Smithwick lophophyllidid and hapsiphyllid corals, x3. Transverse sections are oriented with the cardinal septum at bottom; protosepta indicated by small arrows. Longitudinal sections are mostly at right angles to the plane of the cardinal and counter septa; positions of the transverse sections shown by small italic figures. (81) *Lophotichium amoeum*, n.gen., n.sp., type specimen, no. KU7744–22a, from the Hale formation near Keough quarry, 2½ miles north of Fort Gibson, Oklahoma. (82) *Lophotichium*, sp. A, no. KU7385–21h, from the Hale formation at Greenleaf Lake, southeast of Braggs, Oklahoma. (83) *Lophamplexus captiosus*, n.sp., type specimen, no. KU4520–21f, from the Hale formation, Keough quarry, 2½ miles north of Fort Gibson, Oklahoma; (84) specimen no. KU4520–21L, from same locality as fig. 83; (85) specimen no. KU4520–21i, from same locality as fig. 83. (86) *Lophamplexus*, sp. A, no. KU4520–21e, from same locality as fig. 83. (87) *Lophamplexus*, sp. B, no. KU7385–21r, from same locality as fig. 82. (88) *Hapsiphyllum tumidum*, n.sp., no. P11799c, from the Smithwick shale from tank near Jack Wood's house, Gibbons' ranch, San Saba County, Texas (loc. 205–T–71); (89) specimen no. P11799b, from the same locality as fig. 88.


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88c
89a
89b

K 6 A 3 C 3 A 6 K. Minor septa are indicated merely by low ridges between the major septa. A longitudinal section does not show structures clearly, but does indicate the existence of a strong, solid axial column, septa that are longer just above a tabula than below it, lack of dissepiments, and the presence of thin anastomosing tabulae. The cardinal fossula and alar pseudofossulae are inconspicuous throughout the corallite. The large column is formed by the thickened counter septum and the axial edges of the other major septa, which are fused about it by stereoplasm.

Discussion.—This coral differs from others assigned to *Lophotichium* in its more elongate form and in the nature of its septa. It can be separated from *Lophotichium amoenum*, n.sp., and *L. vescum*, n.sp., by the persistence and length of the septa, its large size, and the lack of conspicuous pseudofossulae.

Occurrence.—Hale formation, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore, at the east end of the dam, Greenleaf Lake, cen. sec. 10, T. 13 N., R. 20 E., southeast of Braggs, Oklahoma (Univ. Kansas loc. 7385).

Material studied.—Only one specimen (Univ. Kansas, specimen no. 7385–21h) of this form was found among the many sectioned corallites from this locality.

Genus LOPHAMPLEXUS Moore and Jeffords, 1941

The immature region of corallites belonging to this genus is characterized by structure like that of *Lophophyllidium* Grabau, whereas the calyx and subjacent region of varying longitudinal extent have the structure of *Amplexus* Sowerby. The form of the corallites is conical to cylindrical and straight or somewhat curved. The theca bears well-marked septal grooves, which are crossed by wrinkles and growth lines. Near the apex the septa are long, most of them reaching to the axis and uniting. Transverse sections at intermediate height but within the lophophyllidial zone show distinct elongation of the counter septum and commonly a marked thickening of its terminal inward part, which forms the axial column; the cardinal septum is shortened and lies in an open fossula; other major septa are long but do not reach the axis. Tabulae slope very steeply upward near the outer wall of the corallite, but in the axial region they arch gently or are subhorizontal. In the amplexoid zone, which comprises the part of the corallite above the region that bears an axial column, the septa are all shortened notably. At intervals there are tabulae like those in *Amplexus*, flat or slightly sagging in the central area and bending strongly downward peripherally.

Genotype.—*Lophamplexus eliasi* Moore and Jeffords (1941, p. 91), Wolfcampian, Lower Permian, Kansas and Oklahoma.

Discussion.—The relationships of this genus have been considered in the paper that introduced *Lophamplexus*. Seemingly, this group of corals is derived from *Lophophyllidium*, and it is evident that immature specimens, which have not attained the amplexoid habit, are not distinguishable from *Lophophyllidium*. The discovery of typical examples of *Lophamplexus* in very early Pennsylvanian rocks, as reported in this paper, considerably increases the stratigraphic range of the genus. Inasmuch as pre-Pennsylvanian representatives of *Lophophyllidium* are as yet unknown, this early occurrence of a supposedly derived genus—*Lophamplexus*—is of special interest.

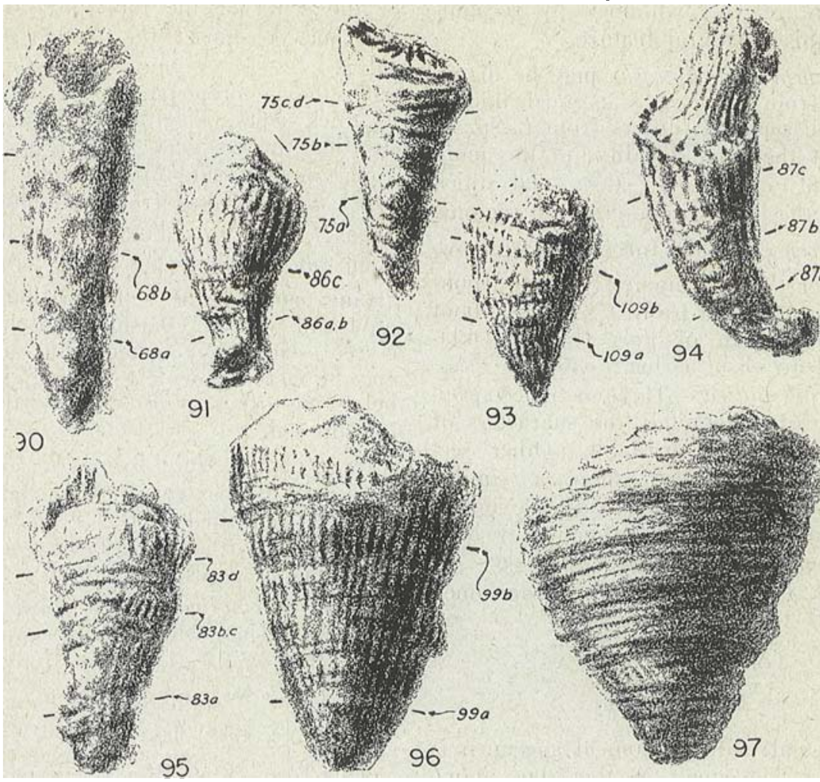
Occurrence.—Morrowan, Lower Pennsylvanian (Upper Carboniferous) to Wolfcampian, Lower Permian; Oklahoma and Kansas.

LOPHAMPLEXUS CAPTIOSUS, n.sp.

Text figs. 83–85, 95

Moderately small, slightly bent conicocylindrical corallites that have a deep calyx, thin theca, and narrow septal grooves are assigned to this species. Fine growth lines run transverse to the septal markings. The type specimen is 9.7 mm. in diameter at the calyx and 21 mm. in length.

In the lower part of the corallites the counter septum is long and slightly thickened at the axis to form a lophophyllidid column, whereas the cardinal septum is short. Other major septa are of equal



Figs. 90–97. Exterior views of Hale, Marble Falls, and Smithwick lophophyllidid and hapsiphyllid corals, x2. The positions of transverse sections are indicated by small italic figures. (90) *Lophotichium vescum*, n.gen., n.sp., specimen no. KU7385–21w, from the Hale formation at Greenleaf Lake, southeast of Braggs, Oklahoma. (91) *Lophamplexus*, sp. A, no. KU4520–21e, from the Hale formation near Keough quarry, north of Fort Gibson, Oklahoma. (92) *Lophotichium improcerum*, n.sp., type specimen, no. KU7385–21q, from the same locality as fig. 90. (93) *Zaphrentoides excentricus*, n.sp., type specimen, no. P11365a, from the Smithwick shale of Ellis pasture, 10½ miles west of San Saba, Texas (loc. 205–T–50). (94) *Lophamplexus*, sp. B, specimen no. KU7385–21f, from the same locality as fig. 90. (95) *Lophamplexus captiosus*, n.sp., type specimen, no. KU4520–21f, from the same locality as fig. 91. (96) *Hapsiphyllum tumidum*, n.sp., specimen no. P11800a, from the Smithwick shale, near tank east of Jack Wood's house, Gibbons' ranch, San Saba County, Texas (loc. 205–T–71). (97) *Hapsiphyllum retusum*, n.sp., no. USGS647d, from the Smithwick shale on Honey Creek, 10 miles southeast of Llano, Llano County, Texas (loc. USGS–647).

length. The septal formula of the type specimen is K 6 A 3 C 3 A 6 K. Near the calyx the counter septum is shortened, so that the column disappears and tabulae are uninterrupted as they cross the interior. Septa are very short and not differentiated. Tabulae rise steeply from the periphery but are nearly horizontal as they join the column. Above the point where the column disappears, the tabulae are horizontal in the axial nonseptate portion but they bend down steeply near the periphery. The cardinal fossula is well developed throughout the corallite. Alar pseudofossulae are identified only in immature stages.

Discussion.—The sections of these corals indicate that the length of the septa varies in accordance with the position of the transverse section. A section of the type specimen taken between tabulae shows shortened septa (fig. 83b), whereas another section, only a very few millimeters higher but through a tabula, shows long septa that reach close to the axis (fig. 83c). Seeming differences among corallites and inconsistencies in septal shortening are readily explained by recognition of this structural feature.

Lophamplexus captiosus may be distinguished from *L. eliasi* by its much thicker theca and septa. It differs from *L.* sp. A, found at the same locality, in the more prominent amplexoid stage and thick septa of the lower lophophyllidid regions.

Occurrence.—Hale formation, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore, about 2½ miles north of Fort Gibson, Oklahoma (Univ. Kansas loc. 4520).

Material studied.—Three sectioned specimens showing definitely the characters of this species were available. Other sectioned corallites that show a similar lophophyllidid stage probably are immature examples of this species; they have not advanced to the amplexoid stage.

Type.—University of Kansas, specimen no. 4520–21f.

LOPHAMPLEXUS sp. A

Text figs. 86, 91

This small solitary conical specimen is curved at the apex in the alar plane. The calyx is not preserved. The moderately thick theca is marked by deep septal grooves, rounded ridges, and fine growth lines. The broken upper surface shows a small rejuvenated corallite that again has long septa. The corallite is 10.8 mm. in length and 8.4 mm. in maximum diameter at the upper surface.

The coral is typically lophophyllidid in the lower half, but disappearance of the column in the upper half, due to shortening of the counter septum, gives this portion the appearance of *Amplexus*. The arrangement of the long septa in the lower part is K 4 A 3 C 3 A 4 K. The greater number of septa in the upper section indicates that septa are added during the breviseptal stage. Minor septa are rudimentary. Tabulae seem to be few and steeply arched in the column-bearing portion, but they cross the upper half of the corallite at close-spaced intervals. These latter tabulae are flat except for their down-turned edges.

Discussion.—This species differs from *Lophamplexus* sp. B in the uniform length of the septa of the lophophyllidid portion and the horizontal tabulae near the calyx. *L.* sp. A may be distinguished from the genotype species, *L. eliasi*, by its thick septa, which lack distinct axial swelling, by its very short septa in the upper portion, and by its small size. *L.* sp. A was collected from the same locality as *L. captiosus*, but it seems to differ from the named species in the nature and arrangement of the septa of the lophophyllidid portion. Inasmuch as this form is represented by one corallite only and may be merely a widely varying specimen belonging to *L. captiosus*, no specific name is proposed.

Occurrence.—Hale formation, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore, about 2½ miles north of Fort Gibson, Oklahoma (Univ. Kansas loc. 4520).

Material studied.—One well-preserved corallite (Univ. Kansas, specimen no. 4520–21e) was sectioned for study.

LOPHAMPLEXUS sp. B

Text figs. 87, 94

This form is a solitary, curved conicocylindrical corallite having an incompletely preserved calyx and faint septal grooves that are crossed by fine growth lines. The specimen is 25.4 mm. in length and 8.7 mm. in diameter at the calyx just below the uppermost rejuvenated portion.

In the lower part of the specimen many septa are extended to the axis where they join the column. Other major septa have a length equal to half the radius. The long counter septum is thickened at the axis to form a solid axial column whereas the cardinal septum is short. The septal arrangement in the upper part of the corallite is K 6 A 3 C 3 A 6 K. In longitudinal sections of this part of the coral the thin tabulae are seen to rise steeply to the column. About two-thirds the length of the corallite above the apex, the septa become very short. The shortening of the counter septum causes the disappearance of the column in the upper third of the specimen, so that tabulae are complete.

A peculiar feature of this specimen is the constriction in the upper part due to rejuvenation. The lophophyllidid youthful stages are not repeated in the renewed growth.

Discussion.—This coral differs from *Lophamplexus eliasi* Moore and Jeffords in the uneven length of the septa and steeply rising tabulae of the lower part, and in the lack of distinct axial thickening of the septa. The thin theca and nature of the slender septa serve to distinguish *L.* sp. B from *L. captiosus* and *L.* sp. A. This is the only specimen having characters of this genus found among nearly a hundred sectioned specimens from the Greenleaf Lake locality, and uncertainty as to its characters and variability make it inadvisable to propose a specific name for it.

Occurrence.—Hale formation, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore, below the dam, Greenleaf Lake, cen. sec. 10, T. 13 N., R. 20 E., southeast of Braggs, Oklahoma (Univ. Kansas loc. 7385).

Material studied.—One well-preserved specimen (Univ. Kansas, specimen no. 7385–21r) was available for study.

Family HAPSIPHYLLIDAE Grabau, 1928

Solitary, straight or curved conical corallites comprise genera assigned to the Hapsiphyllidae. Most are small forms. They have a well developed but not thick theca that is marked externally by septal grooves. The subcircular, moderately deep calyx contains no axial projection, but instead, there is commonly a centrally placed depression that joins or forms part of a strongly defined cardinal fossula. Bordering the depression in some genera is a more or less distinct, stoutly formed inner wall that is made by stereoplasm uniting the axial margins of major septa. There is no axial column; although some transverse sections show a joining of the septa and accumulation of stereoplasm in the axial region, others reveal absence of these features. Tabulae are present but dissepiments are lacking. Range, Devonian to Permian.

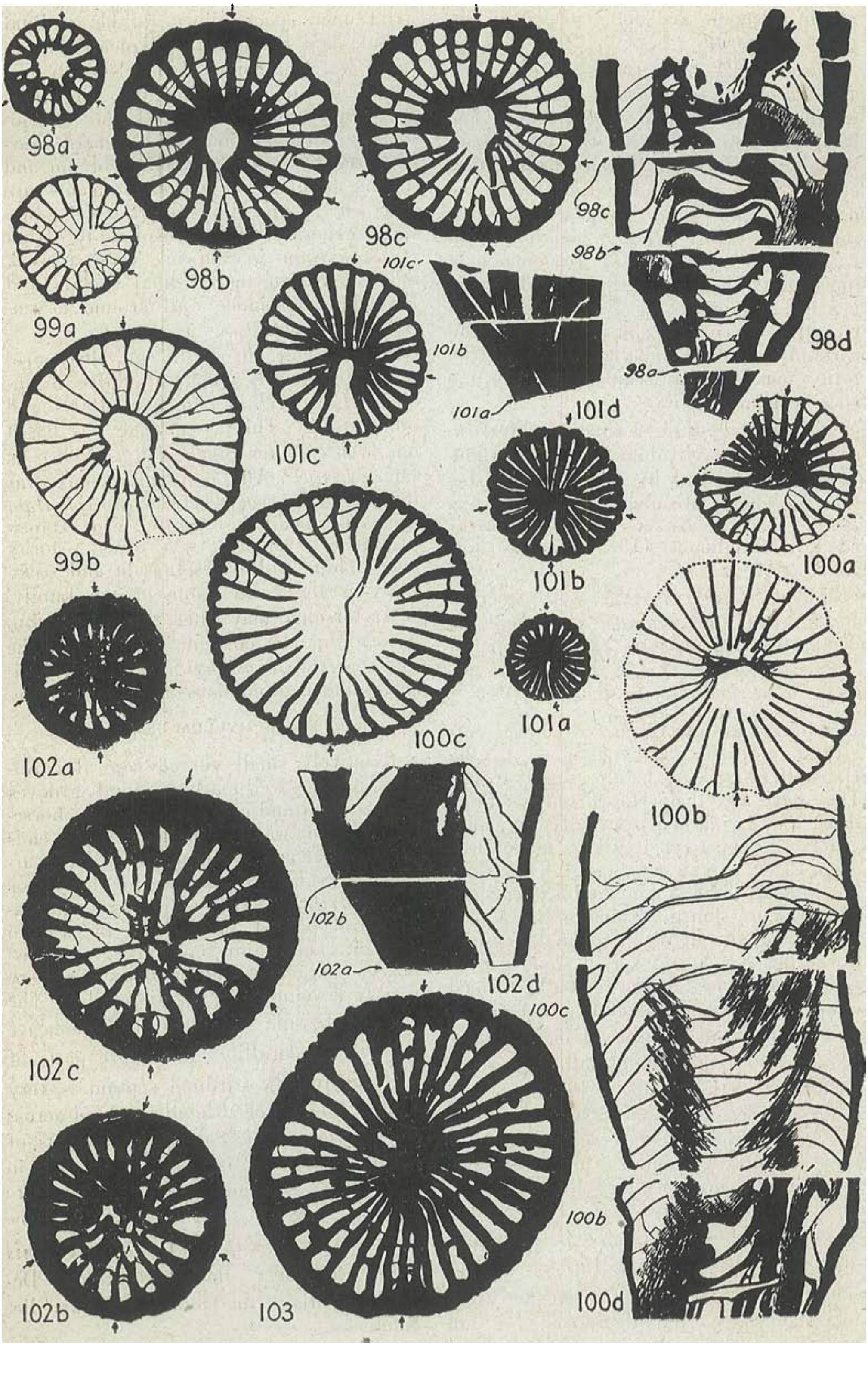
Discussion.—This family is differentiated from the Lophophyllidiidae by absence of an axial column, from the Streptelasmaidae by the distinctness of an axial open space joined to the cardinal fossula and accompanied typically by an inner wall that more or less sharply circumscribes the axial opening, and from the Zaphrenthidae by lack of dissepiments. As here interpreted, genera characterized by lack of an axial column and having tabulae but no dissepiments are assigned to the Hapsiphyllidae. Some such genera differ considerably from *Hapsiphyllum* in showing only a weak development of the cardinal fossula and in lacking an inner wall around a central open space.

Schindewolf, in 1938 (p. 446), proposed the family Zaphrentoididae to include *Hapsiphyllum* Simpson (1900) and other corals. This assemblage was based on *Zaphrentoides* Stuckenberg (1895) as family type. Although this genus was introduced five years before *Hapsiphyllum* was described, the family term Hapsiphyllidae Grabau (1928) has priority over Schindewolf's designation and seemingly is the valid name of the family. A factor that may alter this conclusion, however, is the current insecurity of the diagnosis of *Hapsiphyllum;* this is indicated under discussion of *Hapsiphyllum.*

Genus HAPSIPHYLLUM Simpson, 1900

Relatively small curved conical corallites having well-marked septal grooves on the theca and characterized by a horseshoe-shaped wall connecting inner ends of the septa and opening toward the cardinal fossula are classed in the genus *Hapsiphyllum.* The calyx is comparatively deep and surrounded by a thin margin. The major septa are evenly disposed. Alar pseudofossulae are very weakly developed or not discernible. The cardinal fossula is located on the concave side of the corallite. In mature parts of the corallite the cardinal septum is very short. A few arched tabulae extend across the interior of the corallite, intercepts of them appearing as irregular rings in transverse sections. Dissepiments are lacking.

Genotype. — *Zaphrentis calcariformis* Hall, Onondaga limestone, Middle Devonian, Falls of the Ohio, near Louisville, Kentucky.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100d

Discussion.—Reliable information concerning the internal structure of the genotype species of *Hapsiphyllum* is not at hand. A diagrammatic transverse section published by Simpson (1900, p. 203, fig. 10), purporting to belong to *H. calcariforme*, is stated to represent an example of the species from the "St. Louis group, Washington County, Indiana." Worthen (1890, p. 74, pl. 10, figs. 2, 2a) had earlier described and illustrated a coral from the "Warsaw division of the St. Louis limestone, Coalsburg, Ky." that he identified as *Zaphrentis calcariformis*, but internal structural features are not indicated, and it is far from certain that this coral is rightly identified. Schindewolf's (1938, p. 445, pl. 44, figs. 3–5, pl. 45, figs. 1a–e) description and illustrations of supposed specimens of *H. calcariforme* are reported to have been based on material from the St. Louis limestone in Indiana. Several good transverse sections are given by Schindewolf, but they do not help very much to establish the characters of *Hapsiphyllum*, inasmuch as they probably represent a coral that is not *H. calcariforme*. Accordingly, assignment of any new species to *Hapsiphyllum* must be made with reservation until authentic examples of the genotype species have been critically studied. Such investigation may be expected to reveal the arrangement of septa in the immature region and the nature of tabulae, which presumably are present. The characters of septa and cardinal fossula in the mature region, including the position of the fossula on the concave side of the corallite, are indicated by Hall's description and figures of his type.

Comparison of *Hapsiphyllum*, *Zaphrentoides*, and some other genera is given in the discussion of *Zaphrentoides*.

Occurrence.—Devonian to Permian; North America, Europe, Asia.

HAPSIPHYLLUM TUMIDUM, n.sp.

Text figs. 88, 89, 96, 98–100

This species consists of conical solitary corallites that are slightly bent along the alar or cardinal-counter plane. The calyx is shallow and has a depressed axial portion. Septal grooves on the exterior of the moderately thick theca are deep and narrow; they are separated by low rounded ridges. Transverse fine growth lines are irregularly distributed and a few low wrinkles may be present on the theca. The type specimen is 25 mm. in length and 12.8 mm. in diameter at the calyx.

Thick straight major septa reach close to the axis of the corallite where they are joined together by stereoplasm that forms a thickening around the large fossula. The cardinal septum is short and thick. Other protosepta are similar to the metasepta. Minor septa are lacking. The septal arrangement, which shows very strong acceleration of the counter quadrants, is indicated by the formula K 8 A 4 C 4 A 8 K.

Moderately thick tabulae rise sharply from the periphery to the inner wall that is formed by the axial ends of the septa and then sag slightly in the central portion. The large open fossula, containing the short thick cardinal septum, narrows as it passes through the wall about the thickened ends of the septa and then widens out to form a large axial depression that is more or less circular in outline.

Figs. 98–103. Sections of Smithwick (Bendian) and Hale hapsiphyllid corals, x3, belonging to the genus *Hapsiphyllum* Simpson. Transverse sections are oriented with the cardinal septum at bottom; protosepta indicated by small arrows. Longitudinal sections are mostly at right angles to the plane of the cardinal and counter septa; positions of the transverse sections shown by small italic figures. (98) *Hapsiphyllum tumidum*, n.sp., type specimen, no. P11799a, from the Smithwick shale, near tank east of Jack Wood's house, Gibbons' ranch, San Saba County, Texas (loc. 205–T–71); (99) specimen no. P11800a, from the same locality as fig. 98; (100) specimen no. KU7085–21c, from the same locality as fig. 98. (101) *Hapsiphyllum crassiseptatum*, n.sp., the type specimen, no. KU7744–21b, from the Hale formation about 2½ miles north of Fort Gibson, Oklahoma. (102) *Hapsiphyllum retusum*, n.sp., specimen no. USGS647c, from the Smithwick shale on Honey Creek, 10 miles southeast of Llano, Texas; (103) specimen no. USGS647e, from the same locality as fig. 102.

Alar pseudofossulae are inconspicuous, being indicated only by the short last-formed septa on the counter side of the alar septa. There is no axial column and dissepiments are lacking.

Discussion.—This species most closely resembles a coral from rocks of Moscovian age in China described by Grabau (1928, p. 124) as *Hapsiphyllum moukouense.* This form and the Texas species are similar in the size and shape of the corallite, the large cardinal fossula opening into a circular axial depression, and the presence of a wall formed by union of edges of the septa around the fossula. *H. tumidum* can be distinguished by the lack of even rudimentary minor septa, the greater number of its major septa and tabulae, and constriction of the fossula by the axial edges of the septa on either side of the cardinal septum. *H. tumidum* is similar to *"Zaphrentis" postuma* Smith (1931, p. 4) from the *Anthracoceras* zone of south Wales in the zaphrenthid arrangement of the septa and circular open space at the axis. The European coral has fewer tabulae and septa, and lacks the distinct fossula and greatly shortened cardinal septum of the Smithwick specimens. *H. tumidum* is somewhat like the coral here described as *Paracaninia? sana,* from the Marble Falls limestone. The latter species differs fom *H. tumidum* in lacking a definite inner wall formed by union of the edges of major septa and in having a wider axial open space.

Occurrence.—Smithwick shale, Bendian, Lower Pennsylvanian (Upper Carboniferous); collected by F. B. Plummer, at the cattle tank east of Jack Wood's house, Gibbons' ranch, San Saba County, Texas (loc. 205–T–71).

Material studied.—Five representatives of this species are available for study and all have been sectioned.

Type.—The University of Texas, Bureau of Economic Geology, specimen no. P–11799a.

HAPSIPHYLLUM RETUSUM, n.sp.

Text figs. 97, 102–106

Corallites belonging to this species have a very broad conical form that is nearly symmetrical except for curvature of the apical region. The diameter of the calyx is approximately equal to the length of the coral, these measurements of the type specimen being respectively 25 mm. and 27 mm. Other individuals in the collection are closely similar in shape and size to the type. The calyx is very shallow. Its central part is marked by a small smooth-floored pit that is confluent with a cardinal fossula located on the concave side of the corallite. The theca, which is of moderate thickness, is marked externally by numerous fine septal grooves and by rather strongly defined transverse wrinkles and growth lines; the longitudinal grooves are clearly visible but not deep.

The major septa are long. In immature parts of the corallite they meet in the axial region but in the middle and upper parts they do not reach beyond an inner wall that is formed by stereoplasm connecting their axial extremities; this wall surrounds a central open area that is joined to the cardinal fossula.

Figs. 104–111. Sections of Marble Falls and Smithwick hapsiphyllid corals, x3. Transverse sections are oriented with the cardinal septum at bottom; protosepta indicated by small arrows. Longitudinal sections are mostly at right angles to the plane of the cardinal and counter septa; positions of the transverse sections shown by small italic figures. (104) *Hapsiphyllum retusum,* n.sp., no. USGS647a, from the Smithwick shale on Honey Creek, 10 miles southeast of Llano, Texas; (105) specimen no. USGS647f, from the same locality as fig. 104; (106) type specimen, no. USGS647b, from the same locality as fig. 104. (107) *Zaphrentoides excentricus,* n.sp., specimen no. P11364c, from the Smithwick shale in Ellis pasture, 10½ miles west of San Saba, Texas; (108) specimen no. P11365b, from the same locality as fig. 107; (109) type specimen, no. P11365a, from the same locality as fig. 107; (110) specimen no. P12124, from the Smithwick shale on the Leonard ranch, 4.6 miles southeast of Richland Springs, Texas (loc. 205–T–79). (111) *Barytichisma crassum,* n.gen., n.sp., type specimen, no. P11908b, from the base of the Marble Falls limestone on Wallace Creek, 10 miles southwest of San Saba, Texas (loc. 205–T–43).


104a
104b
105
108a
104c
107
108d
104b
108c
108b
d
108c
111a
108b
a
108e
106a
111c
109a
109b
111b
109b
109c
109a
111c
110c
106b
110a
110b
111d
111b

The cardinal septum is somewhat elongate at early growth stages but becomes much shortened in the upper part of the corallite. The counter septum is recognizable by reference to the cardinal and alars. Alar pseudofossulae are inconspicuous or absent. The septal arrangement shows a strong acceleration of the counter quadrants. The formula for the type specimen is K 8 A 3 C 3 A 8 K, and that of other specimens is similar. Minor septa are rudimentary.

Tabulae are fairly numerous and regular. They rise at a moderate angle from the periphery to the border of the inner wall and bend downward in crossing the central cavity, their surface being concave upward in this region. There are no dissepiments.

Discussion.—This species is distinguished from *Hapsiphyllum tumidum*, n.sp., by its much more rapidly expanded form and greater width at the calyx. The septal grooves on the exterior of *H. tumidum* are noticeably more prominent than those of the species here described. Minor septa are not observed in *H. tumidum*, but are clearly marked in examples of *H. retusum*. Finally, the apical region of *H. retusum* seems characteristically to be more dense.

Occurrence.—The specimens on which this description is based were collected by Dr. C. D. Walcott in 1884 from the "Texas Carboniferous, Honey Creek section, Llano quadrangle," Slaughter ranch, 10 miles southeast of Llano, Llano County, Texas (loc. US95–647). Associated with *Hapsiphyllum retusum* are very numerous specimens of the characteristic Smithwick coral, *Cumminsia aplata* (Cummins). Accordingly, it seems safe to record the horizon of *H. retusum* as Smithwick.

Material studied.—Six specimens, all of which were sectioned, were available for study.

Type.—U. S. Geological Survey, specimen no. 647b.

HAPSIPHYLLUM CRASSISEPTATUM, n.sp.

Text figs. 101a-d

The form of the corallite belonging to this species is nearly straight and steeply conical. The calyx is shallow and near its center is a narrow, deep pit that joins the depression of the cardinal fossula, located on the concave side of the corallite. The theca is moderately thin. Its exterior is marked by strongly defined, closely spaced septal grooves and by faint transverse lines. The length of the type specimen is 17 mm. and the diameter of the calyx is 11 mm.

Throughout the interior of the corallite, long major septa that are characterized by evenness and moderate thickness extend inward to the axis or to the very narrowly curved inner wall at the border of the central pit. The cardinal septum is very short throughout growth, tending to disappear entirely near the floor of the calyx. Alar septa are readily distinguished and the counter septum is identified by its position opposite the cardinal fossula. Alar pseudofossulae are distinct but not prominent in some growth stages. The arrangement of septa is shown by the formula K 7 A 6 C 5 A 7 K, which indicates slight acceleration of the counter quadrants. No minor septa are observed.

Tabulae are present but seemingly not abundant; they slope upward from the theca to the axial region but are not observed to cross the central open space nor are intercepts of them shown in transverse sections of the cardinal fossula. The apical region is almost solid, owing to the thickness of the septa.

Discussion.—This species corresponds to *Hapsiphyllum tumidum* in the shape of the corallite, but it is smaller and has different internal characters. The septa of *H. tumidum* indicate stronger acceleration of the counter quadrants than in *H. crassiseptatum* and the central pit is relatively larger; the species here described is distinguished also by the pronounced shortening of the cardinal septum and by the very small interseptal spaces except near the calyx. *H. crassiseptatum* is so unlike *H. retusum*, n.sp., that detailed comparison is needless.

Occurrence.—Hale formation, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore near Keough quarry, about 2½ miles north of Fort Gibson, Oklahoma (Univ. Kansas loc. 7744).

Material studied.—Only a single very well-preserved specimen representing this species has been found in the many small horn corals from this locality and region that have been sectioned.

Type.—University of Kansas, specimen no. 7744–21b.

Genus ZAPHRENTOIDES Stuckenberg, 1895

Solitary conical corallites, commonly more or less curved longitudinally, are included in *Zaphrentoides.* The theca is moderately thick and is marked externally by septal grooves, transverse wrinkles, and fine growth lines. The calyx varies in depth; it lacks a protuberance in the axial region and is mainly characterized by the depression of the cardinal fossula. Major septa are grouped in quadrants that are marked by the clearly defined cardinal fossula and alar pseudofossulae, and by the less readily identified counter septum. The alar pseudofossulae vary considerably in prominence, both in different stages of growth and in different species. Minor septa are mostly quite short. None of the septa are carinate. Arched tabulae extend from wall to wall beneath the floor of the calyx but they are not thickly crowded or anastomosing. Dissepiments are lacking.

Genotype.—*Zaphrentis griffithi* Edwards and Haime (1852, p. 169), Lower Carboniferous, England. Genotype designated by Schindewolf (1938, p. 449).

Discussion.—Classification of the zaphrenthid corals has engaged the attention of many workers. There has been wide variation in the interpretation of genera and all taxonomic problems, some of which are highly involved, are not yet laid to rest. We undertake here to review briefly only items of observation that are pertinent to classification of the early Pennsylvanian species that are to be described as representatives of *Zaphrentoides, Hapsiphyllum,* and the new genera *Barytichisma* and *Stereocorypha.* This requires reference to *Zaphrenthis* and a few other genera, however.

Zaphrenthis[2] Rafinesque and Clifford (1820, p. 234), to which many corals that now are differently classified were once assigned, is interpreted properly to include only forms having toothed, carinate septa, and dissepiments as in the genotype species, *Z. phrygia* Rafinesque and Clifford. *Caninia* Michelin (1840) and *Siphonophyllia* Scouler (1844) were assigned to *Zaphrenthis* by Edwards and Haime (1850) and other authors, but they are distinguished by a number of characters. In 1875 Billings proposed the genus *Heterophrentis,* with *H. prolifica* as the type, for corals like *Zaphrenthis* but lacking carinae and having very few tabulae. According to Schindewolf (1938, p. 450), *Heterophrentis* is much more closely related to *Streptelasma* than to *Zaphrenthis,* and seemingly late Paleozoic noncarinate zaphrenthids are not referable to Billings' genus. For such forms Grove (1935, p. 358) introduced *Neozaphrentis,* with *Zaphrentis tenella* S. A. Miller as type. This genus resembles *Zaphrenthis* in general structure, but lacks carinae and dissepiments.

In 1900, Simpson described three new zaphrenthid genera under the names *Hapsiphyllum* (p. 203), *Triplophyllum* (p. 209), and *Homalophyllum* (p. 221). The first of these, with *Zaphrentis calcariformis* Hall as genotype, is mainly characterized by development of a horseshoe-shaped inner wall by union of the septal edges, opening toward the cardinal fossula. *Triplophyllum* was based on *Z. terebrata* (Hall), for which no sections showing internal structure have ever been published. According to the diagnosis, this genus is distinguished mainly by the prominence of alar pseudofossulae. *Homalophyllum,* with *Z. ungula* (Rominger) as type, is specialized in having a flattened side along the greatest curvature of the corallite.

Zaphrentoides[2] Stuckenberg (1895) essentially equals *Hapsiphyllum* and *Triplophyllum* except that the horseshoe-like inner wall is less distinct than in *Hapsiphyllum* and there is variation in the strength of the alar pseudofossulae.

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[2]The original, and therefore correct, spelling of this generic name is *Zaphrenthis;* most references to the genus improperly appear as *Zaphrentis.* Genera such as *Neozaphrentis* and *Zaphrentoides,* having been so spelled in original descriptions, are not to be emended to *Neozaphrenthis* and *Zaphrenthoides.*

Schindewolf (1938) considers *Triplophyllum* to be a junior synonym of *Zaphrentoides*, and *Hapsiphyllum* to be classifiable as a subgenus of *Zaphrentoides*. In *Hapsiphyllum* the cardinal fossula lies on the concave side of the corallite, whereas in *Zaphrentoides* it is on the convex side, according to Schindewolf. This distinction seems to us of rather dubious value, and certainly it is not readily applied to corallites that lack distinct curvature. More useful, seemingly, is the definite inner wall as a distinguishing character of *Hapsiphyllum;* such a wall is not an evident feature of *Zaphrentoides*. *Neozaphrentis,* if recognizable at all as a generic entity, differs from *Zaphrentoides* and *Hapsiphyllum* in entire lack of an inner wall, the edges of the septa being unfused.[3]

Three other genera that remain to be mentioned are *Stereolasma* Simpson (1900, p. 205), which is characterized by by a dense axial area formed by fusion of the inner edges of the septa; *Allotropiophyllum* Grabau (1928, p. 130), which has an inner wall somewhat like that of *Hapsiphyllum;* and *Euryphyllum* Hill (1936, p. 28), which has a long closed cardinal fossula, long cardinal septum, and stereoplasmic thickening in the peripheral and axial region. *Zaphrentoides* differs from these both by absence of the characteristic features of each, as just mentioned, and by the presence of other structures that are lacking or weakly developed in these three genera.

[3]Recently, two students of Lower Carboniferous corals have also considered the taxonomic status of the Carboniferous zaphrenthid corals commonly called *Zaphrentis*. Hudson (Proc. Yorkshire Geol. Soc., vol. 24, p. 290, 1941) proposed the genus *Zaphrentites* with *Zaphrentis parallela* Carruthers as the genotype for corals like the well-known Lower Carboniferous species *Zaphrenthis delanouei*. Subsequently, Easton (Illinois Geol. Survey, Rept. Investigations, No. 97, p. 35, 1944) concluded that the characters of the genotype of *Zaphrentoides* were incompletely known, and he proposed the genus *Triplophyllites* with *T. palmatus* Easton, n.sp., as genotype to include the American Carboniferous corals heretofore thought typical of *Triplophyllum*. His genus is described as having sparsely distributed dissepiments that are confined largely to the lower portions of the corallite. This feature is not well shown either in illustrations of the genotype or in other species referred to *Triplophyllites*, but if existent, would serve to distinguish *Triplophyllites* from corals here assigned to *Zaphrentoides*, *Hapsiphyllum*, and *Stereocorypha*. This species referred to *Zaphrentoides* in this paper probably is related to species assigned by Hudson to *Zaphrentites*.

Barytichisma and *Stereocorypha* are discussed under descriptions of those genera.

Occurrence.—Lower and Upper Carboniferous; Europe, North America.

ZAPHRENTOIDES EXCENTRICUS, n.sp.

Text figs. 93, 107-110

This species comprises small curved conical corals that are concave on the cardinal side. The moderately thick theca has deep septal grooves and alternating narrow ridges crossed by occasional fine or coarse growth lines. The deep calyx has a depressed axial pit. The type specimen is 16.2 mm. in length and 9.5 mm. in diameter at the calyx.

Thick major septa extend to the axis where they unite about the cardinal fossula, except at the calyx where the septa become shortened. The thin cardinal septum reaches the axis in early parts of the corallite but is markedly short in the breviseptal stage. Other major septa bend away from the alar and cardinal pseudofossulae and are joined together. The septa of the counter quadrants are shorter than those of the cardinal. The septal arrangement of the type specimen, showing the strong counter acceleration, is shown by the formula K 7 A 5 C 5 A 6 K. Minor septa are lacking.

Thin regularly spaced tabulae rise toward the axis. In transverse section they are seen as curved bars between the septa. There are no dissepiments. The large closed cardinal fossula is divided by the long thin cardinal septum, and enclosed by a wall formed by the joined axial edges of the septa. Alar pseudofossulae are well developed in the corallites below the breviseptal stage.

Discussion. — Transverse sections of *Zaphrentoides excentricus* strikingly resemble those of *Z. delanoui* (Edwards and Haime), from the Lower Carboniferous rocks of western Europe, but the Texas species has more numerous tabulae. *Z. excentricus* is smaller than *Barytichisma repletum*, has a thinner theca, fewer septa, and less dense interior than in that species.

Occurrence.—Smithwick shale, Bendian, Lower Pennsylvanian (Upper Carboniferous); collected by F. B. Plummer, west of big tank in Ellis pasture (loc. 205–T–50) and on the Leonard ranch (loc. 205–T–79), San Saba County, Texas.

Material studied.—Three well-preserved corallites from the former locality and one from the latter were available for sectioning.

Type.—The University of Texas, Bureau of Economic Geology, specimen no. P-11365a, from Ellis pasture.

Genus BARYTICHISMA, n.gen.

Medium to large solitary corallites of cylindrical form, nearly straight in the mature region, gently curved and conical in the immature region, are assigned to this genus. The theca is very thick, and this in itself seems to be an important distinguishing feature. The exterior of the theca bears prominent transverse wrinkles and fine growth lines; it is also marked by distinct septal grooves and low interseptal ridges, but these markings are not prominent. The calyx is deep, its broad floor being about two-thirds of the diameter measurement below the rim. The major septa are fairly numerous, long, and evenly disposed, but a cardinal fossula and alar pseudofossulae are readily distinguished in most sections. At various levels below the floor of the calyx, the major septa, generally excepting the short cardinal septum, meet in the axial region and they are joined together by deposits of stereoplasm. Such junctions are located on the upper surface of a tabula. Longitudinal sections show that the septa do not extend far upward in the axial region, and transverse sections located just below a tabula typically show a broad open space in the axial region. The cardinal fossula is not located constantly with respect to the curvature of the corallite. Acceleration of the counter quadrants is observed. The tabulae are mostly subhorizontal or they sag slightly in the axial region, but peripherally they bend rather steeply downward. Dissepiments are absent.

Genotype.—*Barytichisma crassum*, n. sp., Marble Falls limestone, Morrowan, Lower Pennsylvanian (Upper Carboniferous), southwest of San Saba, Texas.

Discussion.—Absence of an axial column, the attitude of the tabulae, and the unusually thick theca serve to distinguish *Barytichisma* from *Stereocorypha*. From *Zaphrentoides* Stuckenberg (1895, p. 191) this new genus is distinguished mainly by the excessive thickness of the theca, the more marked acceleration of septa of the counter quadrants, more numerous tabulae, and especially the very different appearance of successive transverse sections; the form of the corallite in *Barytichisma* also may be distinguished more or less definitely, inasmuch as *Zaphrentoides* typically is elongate conical and lacks strong transverse wrinkles. *Euryphyllum* Hill (1936, p. 50) differs from *Barytichisma* in the thickness of its septa, form of the corallite, and other features; the thick peripheral stereozone of *Euryphyllum* seems to be penetrated by the outer parts of the septa, whereas the very thick theca of *Barytichisma* is entirely outside of the septa.

Occurrence. — Lower Pennsylvanian (Morrowan); Texas and Arkansas.

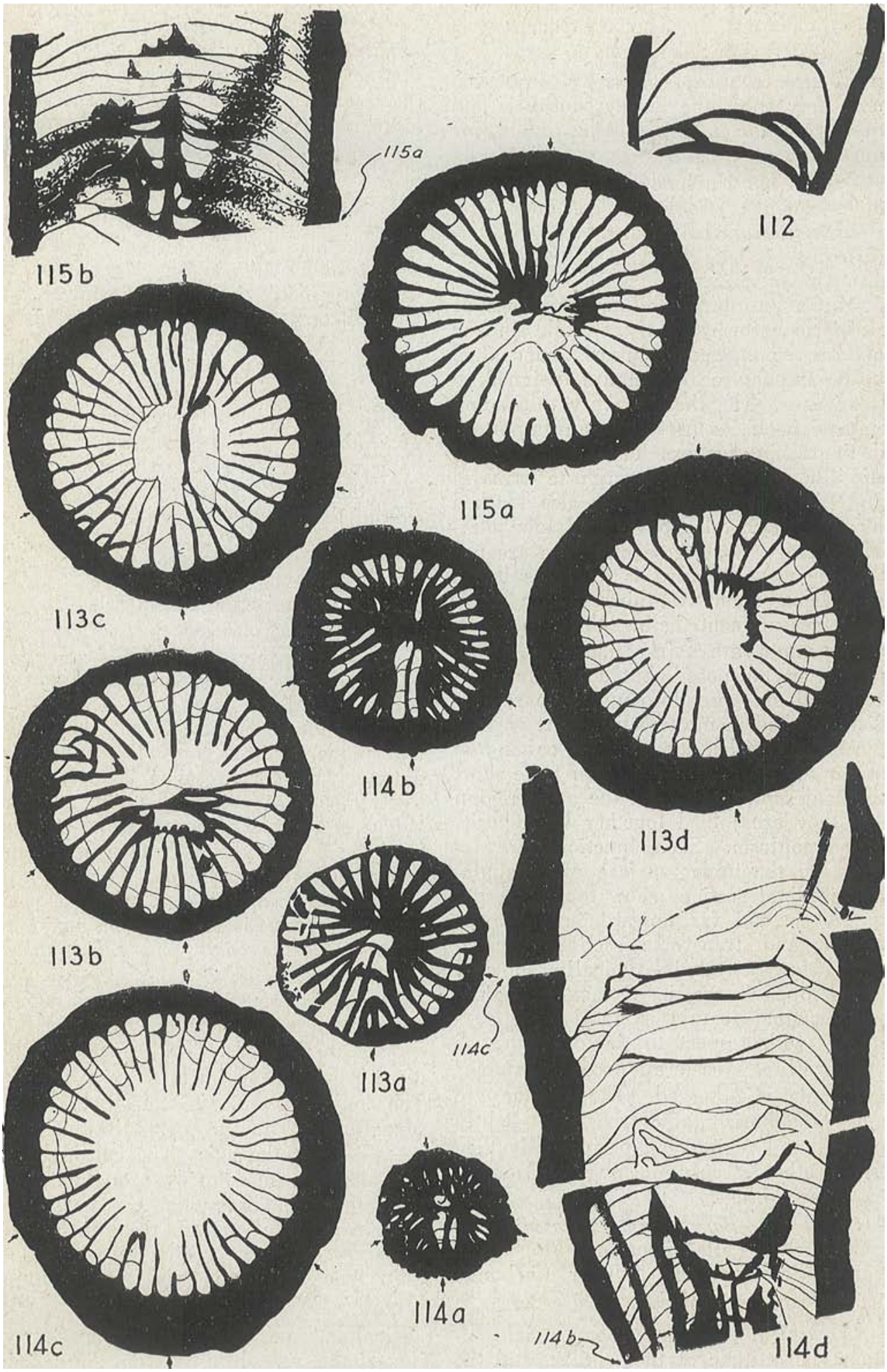
BARYTICHISMA CRASSUM, n.sp.

Text figs. 111–113, 123

Moderately large conical cylindrical curved corallites are included in this species. The curvature is mainly in the alar plane, but the cardinal septum may approach the concave side. The relatively thick theca is marked by low rounded ridges and septal grooves, which are intersected by very fine growth lines and low but definite wrinkles. The calyx is deep and has a broad, nearly flat base. The type species is 15.9 mm. in maximum diameter at the calyx and 40.3 mm. in length.

The major septa are long and numerous in the upper portions, but are not joined at the axis. The shortened cardinal septum lies in a large open fossula. The counter septum is elongated. In the immature part of the corals the thickened septa join at the axis. The cardinal fossula is well developed throughout, but the alar pseudofossulae are noticeable only in youthful periods of growth. The septal arrangement in the lower part of the type specimen is as follows: K 9 A 5 C 5 A 9 K.

Complete or only slightly anastomosing tabulae rise abruptly from the periph-


115a
112
115b
115a
113c
114b
113d
113b
114c
113a
114a
114c
114b
114d

ery and flatten out over the wide central area. They are closely spaced and somewhat thickened in their horizontal portions. In transverse section the tabulae are seen as a few curved bars between the septa. Dissepiments are lacking. The lower portions of these corals are thickened by the addition of stereoplasm and thickening of the septa.

Discussion.—This species, like *Barytichisma repletum*, n.sp., and *B. callosum*, n.sp., has a thick theca, a much-thickened immature portion, and septa reaching closer to the axis just above a tabula. *B. crassum* is distinct from *B. repletum* in the lack of the well-developed pseudofossulae in the fused axial region of immature stages. It differs from *B. callosum* in the smaller size, relatively fewer septa, and less crowded nature of the tabulae. The apical part of the corallite is less solidly filled with stereoplasm also. Transverse sections of *B. crassum* that happen to intersect a thickened junction of septa just above a tabula seem almost identical to transverse sections of *Stereocorypha annectans;* in both, long septa join at the axis. In *Barytichisma crassum* the entire mature part of the corallite, however, is characterized by lack of a continuous axial column, so that many transverse sections show a large axial open space.

Occurrence.—Lower Marble Falls limestone, Morrowan, Lower Pennsylvanian (Upper Carboniferous); San Saba County, Texas; collected by F. B. Plummer and R. C. Moore, 10 miles southwest of San Saba on the Wallace Creek road (loc. 205–T–43 or Univ. Kansas loc. 7171), and 4 miles south of San Saba along the Llano road (loc. 205–T–4 or Univ. Kansas loc. 7132).

Type.—The University of Texas, Bureau of Economic Geology, specimen no. P–11908b, from 10 miles southwest of San Saba, Texas (loc. 205–T–43). In addition to the type, two other well-preserved specimens belonging to this species were sectioned for study.

BARYTICHISMA REPLETUM, n.sp.

Text figs. 114, 124

This species is characterized by a moderately large conical cylindrical curved corallite that has the cardinal septum on the convex side. The deep calyx has steep sides and a broad nearly flat base. The theca is very thick and is marked only by low irregular wrinkles. The type specimen is 19.7 mm. in diameter at the base of the calyx, and 44.1 mm. in length.

Close to the calyx there are 39 thin major septa reaching half the distance to the axis. The cardinal septum is short. In the immature portions of the corallite the major septa are strongly fused at the axis. The cardinal septum is slightly thinner than other septa, but it reaches the center. The weak development of the septa that were inserted last and their tendency to bend away from the adjacent protoseptum produce large closed pseudofossulae on both sides of the cardinal septum and on the counter side of the alar septa. The septal arrangement, showing the strong counter acceleration, is indicated by the formula K 11 A 5 C 6 A 11 K. Minor septa are represented only by one short septum on each side of the counter septum in the section taken at the base of the calyx.

Tabulae are arched and anastomosing close to the periphery, but flatten or sag slightly as they cross the axial portion at regular intervals. Dissepiments are

Figs. 112–115. Sections of Marble Falls hapsiphyllid carols, x3, belonging to the genus Barytichisma, n.gen. Transverse sections are oriented with the cardinal septum at bottom; protosepta indicated by small arrows. Longitudinal sections are mostly at right angles to the plane of the cardinal and counter septa; positions of transverse sections shown by small italic figures. (112) *Barytichisma crassum*, n.sp., specimen no. KU7171–21e, from the base of the Marble Falls limestone on Wallace Creek, 10 miles southwest of San Saba, Texas (loc. 205–T–43); (113) specimen no. KU7132a, from the Marble Falls limestone on Llano road 3.7 miles south of San Saba, Texas. (114) *Barytichisma repletum*, n.sp., type specimen, no. P10126a, from the Marble Falls limestone on the Llano road, 5.2 miles south of San Saba, Texas (loc. 205–T–40). (115) *Barytichisma callosum*, n.sp., specimen no. USGS2619a, from the middle Marble Falls limestone on Rough Creek, 8 miles east and 5 miles south of San Saba, Texas.

lacking and no true axial column is present.

The lower part of the longitudinal section (fig. 114d) is somewhat off center and shows clearly that the septa are longest on the upper surface of the tabulae, and gradually shorten upward to the next tabula. Septa illustrating this feature are found in many of the Rugosa, and have been called amplexoid septa by Carruthers (1910, p. 525).

Discussion.—The thick theca, well-developed pseudofossulae, and fused axial part of the youthful stage serve to characterize this species. *Barytichisma callosum* and *B. crassum* also have a very thick theca and numerous septa, but lack well-developed pseudofossulae in the immature portions. *B. repletum* approaches *Stereocorypha spissata*, n.sp., in size and number of septa, but can be separated readily by the distinctive appearance of the longitudinal sections. The Lower Carboniferous coral called *Triplophyllum dalii* (Edwards and Haime) (?) by Grove (1935, p. 342) resembles this Marble Falls coral in immature portions of the corallite. The apical part of *Barytichisma repletum*, however, is more strongly fused in the center and the pseudofossulae are more prominent. The septa are shorter in the mature parts of the corallite also.

Occurrence.—Lower Marble Falls limestone, Morrowan, Lower Pennyslvanian (Upper Carboniferous); collected by F. B. Plummer along the Llano road, 5.2 miles south of San Saba courthouse, San Saba County, Texas (loc. 205–T–40).

Type.—The University of Texas, Bureau of Economic Geology, specimen no. P–10126a. This single well-preserved corallite was available for study of this species.

BARYTICHISMA CALLOSUM, n.sp.

Text figs. 115, 116, 120–122

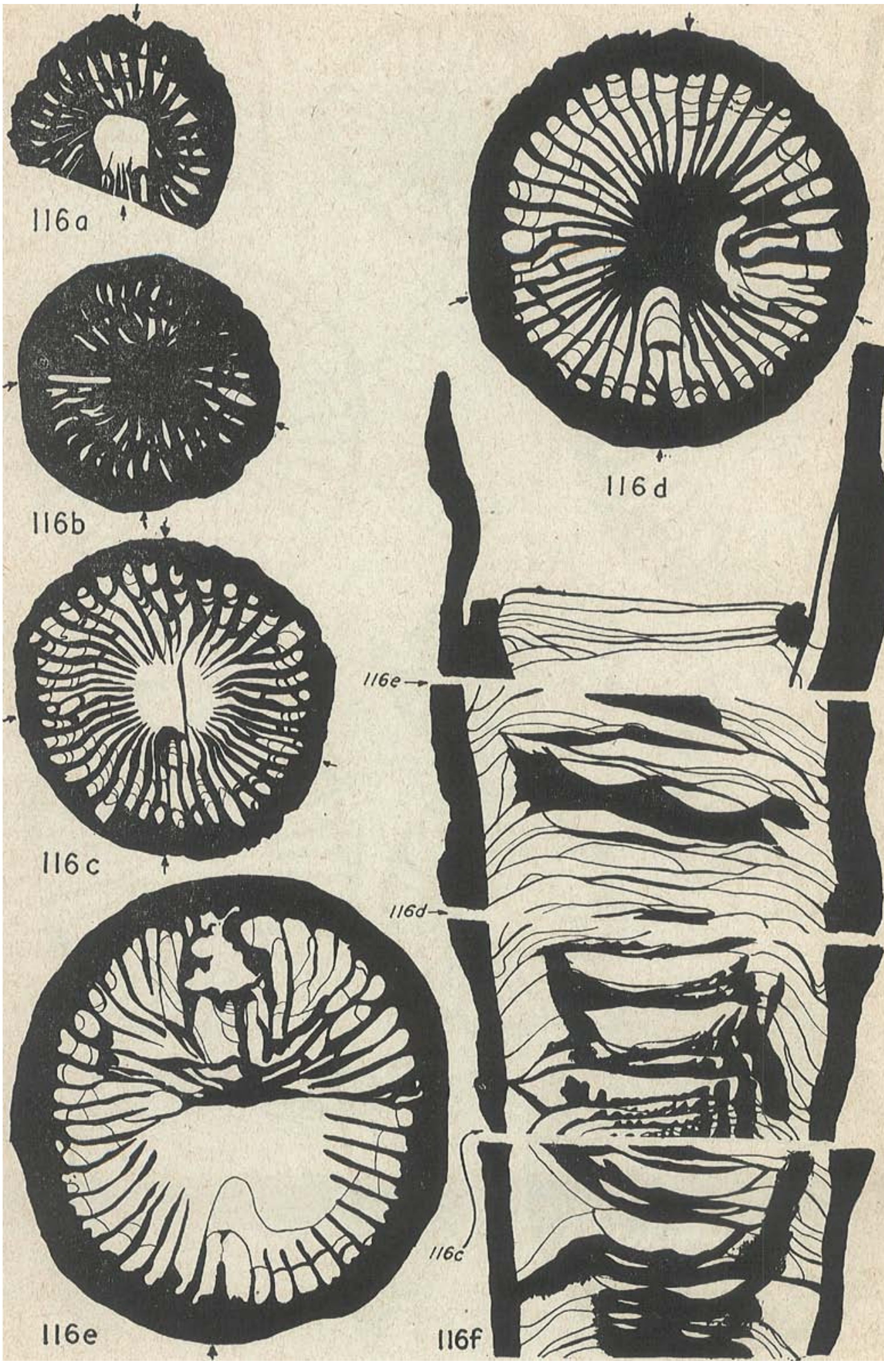
Corals included in this species are large cylindrical forms that are curved near the apex so that the cardinal septum is on the concave side. The deep calyx is bounded by the vertical theca and horizontal tabulae of the base. The thick theca bears low rounded interseptal ridges and narrow septal grooves intersected by transverse wrinkles. The type specimen is 25.0 mm. in maximum diameter at the calyx, and 56.3 mm. in length.

The major septa are long throughout all but the uppermost part of the corallite. In some transverse sections, but not in others, they reach the axis and are solidly joined together by stereoplasm. A longitudinal section shows that junctions of the septa occur only on the upper surface of tabulae. For a short distance just below a tabula the septa do not reach the axis. Thus, transverse sections taken just above a tabula show a thickened axial portion and long septa. A section taken just below a tabula shows an open axial portion and shortened septa. The septa are numerous, closely crowded and distinctly separated except at the apex. They withdraw entirely from the axis near the calyx. The short cardinal septum lies in a large fossula. The septal arrangement of the type specimen is determined to be K 12 A 7 C 8 A 12 K. Minor septa are indicated merely by short ridges between the major septa in the uppermost parts of the coral.

The slightly anastomosing tabulae rise gently from the periphery and then sag slightly in crossing the broad axial area. The extended septa and deposits of stereoplasm on the upper surface of each tabula have made the horizontal axial third of most of the tabulae very thick. Dissepiments are lacking.

Discussion. — This species resembles *Barytichisma crassum* in the thick theca, thick deposit of stereoplasm, and long septa. It is a larger form that has relatively greater number of septa, however, and its tabulae are more crowded and

Fig. 116. Sections of the type specimen of *Barytichisma callosum*, n.gen., n.sp., x3, specimen no. P11916a, from the base of the Marble Falls limestone on Wallace Creek, 10 miles southwest of San Saba, Texas (loc. 205–T–43). Transverse sections are oriented with the cardinal septum at bottom; protosepta indicated by small arrows. The longitudinal section is at right angles to the plane of the cardinal and counter septa; positions of the transverse sections shown by small italic figures.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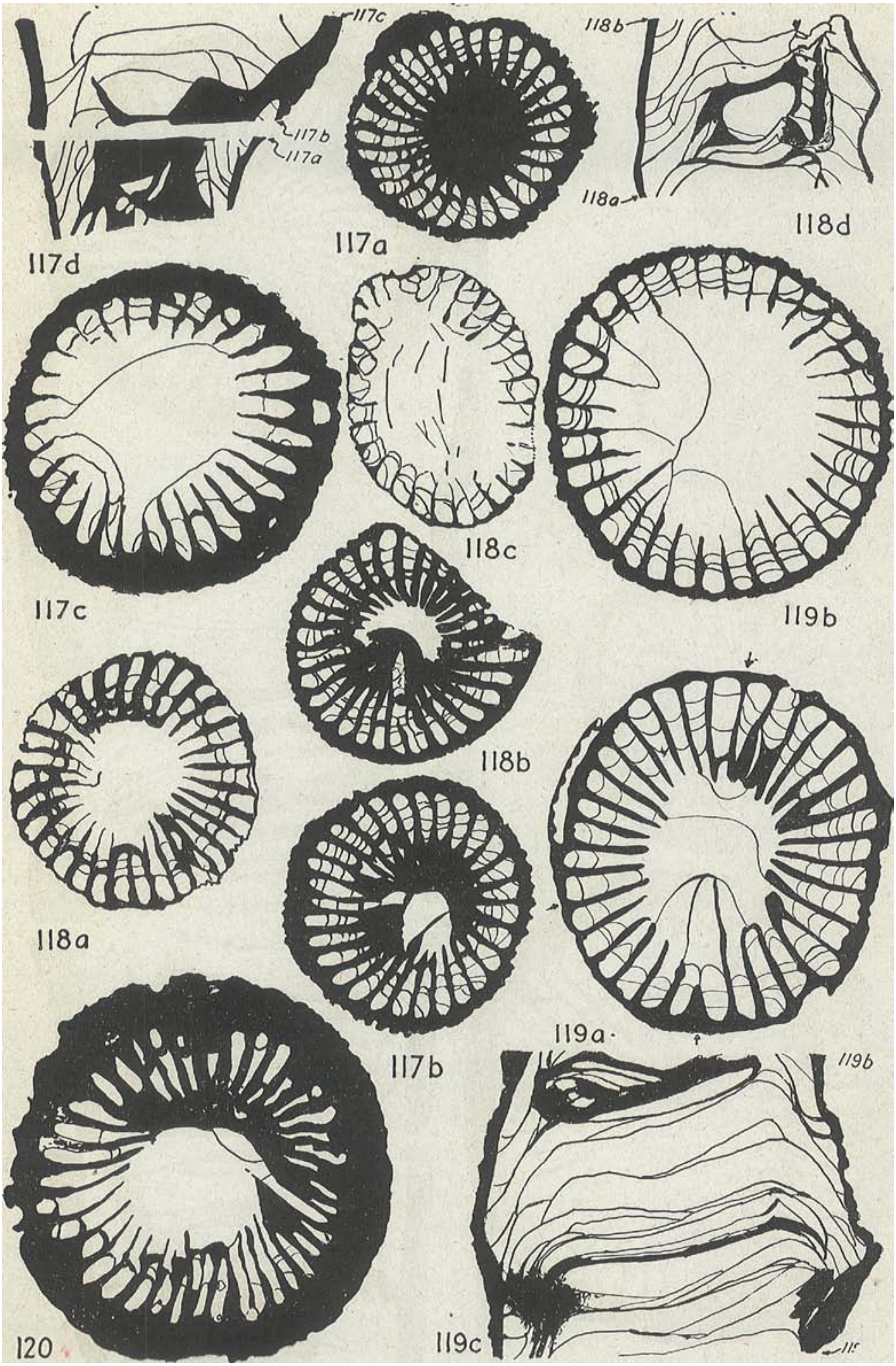
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anastomosing. The septa are more distinctly amplexoid (longer just above a tabula), and the tabulae are more strongly thickened by stereoplasm. *B. callosum* differs from *B. repletum* in the lack of large well-developed alar pseudofossulae and cardinal fossula in the thickened lower portions. It may be distinguished from *Stereocorypha* by structure of the axial region, its larger size and thick theca.

Occurrence.—Basal Marble Falls limestone, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by F. B. Plummer along Wallace Creek road, 10 miles southwest of San Saba, San Saba County, Texas (loc. 205–T–43). One specimen is from the middle Marble Falls limestone at U. S. Geological Survey locality 2619 (San Saba quadrangle, north bank of Rough Creek just east of San Saba-Bend road, 8 miles east and 5 miles south of San Saba courthouse, loc. 205–T–16, collected by P. V. Roundy, 1919). A single specimen from the Brentwood limestone, near Woolsey, Arkansas (Univ. Kansas, specimen no. 7206a) is referred to this species somewhat questionably; the transverse sections of the Brentwood coral show about the same number of septa and other features as the Texas examples of *Barytichisma callosum*, but the longitudinal section has less closely spaced tabulae and the structure of the axial region seems irregular.

Type.—The University of Texas, Bureau of Economic Geology, specimen no. P–11916a, from 10 miles southwest of San Saba, Texas.

Genus PARACANINIA Chi, 1937

Rugose corals having the general form and structural characters of *Caninia* Michelin (1840) except for a lack of dissepiments have been named *Paracaninia* by Chi (1937, p. 93) in a publication that we have been unable to consult, inasmuch as no copies of the paper are known to be in libraries of this country. The genus is cited by Hill (1940, p. 105) who notes that this coral "from the Permian of China closely resembles *Caninia cornucopiae* [genotype of *Caninia*], but never develops dissepiments." It is also cataloged by Lang, Smith, and Thomas (1940) in their index of Paleozoic corals. Huang (1932, pp. 34–39) has described and figured three species of Permian corals from southern China that are referred to *Caninia*, although with hesitation because of their lack of dissepiments. These seem to be assignable to *Paracaninia* and their characters are regarded by us as congeneric with a new species from the Marble Falls limestone of Texas, to be described.

Paracaninia comprises solitary rugose corals having a theca that is more or less plainly marked by septal grooves and by transverse wrinkles and growth lines. The immature part of the corallite has long major septa that reach to the axial region and commonly are joined together for some distance during growth upward, at least partially. A cardinal fossula is well defined and persists into the mature region; alar pseudofossulae are also present more or less distinctly. Major septa are shortened in the upper part of the corallite so that a comparatively broad central area is left open except for the presence of tabulae. Short minor septa may occur in the upper part of the corallite. The tabulae are fairly numerous, and complete or incomplete; their margins bend downward rather steeply but the greater part, occupying the central area of the corallite, is subhorizontal. Dissepiments are lacking.

This diagnosis is based on the statements, previously noted, as to the corre-

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Figs. 117–129. Sections of Smithwick and Brentwood hapsiphyllid corals. ×3. Transverse sections are oriented with the cardinal septum at bottom; protosepta indicated by small arrows. Longitudinal sections are mostly at right angles to the plane of the cardinal and counter septa; positions of the transverse sections shown by small italic figures. (117) *Paracaninia? sana*, n.sp., type specimen, no. USGS7015gd, from the top of the Marble Falls limestone near Bend, Texas; (118) specimen no. USGS7015ge, from the same locality as fig. 117; (119) specimen no. USGS7015ga, from the same locality as fig. 117. (120) *Barytichisma callosum?*, no. KU7206a, n.sp., from the Brentwood limestone, near Woolsey, Arkansas.

spondence of *Paracaninia* to most of the characters of *Caninia*, and it applies to structures observed in the Marble Falls species that is here designated as *Paracaninia? sana*, n.sp.

Genotype.—*Paracaninia sinensis* Chi, from the Wumaling series, Permian, Kiangsi, China.

Discussion.—The only genera, other than *Paracaninia*, that seem to call for consideration in study of these Marble Falls specimens are *Bradyphyllum* Grabau (1928, p. 35), from Middle Carboniferous rocks of China, and *Barytichisma*, n.gen. *Bradyphyllum* has most of the characters that have been described in the diagnosis of *Paracaninia*, including especially the long major septa that may meet at the center in the immature region of the corallite, shortened major septa in the upper part, presence of a cardinal fossula, occurrence of tabulae, and absence of dissepiments. *Bradyphyllum* seems to differ chiefly from *Paracanina* and from our Marble Falls corals in the inverted conical attitude of the tabulae, which are much fewer than in our specimens, and in the arrangement of the septa. *Barytichisma* is distinguished from *Paracaninia* and the Marble Falls corals that are here tentatively assigned to it by the greater thickness of the theca, inconspicuousness or absence of septal grooves on the exterior of the theca, the marked tendency toward elongation of the septa just above tabulae, and the somewhat greater strength of the cardinal fossula.

Occurrence.—?Lower Pennsylvanian of Texas; Permian of China.

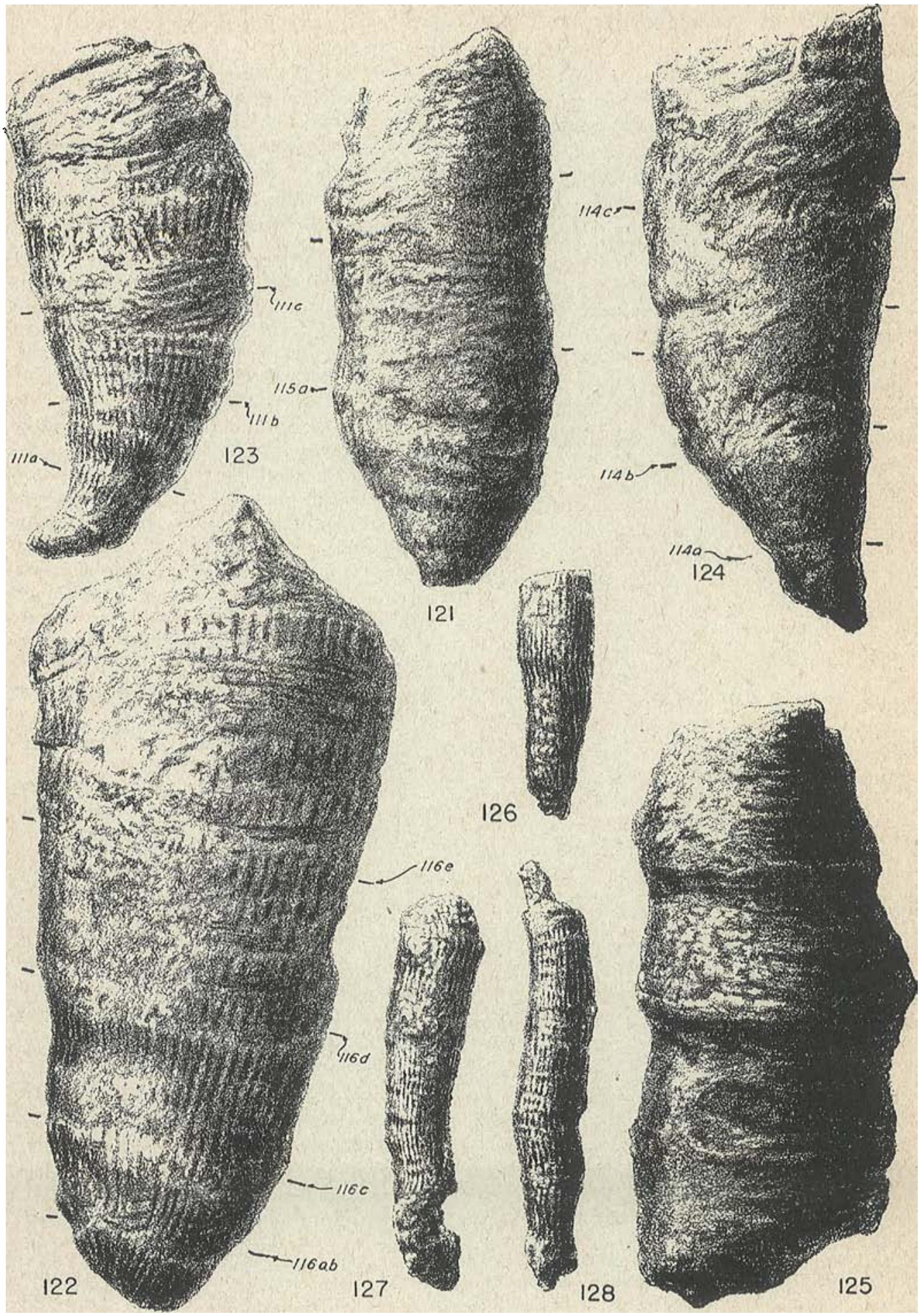
PARACANINIA? SANA, n.sp.

Text figs. 117–119, 125

This species comprises moderately large solitary conical to cylindrical corallites that have a well-developed theca bearing sharp interseptal ridges and broad rounded septal grooves that are crossed by growth lines and low wrinkles. The nature of the calyx is unknown. The type specimen is 21.2 mm. in length and 18.3 mm. in maximum diameter at the base of the calyx, and other specimens reach a maximum length of 53.6 mm. and a diameter of 21.4 mm.

Transverse sections of these corals made near the apex show numerous long major septa that are fused at the axis. In successively higher sections the thick septa shorten until they extend only one-third the distance to the axis. The cardinal septum is slightly shorter than other septa but other protosepta are not distinctive. There is no distinct cardinal fossula and alar pseudofossulae are lacking. About 32 major septa are counted in the mature region, but minor septa are absent. The septal formula is seemingly K 8 A 6 C 6 A 8 K. Longitudinal sections show the apical region to be somewhat complex, owing to the long septa. Higher in the corallites, however, the tabulae are closely packed and anastomosing. They rise from the theca and flatten out or sag slightly in the broad open axial area. Tabulae are seen in transverse sections as numerous curved bars between the septa, especially near the periphery. The appearance of the tabulae in these sections is much like that of dissepiments, but longitudinal sections indicate that dissepiments are lacking.

Figs. 121–128. Exterior views of Marble Falls and Hale hapsiphyllid corals, x2. Positions of transverse sections are indicated by small italic figures. (121) *Barytichisma callosum*, n.gen., n.sp., no. USCS2619a, from the Marble Falls limestone on Rough Creek, 8 miles east and 5 miles south of San Saba, Texas; (122) type specimen, no. P11916a, from the base of the Marble Falls limestone on Wallace Creek, 10 miles southwest of San Saba, Texas (loc. 205-T-43). (123) *Barytichisma crassum*, n.sp., type specimen, no. P11908b, from the Marble Falls limestone at same locality as fig. 122. (124) *Barytichisma repletum*, n.sp., type specimen, no. P10126a, from the Marble Falls limestone on the Llano road 5.2 miles south of San Saba, Texas (loc. 205-T-40). (125) *Paracaninia? sana*, n.sp., specimen no. USGS7015ga, from the top of the Marble Falls limestone near Bend, Texas. (126) *Amplexocarinia corrugata* (Mather), specimen no. KU7096-22j, from the Hale formation near Hulbert, Oklahoma; (127) specimen no. KU7096-22L, from the same locality as fig. 126; (128) specimen no. KU7096-22k, from the same locality as fig. 126.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The cardinal fossula is prominent throughout, and alar pseudofossulae are determinable in some sections. There is no columnar structure.

Discussion.—The closely packed amplexoid tabulae, lack of dissepiments and column, and strong septa readily separate this species from other described American Pennsylvanian corals. The lack of dissepiments and column distinguish *Paracaninia? sana* from the Lower Pennsylvanian corals here assigned to *Pseudozaphrentoides*, *Neokoninckophyllum*, and *Lophophyllidium*. The tabulae of *Paracaninia? sana* are more closely spaced than in *Amplexocarinia corrugata* (Mather); the corallites of *Paracaninia? sana* are much larger and they differ greatly from Mather's species in the nature of the septa. This species most closely resembles *Barytichisma crassum*, n.sp., and *B. callosum*, n.sp., which, like *Paracaninia? sana*, are corals of the Marble Falls limestone. The specimens described as *P.? sana* are all characterized by a theca that bears strongly marked septal grooves on the exterior and that has only a moderate thickness; whereas the species of *Barytichisma* are nearly smooth externally and have a notably thickened theca. The number and arrangement of the septa in *B. crassum* are nearly the same as in *Paracaninia? sana*, but the tabulae of the former species are much more even and widely spaced. *B. callosum* is less similar to *P.? sana*, differing in the number of septa and in its size.

Occurrence.—Top of Marble Falls limestone, Bendian, Lower Pennsylvanian; U. S. Geological Survey locality 7015 (San Saba quadrangle, about half a mile southwest of Bend, Texas, probably from base of lower limestone ledge below black shale), San Saba County, Texas.

Type.—U. S. Geological Survey, specimen no. 7015gd. This specimen and four others were sectioned for study.

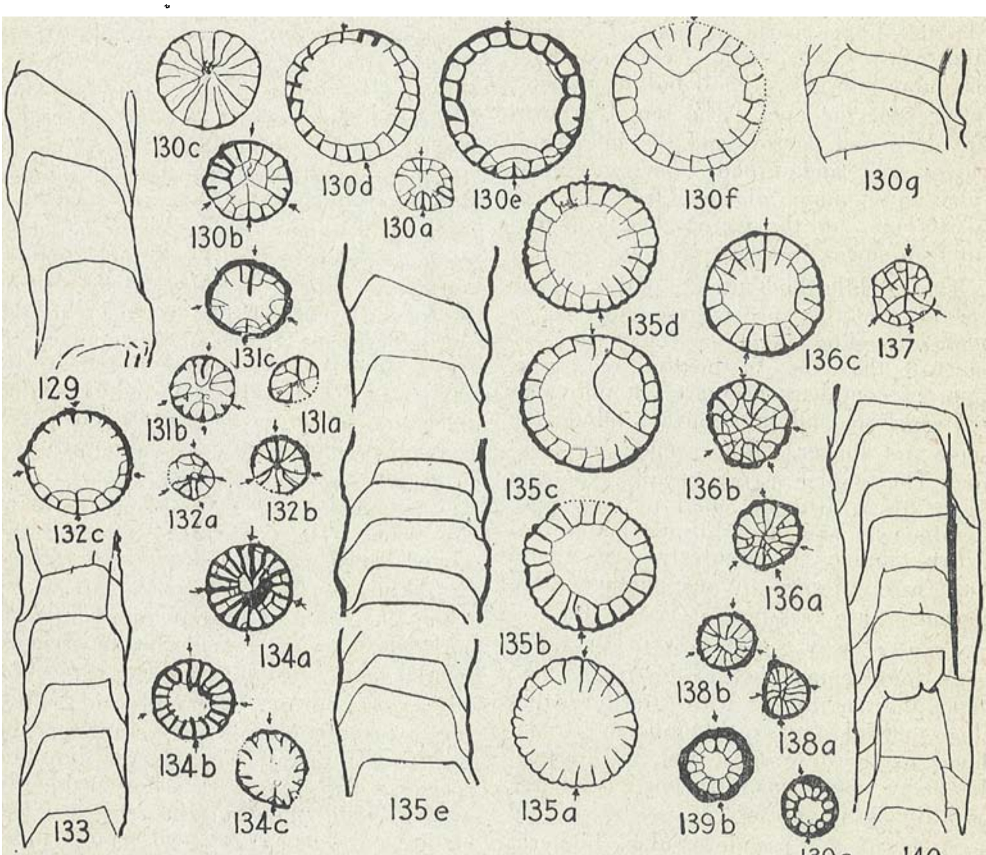
Genus AMPLEXOCARINIA Soschkina, 1928

Subcylindrical straight or gently curved solitary corallites characterized by very short septa throughout most of their length and the presence of a so-called inner wall formed by steeply down-bent peripheral parts of the tabulae are classed in the genus *Amplexocarinia.* The theca is moderately thin. It bears well-defined septal grooves, and there are uneven transverse wrinkles and growth lines. Within a few millimeters of the apex the septa are relatively long, reaching the axis and uniting, but higher in the corallite the septa are much shortened so as to leave a large central space that is occupied only by the more or less regularly spaced tabulae. The cardinal, counter, and alar septa are identifiable near the apex, all of them long. There are no fossulae. In mature parts of the corallite, characterized by the breviseptal structure, the counter septum may be slightly thicker and longer than other septa or it may not be distinguishable. The broad central part of each tabula is subhorizontal, but the peripheral parts bend abruptly and very steeply downward, joining the theca or a subjacent tabula. This structure of the tabulae gives rise to the seeming presence of an inner wall, as transverse sections of the corallite are examined, but this is not evident or it is indicated only intermittently in longitudinal sections. Dissepiments are lacking in this genus.

Genotype. — *Amplexocarinia muralis* Soschkina (1928, p. 379), Lower Permian, northern Ural Mountains, U. S. S. R. (by monotypy).

Discussion.—This genus most closely resembles *Amplexus* Sowerby (1812), described from Lower Carboniferous rocks from Ireland. Many corals from Lower and Upper Carboniferous rocks and from the Permian in various parts of the world have been assigned to *Amplexus*, most of them probably erroneously, inasmuch as it has been shown (Weissermel, 1897, p. 878; Schindewolf, 1940, pp. 401, 403; Moore and Jeffords, 1941, p. 90) that various unrelated coral stocks develop the structural characters of *Amplexus* as an advanced evolutionary trait. One must study the structure of the immature region of these corallites in order to learn the nature of ancestral forms from which a given "*Amplexus*" was developed. Such investigations of the genotype of *Amplexus*, which is *A. coralloides* Sowerby, seems yet to be reported, so that the true nature of this genus is in doubt. The mature parts of *Amplexus*, interpreted from illustrations of *A. coralloides*, are readily distinguished from those of *Amplexocarinia*, however, by the absence of down-bent margins of the tabulae in the former. *Amplexocarinia* is very unlike *Lophamplexus* in having the immature region restricted to an extremely small part of the corallite, in lacking an axial column, and in the different arrangement of the tabulae.

Occurrence.—This genus has been reported chiefly from Permian strata in various parts of the world. Felser (1937, p. 7) has described a species from Upper Carboniferous and Permian rocks of the Carnic Alps, and Heritsch (1939, p. 93) records a species from "Late Paleozoic" beds of Spitzbergen. The assignment of a Morrowan species to this genus seems to extend the known range of *Amplexocarinia* downward.



Figs. 129–140. Sections of Hale and Marble Falls hapsiphyllid corals, x3, belonging to the genus *Amplexocarinia* Soschkina. Transverse sections are oriented with the cardinal septum at bottom; protosepta indicated by small arrows. Longitudinal sections are mostly at right angles to the plane of the cardinal and counter septa. (129) *Amplexocarinia corrugata* (Mather), specimen no. KU7096–22m, from the Hale formation near Hulbert, Oklahoma; (130) specimen no. KU7079–21a, from the Marble Falls limestone, on the Sloan ranch near King Springs, 12.9 miles west-southwest of San Saba, Texas; (131) specimen no. KU7385&23k, from the Hale formation at Greenleaf Lake, southeast of Braggs, Oklahoma; (132) specimen no. KU7096–22i, from the same locality as fig. 129; (133) specimen no. KU7096–22n, from the same locality as fig. 129; (134) specimen no. KU7385–23i, from the same locality as fig. 131; (135) specimen no. KU7096–22a, from the same locality as fig. 129; (136) specimen no. KU7385–23d, from the same locality as fig. 131; (137) specimen no. KU7385–24f, from the same locality as fig. 131; (138) specimen no. KU7096–21g, from the same locality as fig. 129; (139) specimen no. KU7385–21q, from the same locality as fig. 131; (140) specimen no. KU7096–22e, from the same locality as fig. 129.

AMPLEXOCARINIA CORRUGATA (Mather)

Text figs. 126–140

Amplexus corrugatus MATHER, 1915, Denison Univ. Bull., Jour. Sci. Labs., vol. 18, p. 90, pl. 1, figs. 7–10. CRONEIS, 1930, Arkansas Geol. Survey, Bull. 3, p. 84, pl. 21, figs. 4, 5.

Small irregularly curved solitary corallites that are conical close to the apex but cylindrical throughout most of the length comprise this species. The deep calyx has steep sides and a flat base. The corals may be of uniform diameter in the middle and upper parts or marked by distinct constrictions due to rejuvenation at irregular intervals. Small hollow radicles occur near the apex. The septal grooves are deep and narrow and the interseptal ridges low and broad. The specimens range in maximum diameter from 3.4 mm. to 7.6 mm., and the average length of mature specimens is about 35 mm.

The middle and upper parts of the corallites of this species have short major septa extending about one-fourth the distance to the axis. In the lowermost portions of complete specimens, at points of rejuvenation, and just above a tabula the septa are longer. Minor septa are lacking. The tabulae ascend steeply from the theca for a distance equal to one-eighth the diameter and then abruptly flatten out. These tabulae are regularly spaced and only rarely joined to one another. Dissepiments are lacking.

Transverse sections close to the apex show long septa united at the axis. These septa shorten rapidly with growth so that this youthful stage in development is confined to the lowermost few millimeters. In many specimens this portion of the corallite is not preserved.

Study of the pseudofossulae, bilateral symmetry, and septal groove pattern permits positive determination of the protosepta in most cases. The counter septum is somewhat longer and thicker than other septa and may remain slightly longer in the typical upper amplexoid portions. The cardinal septum is prominent and not noticeably shortened. Alar septa extend to the axis. The counter quadrants are slightly accelerated. True fossulae seem lacking and pseudofossulae are but weakly developed.

Discussion.—These corals are in close accord with the original description of *Amplexus corrugatus.* Mather (1915, p. 90) states that the septa extend slightly more than one-half the distance to the axis in the mature region, but the single illustrated transverse section shows septa shorter than this. It is the counter septum, rather than the cardinal, that is distinguished by its longer length. Dissepiments, mentioned as rarely present near the periphery, seem to have been misidentified tabulae.

Amplexus zaphrentiformis White (1876, pp. 88, 107), a "Lower Aubrey" (?Pennsylvanian) species from Utah, was not illustrated nor were internal structures described. The Morrow species differs in the distinct cylindrical form and smaller size of the corallite and in the fewer number of septa. *Amplexocarinia corrugata* is distinguished from the Burlington coral called *Amplexus blairi* S. A. Miller by Keyes (1894, p. 108) in the sharp peripheral slope of its tabulae. *A. brevis* and *A. rugosus,* described by Weller (1909, p. 271) from the Fern Glen formation, differ in the more conical and coarsely wrinkled form of the corallite.

Amplexocarinia corrugata seems most similar to Permian species assigned to this genus. The transverse section of the Timor coral called *A. muralis irginae* Soschkina by Heritsch (1937, p. 6) is much like those of the Morrow coral. *A. corrugata,* however, seems to have more regular and constant tabulae.

Two well-preserved amplexoid corallites from the Marble Falls limestone of Texas are tentatively referred to this species. The septa are shortened only gradually in the youthful stages. The mature parts have shortened septa typical of "*Amplexus.*" Transverse sections lower down show long thin septa that reach the axis. The counter and cardinal septa are long, and other major septa are approximately equal in length. The septal arrangement in the immature stage is K 5 A 2 C 2 A 5 K. Minor septa are lacking. The Texas specimens differ from the typical Morrow examples of this species in the persistence of the long septa in the lower parts of the corallite. In average specimens the septa become greatly shortened within a very few millimeters from the apex. Longitudinal sections of these corals are similar.

Occurrence.—Hale formation, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore and University of Kansas students at Keough quarry, 2½ miles north of Fort Gibson, Oklahoma (Univ. Kansas loc. 4520), and at east end of the dam, Greenleaf Lake, cen. sec. 10, T. 13 N., R. 20 E., southeast of Braggs, Oklahoma (Univ. Kansas loc. 7385); also collected by R. C. Moore from Morrowan beds along north line sec. 22, T. 16 N., R. 20 E., south of Hulbert, Oklahoma. Lower Marble Falls limestone, Morrowan, Pennsylvanian (Upper Carboniferous); collected by F. B. Plummer and R. C. Moore at Sloan ranch, on King Creek, 1300 feet southwest of King Springs, 0.6 of a mile south of Maxwell Crossing on San Saba River and about 13 miles west-southwest of San Saba, Texas (Univ. Kansas loc. 7096); collected by F. B. Plummer from road bank 5.2 miles south of San Saba (loc. 205–T–40). Upper Marble Falls from banks of Colorado River at Marble Falls (27–T–10).

Material studied.—Numerous specimens of this species from the three Oklahoma localities were studied and 25 corallites were sectioned. Two sectioned corallites from the Marble Falls limestone are assigned to this species.

Family ZAPHRENTHIDAE, new name

Solitary conical to cylindrical corallites, straight, curved, or irregularly bent longitudinally, are included in this family. They vary greatly in size, some forms attaining a length of 60 cm. The calyx is moderately deep and commonly is marked by a prominent cardinal fossula; alar pseudofossulae may be well developed also. The theca is medium in thickness and its outer surface in most genera bears distinct septal grooves. Tetrameral pattern of the septa is clearly defined throughout growth of the corallite or obscured in mature stages. Major septa may meet axially but no axial column is formed; generally there is a centrally located open space that may or may not be confluent with the cardinal fossula. Tabulae are well developed and commonly they are complete. Dissepiments occur sparingly to abundantly. Range, Devonian to Permian.

Discussion. — Judgment of paleontologists as to selection of genera that should be associated with *Zaphrenthis* Rafinesque and Clifford, the family type, is far from uniform. An assemblage named from this genus was first proposed by Edwards and Haime (1850), who recognized a subfamily of the Cyathophyllidae which they named Zaphrentinae. Later, family rank was assigned to the group and under the designation Zaphrentidae it has been incorporated in most published classifications of Paleozoic corals. The family name is here emended to Zaphrenthidae, inasmuch as the correct spelling of the type genus is *Zaphrenthis*—not *Zaphrentis,* as given by Lang, Smith and Thomas (1940, p. 141), who call attention to the original spelling but, without any basis provided by the International Rules, reject it.

Zaphrenthis has a well-defined cardinal fossula and, at least in the immature part of the corallite, distinct alar pseudofossulae; there is no axial column. Schindewolf (1938) has shown that this genus is distinguished from *Zaphrenthis*-like genera, such as *Zaphrentoides* Stuckenberg and *Hapsiphyllum* Simpson, by the toothed, carinate nature of its septa and by the presence of dissepiments. Other genera that have been assigned family association with *Zaphrenthis,* such as *Caninia* Michelin, *Siphonophyllia* Scouler, and *Pseudozaphrentoides* Stuckenberg, differ from *Zaphrenthis* in characters of the septa but correspond with this genus in having dissepiments and in other significant features. We agree with Grabau (1928, p. 115) and Schindewolf (1938, p. 449) in removing from the Zaphrenthidae genera of zaphrenthid type that lack dissepiments and these are here classed under the name Hapsiphyllidae. *Zaphrenthis*-like genera that have dissepiments are assigned to the Zaphrenthidae.

Genus PSEUDOZAPHRENTOIDES Stuckenberg, 1904

Corals assigned to this genus are solitary individuals having a conical to cylindrical form, commonly more or less curved in the apical region. The theca is thin and marked externally by growth lines and wrinkles, but septal grooves are faint or lacking. The major septa are long throughout growth but reach the axis only in immature stages of the corallite. The cardinal septum typically is shorter than the other major septa and lies in an open fossula that may be accentuated by downbending of the tabulae; in advanced species the cardinal septum and fossula are commonly not differentiated clearly. The counter septum is not distinguished from other major septa, which have approximately equal length, except that it may be a little longer. Alar pseudofossulae are reported in the genotype species but they are weakly developed; they are not observed in species that are here referred to the genus. Minor septa are of various lengths in different species. The acceleration of the counter and cardinal quadrants seems to be about equal. A peripheral zone of dissepiments is very well developed. In this zone the septa are commonly thin but they are not interrupted as in lonsdaleoid dissepimental peripheral areas. The tabulae are closely spaced and very numerous; they are complete or slightly inosculating, the broad central region being subhorizontal or bowed upward very gently and the margins bent downward. There is no axial column.

Genotype.—*Pseudozaphrentoides jerofeewi* Stuckenberg, Lower Carboniferous, central U.S.S.R.

Discussion.—The generic classification of corals having the structural characters indicated in the description of *Pseudozaphrentoides* has long been confused and uncertain. This is due partly to a lack of precision in definition of the characters of different genera that have been proposed for Devonian, Carboniferous, and Permian corals that are characterized by absence of a column, shortening of the septa in the mature region, presence of numerous tabulae, and occurrence of dissepiments. Still more it is due to lack of knowledge of the actual phylogenetic relations of various intergrading types of these corals and inability to set up clearly defined distinctions between groups. European workers have classified the forms here discussed under the generic names *Cyathophyllum, Amplexus, Caninia, Campophyllum, Zaphrenthis, Siphonophyllia, Palaeosmilia, Cyathopsis, Pseudozaphrentoides, Caninophyllum,* and *Peetzia.* Some of these genera are synonymous, but the majority can be differentiated with sufficient definiteness to be recognized as valid. A tendency among modern specialists in the study of the late Paleozoic corals is to consider *Campophyllum, Siphonophyllia,* and *Cyathopsis* as junior synonyms of *Caninia,* and to treat *Cyathophyllum, Amplexus, Palaeosmilia,* and *Zaphrenthis* as genera having little or no close connection with *Caninia.* Only two or three species of corals have yet been assigned to *Pseudozaphrentoides* and *Peetzia* and less than a dozen species to *Caninophyllum.* In North America, additional genera that call for consideration are *Charactophyllum* and *Barbouria,* and from the Permian of China a new genus called *Paracaninia* has been described by Chi (1937, p. 93). Until recently, American corals having a well-developed dissepimental zone surrounding a tabulate area not traversed by septa have commonly been classed as belonging to *Campophyllum.* A well-known example is the Pennsylvanian coral *Campophyllum torquium* (Owen), which was originally referred to *Cyathophyllum.* Most paleontologists now accept the very broad definition of *Caninia* that is advocated by European students and designate this species as *Caninia torquia.* Unquestionably, the Morrowan corals that are here described as species of *Pseudozaphrentoides* are congeneric with the so-called *Caninia torquia,* as well as with the genotype of *Barbouria.* Considerations in support of our classification will be presented as concisely as possible.[4]

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[4]Easton (Jour. Paleon., vol. 18, pp. 119–132, pl. 22, text figs. 1–4, 1944) has reviewed the morphology and generic relationships of American corals commonly referred to *Campophyllum* and has given excellent illustrations of the internal structures of several species. Easton assigns the coral called *Campophyllum torquium* to *Caninia,* which he interprets very broadly. In our opinion, *Caninia* should be restricted to species having a few dissepiments only, and corals having a broad dissepimental zone like *Campophyllum torquium* belong rather to *Pseudozaphrentoides.*

Cyathophyllum Goldfuss, which is reported to range from Ordovician to Lower Carboniferous strata, is essentially a Devonian genus that is characterized by long septa reaching from periphery to axis throughout the corallite and by a well-developed dissepimental zone. The septa are evenly disposed and there are no distinct fossulae. The greater length of the septa throughout the corallite distinguishes *Cyathophyllum* from *Caninia*, *Amplexus*, and the corals considered here.

Amplexus Sowerby (1814, p. 165) resembles *Caninia*, *Pseudozaphrentoides*, and some others of the genera that have been mentioned in having prominent uparched tabulae and shortened septa, but it differs markedly in the entire absence of dissepiments, the wide spacing of the tabulae, and the very pronounced shortening of the septa.

The genus *Caninia* was introduced by Michelin in 1840, a new species called *C. cornucopiae* being designated as the genotype. This coral is a moderately small form having typically a diameter of about 15 mm. and attaining a length of 75 mm. or more. It is straight or subcylindrical, except for the curved apical portion. The immature stages of growth are characterized by long septa that meet one another or almost join at the center, but this is not true of the cardinal septum, which is short and lies in a conspicuous fossula; alar pseudofossulae are faint or lacking; up-arched tabulae are present but dissepiments are virtually or entirely absent. The mature stage is marked by shortening of the major septa to about one-half of the radius of the coral and by the appearance of extremely short secondary septa; the cardinal fossula persists but is inconspicuous; tabulae are numerous and a few dissepiments are developed locally in a very narrow peripheral zone. The most noteworthy features are the fairly broad central tabulate area, which lacks any suggestion of a column, the regularly disposed major septa of intermediate length, and the extremely small development of dissepiments (Carruthers, 1908, pl. 6, figs. 1–4). It happens that first description and illustration of *C. cornucopiae* was delayed until 1847 (Michelin, p. 256, pl. 59, fig. 5), and meanwhile that Michelin (1843, p. 81, pl. 16, fig. 1) published the characters of another coral, naming it *C. gigantea*. This species differs importantly from the genotype of *Caninia* in having very abundant dissepiments that form a wider peripheral zone, and according to observations of later workers, outer parts of the septa in the mature region may be interrupted by the dissepiments, failing to reach the periphery. *C. gigantea* was not only accepted as an authentic representative of *Caninia* but until studies by Carruthers (1908) was misidentified universally as the genotype species. If *Caninia* is defined to embrace *C. gigantea* along with *C. cornucopiae*, both of which occur in Tournaisian rocks of Belgium, the genus seemingly must also include forms having intermediate characters, such as "*C.*" *torquia* and the Morrowan corals to be described. It seems very undesirable so to interpret *Caninia*.

In 1844 Scouler proposed the genus *Siphonophyllia*, based on *S. cylindrica* Scouler as genotype. Attention was directed to the prominence of the dissepimental zone and to the nature of the cardinal fossula, which is accentuated in this species by an abrupt downbending of the tabulae to form funnel-like depressions in the region of the cardinal septum. Edwards and Haime (1851, p. 339) did not recognize either *Caninia* or *Siphonophyllia* as valid genera, and assigned both *Caryophyllia gigantea* Lesueur (1821, p. 296) and *Caninia gigantea* Michelin to *Zaphrentis* [*Zaphrenthis*]. They recognized the latter species under the designation *Z. cylindrica* (Scouler), inasmuch as *Caninia gigantea* Michelin (1843) was considered to be a homonym of *Caryophyllia gigantea* Lesueur (1821). In this procedure they were followed by de Koninck (1872, p. 84). Salée (1910, p. 27), in a monographic study of *Caninia*, assigned *Zaphrenthis cylindrica* (Scouler) to *Caninia*, designating the species as *C. cylindrica* (Scouler), rather than *C. gigantea* Michelin. Later European writers have somewhat indiscriminately used one specific name or the other, classifying the species as belonging to *Caninia*. The taxonomic muddle is extreme and it is the more unfortunate because little real reason for the confusion seems to exist.

The genus *Campophyllum* was introduced in 1850 by Edwards and Haime (p. lxviii) to include elongate solitary corals having well-developed septa, "tabulae very large and smooth towards the center," and "interseptal loculi filled with small vesiculae." *Cyathophyllum flexuosum* Goldfuss (1826–1833, p. 57) was designated as the genotype. Goldfuss' illustrations of this species are insufficient to permit determination of structural characters and the specimen figured by Edwards and Haime (1851, pl. 8, figs. 4, 4a) has been determined by Frech (1885, p. 27) to be different from *C. flexuosum*. Hill (1940, p. 116) has reviewed the problem of recognizing *Campophyllum* and concludes that this genus is probably synonymous with *Palaeosmilia* Edwards and Haime (1848). On the other hand, Schindewolf (reported by Lang, Smith, and Thomas, 1940, p. 30) has stated that his study of Goldfuss' types of *Cyathophyllum flexousum* indicates identity of this species with representatives of *Caninia*. As matters stand, *Campophyllum* seems to have no basis for recognition. It may be a junior synonym of *Caninia*, although Edwards and Haime's statement about the occurrence of dissepiments in *Campophyllum* makes it seem unlikely that their genus is closely similar to the genotype of *Caninia*, which is almost lacking in dissepiments. As suggested by Hill, *Campophyllum* may also be a junior synonym of *Palaeosmilia*, or adequate illustrations and description of *Cyathophyllum fleuxosum* (renamed by Frech *C. acquisgranense* because Goldfuss' name is a homonym) may show that *Campophyllum* has characters essentially the same as *Pseudozaphrentoides* and may be accepted as a valid genus in place of Stuckenberg's genus.

Palaeosmilia Edwards and Haime (1848, p. 467) differs from *Caninia*, *Pseudozaphrentoides* and *Siphonophyllia* in having long septa that meet in the axial region throughout all growth stages. There are other distinctions in structure, also, which set *Palaeosmilia* clearly apart from the corals here considered, and detailed notice of the characters of this genus is unnecessary. The same may be said of *Zaphrenthis*.

As judged from Stuckenberg's diagnosis of *Pseudozaphrentoides* and the published illustrations of the genotype species, the essential structural features of this genus fully agree with characters observed in the specimens here designated under this name. The only differences between *P. jerofeewi* and our corals that seem worthy of notice are the more elongate, cylindrical form of the American species and lack of differentiation of the alar septa in the latter. Stuckenberg's figures of the genotype, however, do not show recognizable alar pseudofossulae; both transverse and longitudinal sections of *P. jerofeewi* correspond very closely to those of our new species. Interpreting *Caninia* as properly including only corals that have structural features like those of the genotype, *C. cornucopiae*, this genus may be differentiated from *Pseudozaphrentoides* by the very slight development of dissepiments in *Caninia* and perhaps also by the greater contrast in characters of the immature and mature regions in *Caninia*. We interpret *Siphonophyllia* as a valid genus that is differentiated from *Pseudozaphrentoides* and *Caninia* by the prominence of its wide dissepimental zone, the weakening of outer parts of the septa so that they fail to reach the theca, and the presence of a more or less well-developed siphonofossula, formed by downbending of the tabulae near the cardinal septum. Lower Carboniferous corals from England that have the same structure as our specimens and that we would assign to *Pseudozaphrentoides* include forms variously identified as *Cyathophyllum (Caninia) giganteum* (Thomson and Nicholson, 1876, p. 69, pl. 6, figs. 1, 2), *Campophyllum cylindricum* (Thomson, 1883, p. 377, pl. 7, fig. 11), *Campophyllum (Caninia) giganteum* (Thomson, 1883, p. 378, pl. 7, fig. 4), *Caninia juddi* (Lewis, 1924, p. 391, pls. 17–19), *Caninia benburbensis* (Lewis, 1927, p. 378, pl. 16, figs. 5, 6, pl. 17, figs. 1–4), and many others.

Barbouria Lang, Smith, and Thomas (1940, p. 26), which was proposed as a new name for the homonym *Craterophyllum* Barbour (1911, p. 37), is based on specimens from Pennsylvanian (Virgilian) rocks in Nebraska. Sections of topotype material, which we have in abundance, prepared by the junior author of this paper, show that the internal structure of these corals is essentially the same as that of the forms from Morrowan strata here assigned to *Pseudozaphrentoides.* The structure of the tabulae, as represented in Barbour's Plate 4, figure 11, which shows sharply up-bent outer parts of the tabulae, seemingly was entirely misconstrued by Barbour; the outer parts of the tabulae slope downward. We conclude that *Barbouria* is a junior synonym of *Pseudozaphrentoides.*

Caninophyllum Lewis (1929, p. 457) differs from *Pseudozaphrentoides* in the greater length of the septa, which meet one another or almost meet in the mature part of the corallite, as well as in the immature region; also, the cardinal fossula of *Caninophyllum* commonly is more conspicuous. *Charactophyllum* Simpson (1900, p. 209) is distinguished from the genera here discussed by its carinate septa. *Peetzia* Tolmatchoff (1924, p. 309), from the Lower Carboniferous of the U. S. S. R., is not clearly determinable from the description and figures of the genotype, *P. minor* Tolmatchoff, which Hill (1940, p. 105) considers to be synonymous with *Caninia cornucopiae vesicularis* Salée. Seemingly, *Peetzia* is a junior synonym of *Caninia.* The genus *Paracaninia* Chi (1937), which is mentioned by Hill (1940, p. 105), was described in a publication that we have been unable to find in this country. This coral is reported from the Permian of China and is said to resemble *Caninia cornucopiae* closely but lacks dissepiments.

Occurrence. — Lower Carboniferous, Europe; Lower Pennsylvanian, North America.

PSEUDOZAPHRENTOIDES LEPIDUS, n.sp.

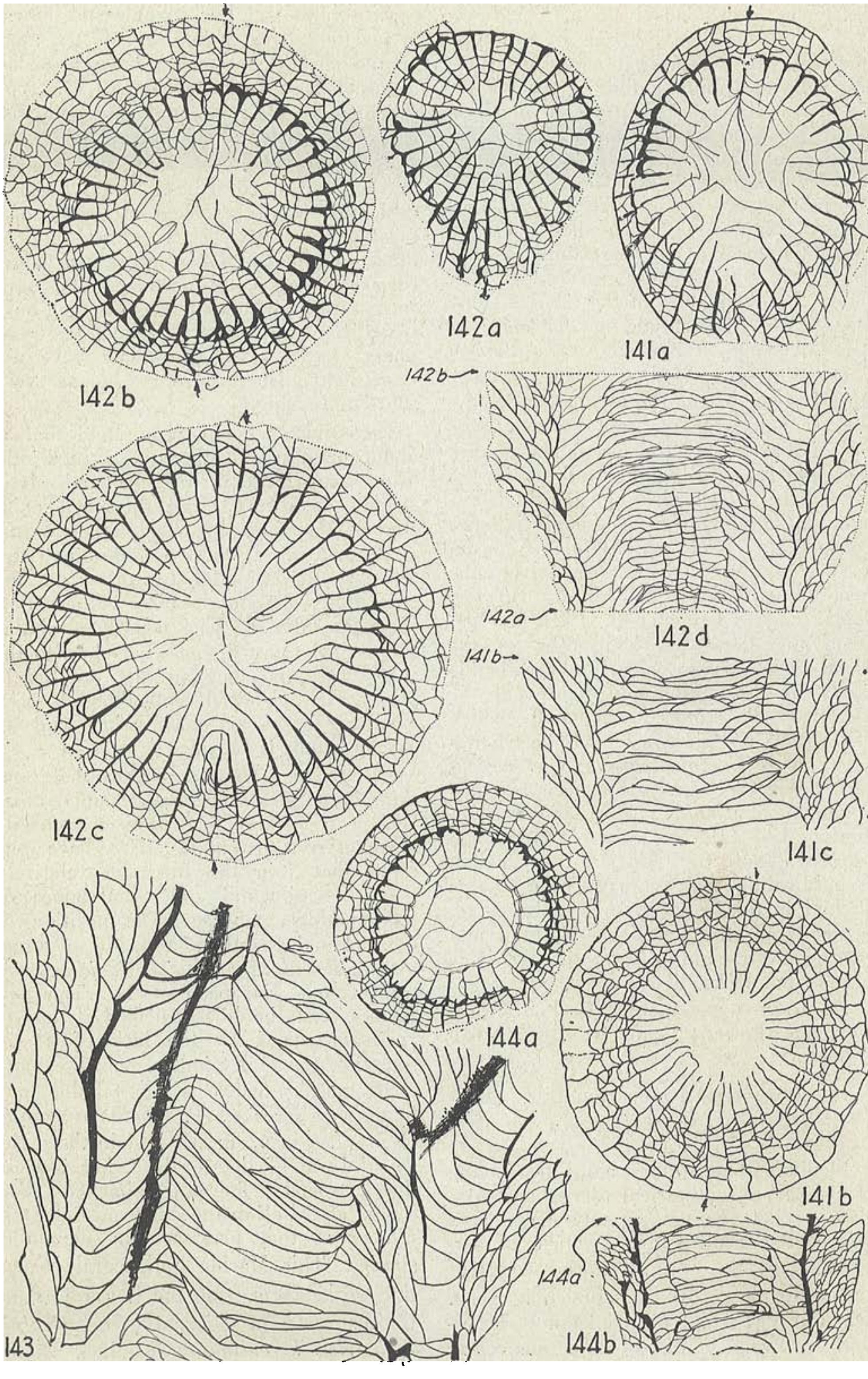
Text figs. 141, 142, 152

Medium-sized solitary corallites having a conical to cylindrical shape comprise this species. The moderately deep calyx has a flat central area, which is surrounded by the upward sloping edges of the septa and the dissepimental zone. Septal grooves are inconspicuous. Transverse markings consist of numerous coarse growth lines and low wrinkles. A down-arched lateral extension close to the apex of the corallite seems to have provided a broad base for attachment. The type specimen is 42.7 mm. in length and 16.8 mm. in diameter at the calyx.

There are about 40 long major septa in the mature corallites. The septa are thin and slightly crooked in the dissepimental zone but become thick at the inner edge of the dissepiments. In young forms a few septa extend to the axis. In mature individuals the septa reach only two-thirds of the distance from the periphery to the axis. Protosepta have not been distinguished. Minor septa are very short or lacking.

Dissepiments occur in a band that is about one-third of the radius in width. They are irregular in size and slope steeply downward. The thickened axial edge of the innermost dissepiments forms a distinct inner wall. Longitudinal sections show the axial two-thirds of the corallite to contain complete or inosculating thin tabulae. The complete tabulae are arched upward somewhat close to the inner wall and they are flat or slightly sagging in the broad central region. The cardinal fossula is not distinct and an axial column is lacking.

Discussion.—This coral resembles *Pseudozaphrentoides jerofeewi* and other European species that have customarily been referred to *Caninia.* They have long septa that join the theca, a relatively wide dissepimental zone, and more or less complete tabulae. The position of the cardinal fossula is difficult to recognize in *Pseudozaphrentoides lepidus,* as is true of some European species. This new species can be distinguished from *P. spatiosus,* n.sp., by the lack of a distinct intermediate tabular zone, the more anastomosing nature of its tabulae, and by its smaller size. *P. lepidus* resembles *P. nitellus,* n.sp., in size and in the cylindrical form of the corallite, but it lacks the extremely fine dissepiments, short septa, and well-defined intermediate tabular area that are seen in the latter species. This Marble Falls coral is similar to the form from the Lower Carboniferous rocks of Tournai called *Caninia cylindrica herculina* de Koninck (Salée,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1910, p. 37) in the coarseness of its dissepiments and in the appearance of transverse sections of adult portions of the corallite. *Pseudozaphrentoides lepidus* lacks the conspicuous cardinal fossula, lonsdaleoid dissepiments near the calyx, and more complete tabulae of the Belgian coral, however, and is considered to be generically different.

Occurrence.—Marble Falls limestone, Bendian, Lower Pennsylvanian (Upper Carboniferous); collected by F. B. Plummer, halfway up bluff on Big Saline Creek, 1.8 miles north-northwest of old Pfluger ranch house or 3 miles southeast of London, Kimble County, Texas (loc. 134–T–6); by R. C. Moore, from the type locality of the Marble Falls limestone, along Colorado River at Marble Falls, Texas (Univ. Kansas loc. 8093 or loc. 27–T–10), the specimens of this coral coming from a point on the north side of the river just above the steel highway bridge.

Material studied.—Five specimens including two sectioned corallites of this species from the former locality were studied, as well as several sectioned specimens from the Colorado River locality.

Type.—The University of Texas, Bureau of Economic Geology, specimen no. P–8607b, from the locality southeast of London, Texas.

PSEUDOZAPHRENTOIDES SPATIOSUS, n.sp.

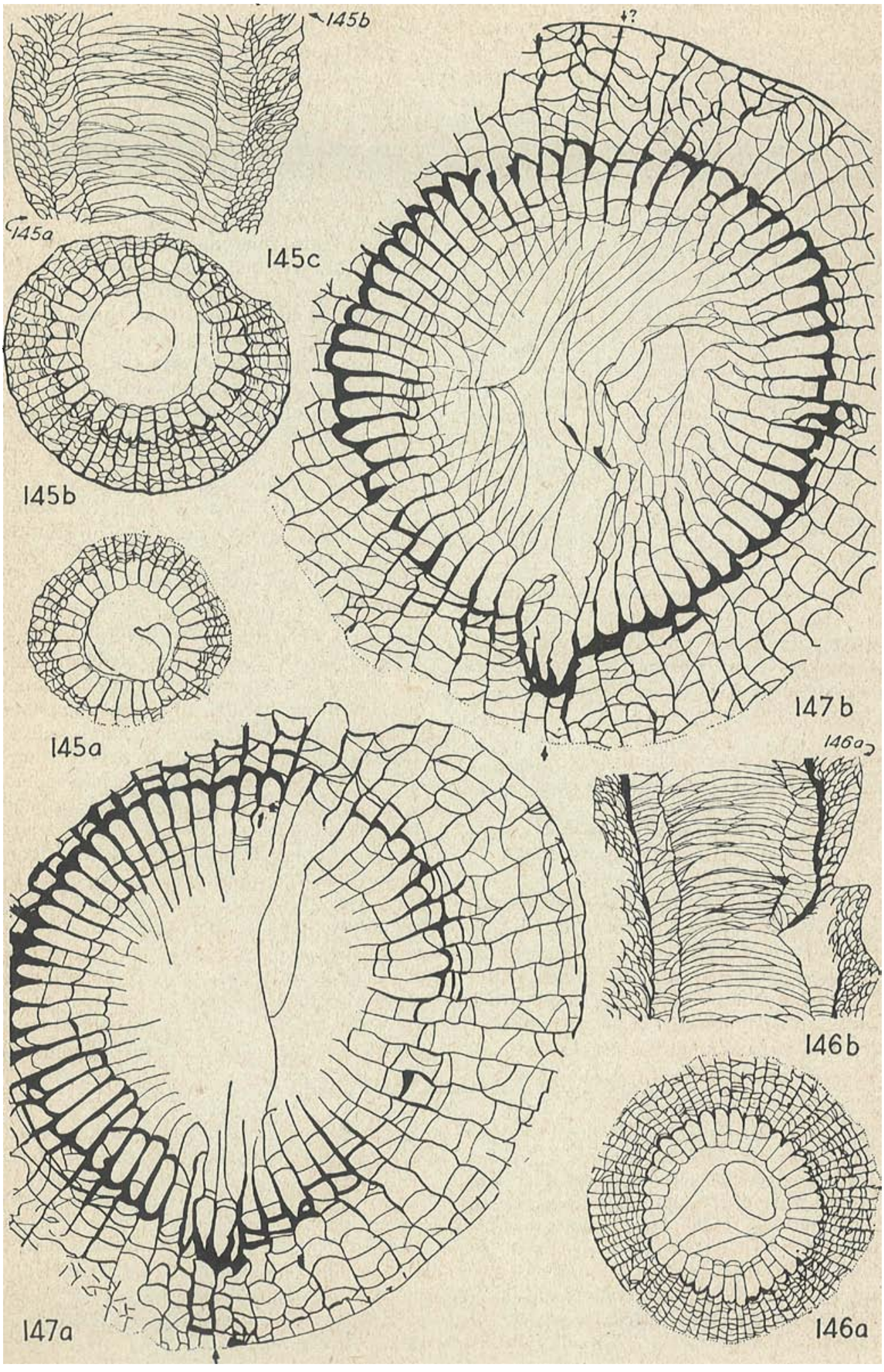
Text figs. 143, 147

A large strongly curved conical-cylindrical corallite represents this species. The nature of the calyx is not known. The thin theca bears fine growth lines and prominent wrinkles, but there are no longitudinal markings. The type specimen is 38 mm. in diameter close to the calyx and 117.5 mm. in length, measured along the curved corallite.

The 60 major septa in the mature portion of this coral are long and regularly spaced. The cardinal septum is shortened and lies in a deep fossula. Other major septa are of approximately equal length and not differentiated from one another. The septa are thin in the dissepimental zone but thicken abruptly at the inner edge of this zone and then become attenuate towards the axis. Minor septa are very short. The cardinal fossula is conspicuous in all tranverse sections and is marked by an indentation of the inner wall that is formed by the thickened margin of the dissepimental zone and thickening of the septa. The dissepiments, which are large and irregular, occur in a broad peripheral band. In transverse sections they are seen as more or less parallel bars between the septa. Thin, closely spaced, complete or slightly anastomosing tabulae rise steeply from the edge of the dissepimental zone to the inner edges of the septa and then flatten out in the axial area. A column is lacking.

Discussion.—This species is represented by the largest corallite in the collections of Morrowan corals. It is distinguished from *Pseudozaphrentoides lepidus* and *P. nitellus* by its greater size, very large uneven dissepiments, wide non-septate axial area, and the subparallel appearance of the dissepiments as seen in transverse sections. *P. spatiosus* differs from *P. torquius* (Owen), as described by Keyes (1894, p. 107), in the more irregular nature and steeper slope of the dissepiments, and the presence of a thickened inner wall. The closely spaced regular tabulae and broad axial area of *P. spatiosus* resemble those of the Lower Carboniferous coral *P. juddi* (Thomson)

Figs. 141–144. Sections of Marble Falls and Hale zaphrenthid corals, x3, belonging to the genus Pseudozaphrentoides Stuckenberg. Transverse sections are oriented with the cardinal septum at bottom; protosepta indicated by small arrows. Longitudinal sections are mostly at right angles to the plane of the cardinal and counter septa; positions of the transverse septa shown by small italic figures. (141) *Pseudozaphrentoides lepidus*, n.sp., the type specimen, no. P8607b, from the Marble Falls limestone on the Pfluger ranch, 3.2 miles southeast of London, Kimble County, Texas (loc. 134–T–6); (142) specimen no. P8607a, from the same locality as fig. 141. (143) *P. spatiosus*, n.sp., type specimen, no. P6977, from the Marble Falls limestone about 1.7 miles south-southeast of San Saba, Texas (loc. 205–T–165). (144) *P. nitellus*, n.sp., no KU7385–22c, from the Hale formation at Greenleaf Lake, southeast of Braggs, Oklahoma.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illustrated by Lewis (1924, pl. 17–19) and *P. kokscharowi* (Stuckenberg), illustrated by Greck (1936, pl. 1–3). The Marble Falls coral, however, can be differentiated by the parallel appearance of the dissepiments in transverse section and the lack of a distinct downbending of the tabulae about the fossula.

Occurrence.—Middle part of the Marble Falls limestone, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by J. A. Udden, on San Saba-Chappel road, 1.7 miles south-southeast of courthouse at San Saba, San Saba County, Texas (loc. 205–T–165).

Material studied.—One large corallite imbedded in black limestone was sectioned for study. Numerous flattened specimens of similar size or a little smaller, from the Marble Falls limestone at Marble Falls, Texas, are in the collection, but the internal structure is too greatly disturbed to permit satisfactory determination of characters. Some of these corals resemble the type of *Pseudozaphrentoides spatiosus* but others are distinguished by much closer spacing of the septa along the periphery.

Type.—The University of Texas, Bureau of Economic Geology, specimen no. 6977.

PSEUDOZAPHRENTOIDES NITELLUS, n.sp.

Text figs. 144–146, 153, 154

Solitary corallites of broadly conical form near the base and cylindrical above are included in this species. The calyx is deep, the walls steeply sloping and the base large and flat. Longitudinal grooves and ridges are lacking, although they seem to be present on weathered specimens. Transverse markings consist of numerous fine growth lines and irregularly spaced low wrinkles. The bent apex and uneven broad radicles indicate firm attachment at the base. The type specimen is 32.2 mm. in length and 13.5 mm. in diameter at the calyx.

The closely spaced major septa, of which there are about 30 in mature specimens, extend about two-thirds of the distance to the axis. These septa are thin and slightly crooked in the peripheral dissepimental zone, but they thicken abruptly at the axial edge of this zone and then gradually thin towards the axis. The major septa are of equal length, except one that is slightly shorter than the rest, and is believed to be the cardinal septum. Minor septa extend to the inner edge of the dissepimental zone in mature portions of the corallite.

Three concentric zones are recognizable in these corals, and the zones can be differentiated both in transverse and longitudinal sections. The peripheral zone consists of a broad band of dissepiments. Individual dissepiments are somewhat irregular in size but mostly small, and have the convex surface sloping evenly downward toward the axis. In transverse section they appear as more or less parallel concentric bars between the septa, but some are very irregular. The inner edge of this zone, which is located a little over one-third of the distance from theca to axis, is marked by a distinct wall. This so-called inner wall is produced by the deposition of stereoplasm and skeletal thickening in the innermost dissepiments. Next to the dissepimental zone is a narrow intermediate zone, which consists of irregular anastomosing tabulae sloping gently upward. The axial edge of this zone coincides with the inner edge of the septa. This part of the corallite may be designated as the outer tabulate zone. Its width in the species here described is equal to that of the dissepimental zone or less than equal. The third

Figs. 145–147. Sections of Hale and Marble Falls zaphrenthid corals, x3, belonging to the genus *Pseudozaphrentoides* Stuckenberg. Transverse sections are oriented with the cardinal septum at bottom; protosepta indicated by small arrows. Longitudinal sections are mostly at right angles to the plane of the cardinal and counter septa; positions of transverse sections shown by small italic figures. (145) *Pseudozaphrentoides nitellus*, n.sp., type specimen, no. KU7385–22d, from the Hale formation at Greenleaf Lake, southeast of Braggs, Oklahoma; (146) specimen no. KU7385–21f, from the same locality as fig. 145. (147) *P. spatiosus*, n.sp., type specimen, no. P6977, from the Marble Falls limestone about 1.7 miles south-southeast of San Saba, Texas (loc. 205–T–165).

zone, which occupies the axial region of the corallite, is characterized by closely spaced tabulae and by absence of septa; the zone is here called the inner tabulate area or the axial region. The tabulae of this zone are irregularly anastomosing, and they arch upward very slightly. In transverse sections (figs. 145b, 146a) they appear as concentric rings inside the axial edges of the septa or curved bars connecting these edges. In longitudinal sections (figs. 145c, 146b) the edges of the inner tabulate area are defined more or less well by abrupt deflections of the tabulae. There is no axial column. The cardinal fossula is only weakly developed.

Discussion. — This species resembles *Pseudozaphrentoides verticillatus* (Barbour), which is the genotype of *Barbouria,* but may be distinguished by slight differences of the outer tabulate zone, the more closely packed and nearly horizontal attitude of the tabulae in the broad axial zone, the smaller size of the corallite, and lack of rings of calicular buds. It differs from *Pseudozaphrentoides lepidus* in the shorter and more even length of the septa, long minor septa, smaller dissepiments, and presence of distinct outer and inner tabulate zones. *P. nitellus* mainly differs from *P. spatiosus* in its much smaller size and in its clearly marked three internal zones.

Occurrence.—Hale formation, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore and University of Kansas students below dam, Greenleaf Lake, cen. sec. 10, T. 13 N., R. 20 E., southeast of Braggs, Oklahoma (Univ. Kansas loc. 7385).

Material studied.—About 20 well-preserved specimens were available for study and representative material was sectioned.

Type.—University of Kansas, specimen no. 7385–22d.

Family CLISIOPHYLLIDAE Thomson and Nicholson, 1876

The Clisiophyllidae comprise solitary and compound corallites, the latter loosely bundled or crowded closely together, individuals having a cylindrical to prismatic form. A thin theca is generally present but may be suppressed in colonial growths. The shallow to moderately deep calyx is characterized by a central elevation or boss that is formed by an axial column. Septa are very numerous, long, and evenly distributed, so as to obscure bilateral symmetry; commonly they are dilated just inside the zone of dissepiments. A small open cardinal fossula, which is distinct in some genera but indistinct in others, is defined chiefly by an outward extension of tabulae into the zone of dissepiments at the position of the cardinal septum. Tabulae and dissepiments are abundant; their arrangement, combined with structural peculiarities of septa and axial column, produces an inner zonation of the corallite that is well shown in transverse and longitudinal sections. The axial column consists of variously disposed intersecting lamellae and is open-textured rather than solid. Range, Mississippian to Permian.

Discussion.—This family is a well-characterized assemblage that is distinguished from otherwise similar corals of the Cyathophyllidae by the presence of an axial column and by the nature of the cardinal fossula. The clisiophyllids are distinguished from families such as the Cyathaxonidae, Lophophyllidiidae, and Lithostrotionidae by the nature of the columnar structure. According to Hill (1938, p. 54), the clisiophyllid fossula differs sharply from that of caninid genera in the outward extension of depressed tabulae into the zone of dissepiments, inasmuch as *Caninia* shows no such invasion of the dissepimental zone by tabulae in the cardinal fossula.

The Lonsdaleidae (Huang, 1932) are similar to the Clisiophyllidae in stratigraphic range and in many structural characters. These families differ in that among lonsdaleid corals the tabulae are subhorizontal or slope upward toward the dissepiments near the junction of these two zones, whereas the tabulae of the clisiophyllids slope downward from the axial region so as to make an acute angle with the dissepiments. This angle is right or obtuse in the Lonsdaleidae.

The Clisiophyllidae are abundant in some Lower Carboniferous rocks and they are represented by many described Permian corals; few Upper Carboniferous species belonging to the family have yet been made known but this does not mean necessarily that clisiophyllids are rare in marine rocks of this age.

Genera assigned to the Clisiophyllidae by Hill (1938, p. 54; 1939, p. 100) include *Clisiophyllum* McCoy, *Aulophyllum* Edwards and Haime, *Dibunophyllum* Nicholson and Thomson, *Koninckophyllum* Thomson and Nicholson, *Arachniophyllum* Smyth, *Auloclisia* Lewis, *Corwenia* Smith and Ryder, and ?*Cyathoclisia* Dingwall—all from Lower Carboniferous rocks of western Europe. In our opinion, *Rodophyllum* Thomson and possibly other described European Lower Carboniferous forms should be added to this list; a new Lower Pennsylvanian species from Texas is assigned by us to *Rodophyllum*. *Acrophyllum* Thomson and Nicholson, from the Devonian of North America, and numerous additional genera reported from Carboniferous and Permian rocks of Asia, Australia, and Russia are tentatively placed by Hill (1938, p. 55) in this family. We include here Fomitchev's genus *Neokoninckophyllum*, described from Middle or Upper Carboniferous rocks of Russia, and recognize three new American species of Pennsylvanian age as belonging to it.

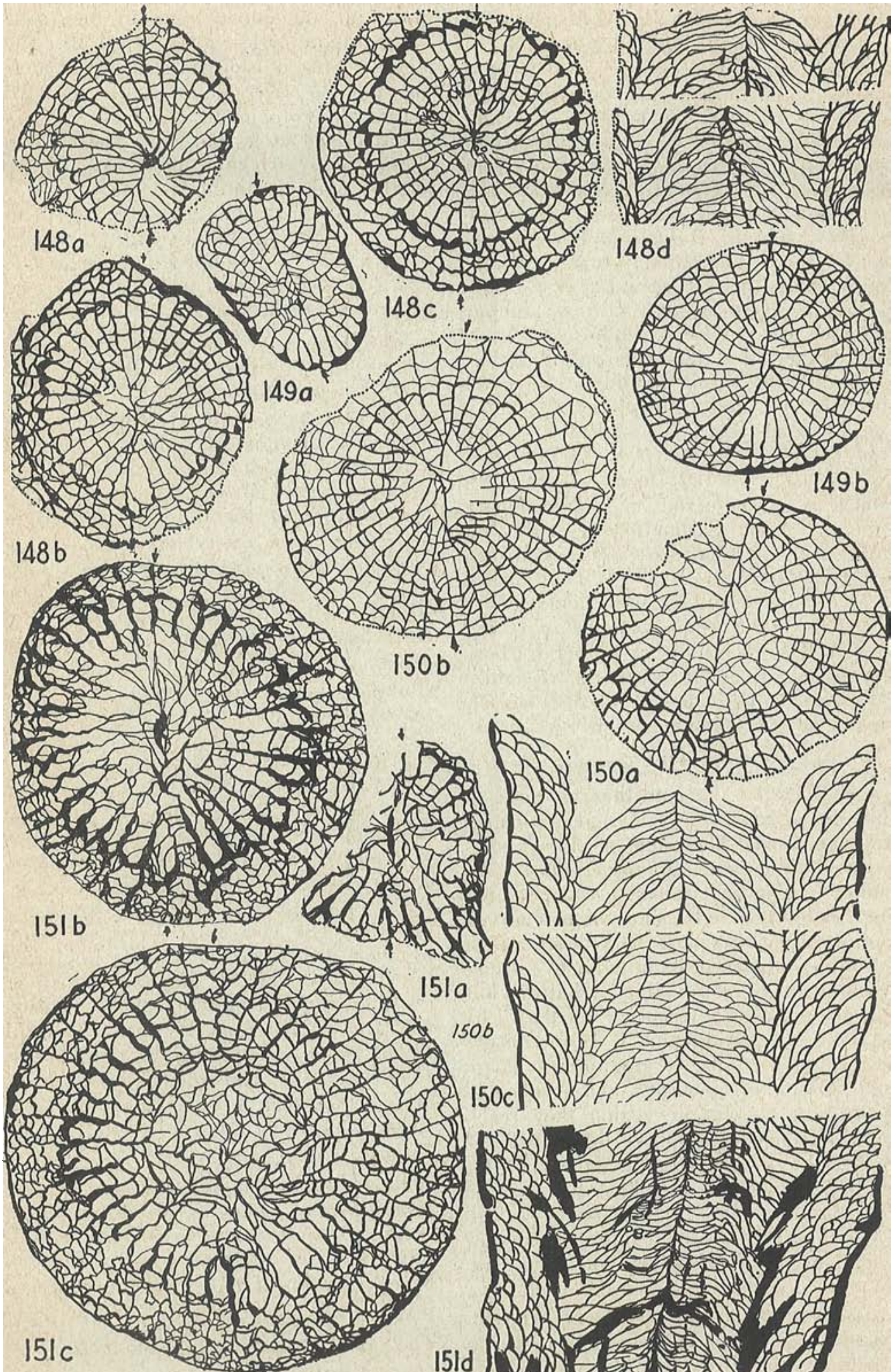
Genus RODOPHYLLUM Thomson, 1874

The form of the corallites assigned to this genus and chief internal structures are very much the same as in *Pseudozaphrentoides* and *Dibunophyllum*. An elongate subcylindrical mature part of the coral is built upon the more or less curved conical immature part. The theca, which is thin, is marked externally by strong wrinkles and growth lines; shallow but distinct septal grooves occur on the theca of the Texas species that is here referred to *Rodophyllum*. The major septa are long, thin, very numerous, and evenly disposed. In the mature region they reach inward from the periphery to the edge of the axial columnar structure, the diameter of which is about one-third that of the corallite. A weak cardinal fossula is commonly discernible, marked by the shorter length of the cardinal septum and an indentation of the inner margin of the dissepimental zone. Minor septa are present. Abundant fine dissepiments occur in a peripheral band and a deposit of stereoplasm at the inner edge of the zone forms a more or less prominent wall. The tabulate area is crowded with anastomosing tabulae that slope gently upward toward the column, which is not sharply differentiated at its borders. The column is formed by irregular upbending of the tabulae and discontinuous, unevenly distributed vertical lamellae, which seem to be extensions of tabulae for the most part; a poorly developed median lamella that is joined to the counter septum may be present in the immature region.

Genotype. — *Rodophyllum craigianum* Thomson, Lower Carboniferous, Scotland.

Discussion.—Among a half-dozen or more genera of solitary corals having abundant dissepiments and a nonsolid axial column, founded on Lower Carboniferous species from western Europe, *Rodophyllum* is the oldest. Included in the group just indicated are *Kumatiophyllum* Thomson (1875, p. 273), *Centrephyllum* Thomson (1880, p. 227), *Albertia* Thomson (1878, p. 165), and *Dibunophyllum* Thomson and Nicholson (1876, p. 457). Hill (1938, p. 65) concludes that all these genera are synonymous, and, ignoring the Rules, accepts *Dibunophyllum* as the valid designation for species severally assigned to the inferred synonyms. If Hill is right in her contention that these forms are not separable, the accepted name for them must be *Rodophyllum*, and not *Dibunophyllum*, unless formal action to abrogate the Rules in this case is taken by the Commission. The correct spelling of *Rodophyllum* is held to be as first published by Thomson, which is not *Rhodophyllum*, as altered by Thomson and Nicholson (1875, p. 273) and accepted by Hill (1938, p. 66), Lang, Smith, and Thomas (1940, p. 114), and others. No evidence of an error that is emendable under the Rules is found in the original publication (Moore, Weller, and Knight, 1942).

Judged on the basis of genotype species, *Rodophyllum* seems to be distinguished readily from *Dibunophyllum*, and the differentiation of these genera is borne out by comparison of numerous other species that are assigned to one or the other. The axial column of *Rodophyllum* is composed mainly of tabulate elements,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which in transverse section show a decidedly irregular pattern; that of *Dibunophyllum* is formed by a prominent median lamella, radially diverging vertical lamellae that do not meet at a common point, and steeply inclined extensions of tabulae (or tabellae), all of these together forming a distinct cobweb-like pattern in transverse section. *Neokoninckophyllum* has a column that is intermediate between those of the genera just compared, but considerably less complicated than either.

Occurrence.—Lower and Upper Carboniferous.

RODOPHYLLUM TEXANUM, n.sp.

Text figs. 151, 155

Large solitary corallites of curved conico-cylindrical form comprise this species. The deep calyx has steeply sloping walls and a horizontal floor, except for the low rounded axial column. The thin theca is marked by low, well-developed septal grooves, fine growth lines, and low wrinkles. The type specimen is 24 mm. in diameter at the calyx and 49.5 mm. in height.

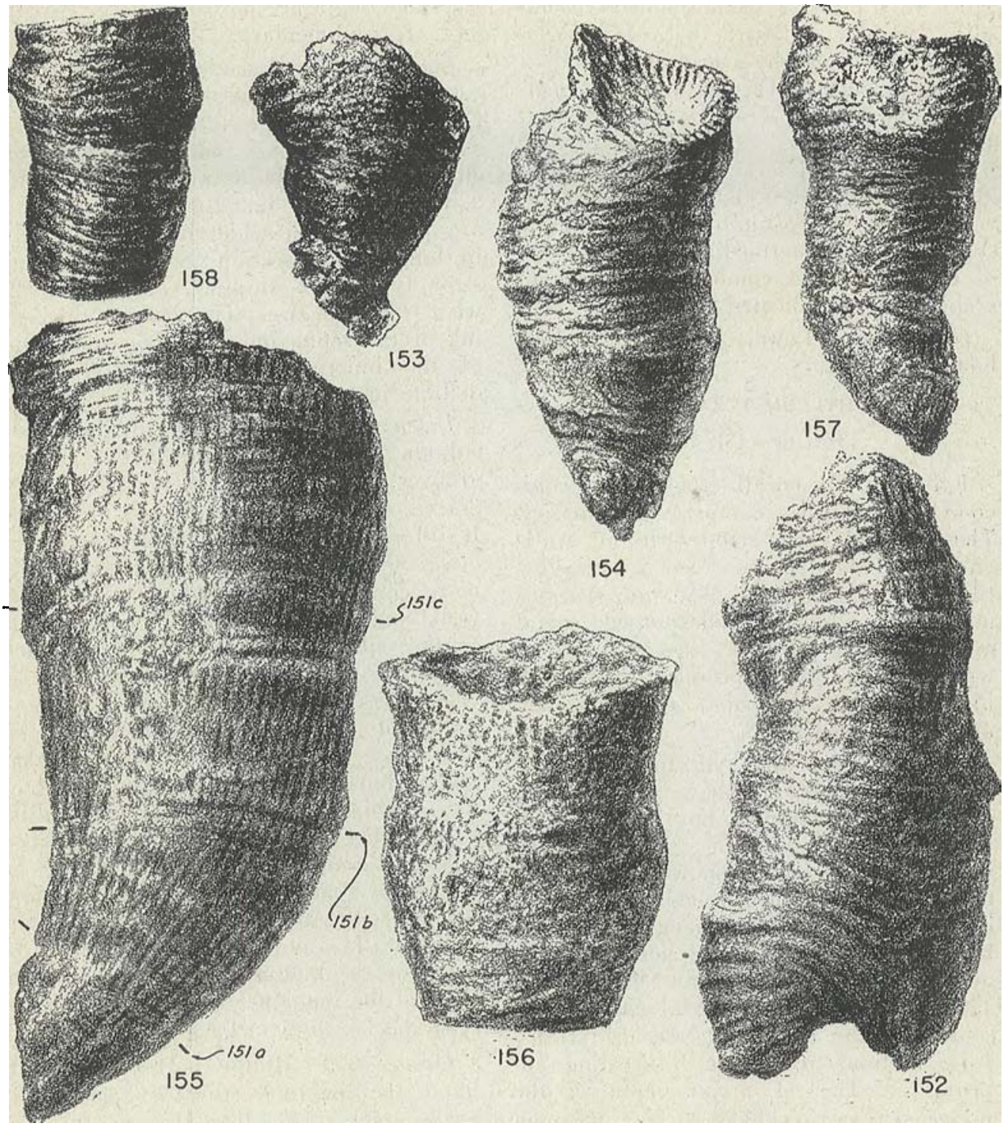
Transverse sections of the immature region of this coral show a well-developed median lamella but only poorly indicated radial lamellae. A section 13 mm. below the calyx shows the column to consist of steeply arched tabulae and inconspicuous lamellae. Long major septa become thin in the peripheral dissepimental zone, but are not lonsdaleoid. The intersection of the axial ends of the septa and the tabulae, as seen in transverse section, presents a bifurcating appearance. The 41 major septa of the uppermost section have an arrangement shown by the formula K 10 A 9 C 8 A 10 K. The cardinal septum is slightly shortened, but other septa are not distinctive. Minor septa are rudimentary.

The longitudinal section shows the thin anastomosing tabulae that rise gently from the periphery towards the broad axial column. This column consists of closely packed tabulae (or tabellae) and a few irregular lamellae. Dissepiments are present in a wide peripheral band; in longitudinal section they are seen as strongly convex sloping cysts of somewhat variable size. The abrupt thickening of the septa and excessive thickening of the innermost dissepiments form a definite inner wall.

Discussion.—The nature of the axial column, together with the distinct septal grooves, separate this species from other described Lower Pennsylvanian corals. It differs from *Neokoninckophyllum arcuatum*, n.sp., and *N. simplex*, n.sp., in the more conical shape of the corallite, the weak and irregularly developed lamellae of the column, and the closely crowded anastomosing nature of the tabulae. The broad dissepimental zone, long septa, and shape of *Rodophyllum texanum* resembles those of species of *Pseudozaphrentoides*, but the strong axial structure of *R. texanum* permits separation readily. The Texas species can be distinguished from *R. craigianum* Thomson (1874, p. 557), the genotype, by the smaller number of septa, thickened septa within the inner wall, and strong alar pseudofossulae of the mature region. No illustrations of the immature regions of the genotype species seem to have been published.

Occurrence.—Middle part of the Marble Falls limestone (fusuline-bearing Big Saline beds), Bendian, Lower Pennsylvanian (Upper Carboniferous); collected by F. B. Plummer, at the spillway at

Figs. 148–151. Sections of Hale and Marble Falls clisiophyllid corals, x3. Transverse sections are oriented with the cardinal septum at bottom; protosepta indicated by small arrows. Longitudinal sections are mostly at right angles to the plane of the cardinal and counter septa; positions of transverse sections shown by small italic figures. (148) *Dibunophyllum? inauditum*, n.sp., type specimen, no. KU7744–22b, from the Hale formation at Keough quarry, north of Fort Gibson, Oklahoma. (149) *Neokoninckophyllum simplex*, n.sp., specimen no. KU7130–21b, from the Hale formation south of Keough quarry, north of Fort Gibson, Oklahoma; (150) type specimen, no. KU7130–21a, from the same locality as fig. 149. (151) *Rodophyllum texanum*, n.sp., type specimen, no. P9897, from the Marble Falls limestone at Shropshire Lake, 3.3 miles east-southeast of Brady courthouse, Brady, Texas (loc. 153–T–85).



Figs. 152–158. Exterior views of Hale and Marble Falls zaphrenthid and clisiophyllid corals, x2. Positions of transverse sections are indicated by small italic figures. (162) *Pseudozaphrentoides lepidus*, n.sp., type specimen, no. P8607b, from the Marble Falls limestone on the Pfluger ranch, 3.2 miles southeast of London, Kimble County, Texas (loc. 143–T–6). (153) *P. nitellus*, n.sp., specimen no. KU7385–22f, from the Hale formation at Greenleaf Lake, southeast of Braggs, Oklahoma; (154) specimen no. KU7385–22e, from the same locality as fig. 153. (155) *Rodophyllum texanum*, n.sp., type specimen, no. P9897, from the Marble Falls limestone at Shropshire Lake, 3.3 miles east-southeast of courthouse at Brady, Texas (loc. 153–T–85). (156) *Neokoninckophyllum simplex*, n.sp., type specimen, no.KU7130–21a, from the Hale formation south of Keough quarry, north of Fort Gibson, Oklahoma. (157) *N. arcuatum*, n.sp., specimen no. P7234i, from the Marble Falls limestone near Smith Crossing of Llano River, 4.8 miles S. 45° E. of London, Kimble County, Texas (loc. 133–T–2). (158) *N. gracile*, n.sp., type specimen, no. KU7994–21a, from the Marble Falls limestone at Marble Falls, Texas.

Shropshire Lake, 3.3 miles S. 62° E. of the courthouse at Brady, McCulloch County, Texas (loc. 153–T–85).

Material studied.—One large very well-preserved corallite was available for study of the characteristics of this species.

Type.—The University of Texas, Bureau of Economic Geology, specimen no. P–9897.

Genus DIBUNOPHYLLUM Thomson and Nicholson, 1876

Solitary corallites having the general form and structure of *Rodophyllum* are included in this genus. *Dibunophyllum* is distinguished mainly by the nature of the axial column, which has a median lamella joined to the counter septum, radiating vertical lamellae that meet the median lamella at different points, and steeply inclined portions of the tabulae, or tabellae. The cobweb-like appearance of the column in transverse sections of the corallite is a diagnostic feature.

Genotype. — *Dibunophyllum muirheadi* Thomson and Nicholson, Lower Carboniferous, Scotland.

Discussion.—A coral that exhibits the typical internal structure of *Dibunophyllum* has been described from Pennsylvanian rocks of North America. It has been described as *D. valeriae* Newell (1935, p. 343, pl. 33, figs. 1–3); this species occurs in the Stanton limestone, Missourian, of southeastern Kansas. Comparison of *Dibunophyllum* with *Rodophyllum* and *Pseudozaphrentoides* has been given in discussion of these genera.

Occurrence.—Lower Carboniferous to ?Permian; Europe, Asia, Australia, and North America.

DIBUNOPHYLLUM? INAUDITUM, n.sp.

Text figs. 148a-d

Solitary broadly conical corallites that have a thin theca, fine growth lines, and wrinkles comprise this species. The calyx is not well preserved, but seemingly the sides slope gradually to a horizontal base that has a low rounded column at the axis. The type specimen is 16 mm. in diameter at the calyx and 21.3 mm. in height.

There are 40 long slender major septa in the uppermost transverse section of the type. The septa are long throughout growth, and many are extended to the median lamella of the column. They are thin and somewhat crooked in the peripheral dissepimental zone, but are not lonsdaleoid. The cardinal septum is short and lies in a shallow fossula, the counter septum may be long and attached to the median lamella, and other major septa are mostly of uniform length. Minor septa are indicated only by rudimentary ridges in the uppermost regions of the corallites.

Closely crowded anastomosing tabulae rise gently from the periphery towards the axis. A poorly defined outer tabulate zone, in which the tabulae are nearly horizontal, is seen in longitudinal section between the axial column and the dissepimental zone. Dissepiments occur in a broad peripheral band as small steeply sloping cysts. In transverse sections they are indicated by more or less parallel bars between the septa. An inner wall is produced by the deposition of stereoplasm and skeletal thickening of the innermost dissepiments, accompanied by an abrupt thickening of the septa. The axial column has a prominent median lamella and a few radiating lamellae that meet it at different points. These lamellae seem to be extensions of some of the septa. In longitudinal sections the column is differentiated slightly from the outer tabulate zone. It consists of closely packed anastomosing tabulae that rise gently to the vertical lamellae. Carinae are lacking.

Discussion.—The corals here questionably assigned to *Dibunophyllum* resemble typical species of that genus in the well-developed median lamella, radiating lamellae, and outer and axial tabulate regions. They differ in the more crooked and thickened radiating lamellae, and irregular tabulae, which do not give a weblike appearance to the transverse sections of the Morrowan corals. Also, the axial column is separated indistinctly from the outer tabulate area and not strongly set off, as in *Dibunophyllum*.

Dibunophyllum? inauditum resembles *Neokoninckophyllum simplex,* n.sp., in the form of the corallite and appearance of the septa. The former species may be distinguished, however, by the prominent radiating lamellae which bifurcate outward from the median lamella and join the axial edges of the septa. The broad axial column, outer tabulate zone, and conical shape serve to separate this species from *N. arcuatum*, n.sp. *Dibunophyllum? inauditum* differs from *D. valeriae* Newell (1935, p. 343), from the Eudora shale of southeastern Kansas, in the lack of a distinct weblike appearance of the column in transverse section, longer septa and more prominent median lamella.

Occurrence.—Hale formation, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore at Keough quarry, 2½ miles north of Fort Gibson, Oklahoma (Univ. Kansas loc. 7744).

Material studied.—Two sectioned corallites are assigned to this species.

Type.—University of Kansas, specimen No. 7744–22b.

Genus NEOKONINCKOPHYLLUM Fomitchev, 1939

Solitary corallites of elongate subcylindrical form, having a well-developed dissepimental zone at the periphery, an inner area of up-arched irregular tabulae, an indefinite axial column that lacks a distinct weblike appearance in transverse section, and numerous subequal long major septa may be identified as representatives of *Neokoninckophyllum*. The theca is thin, its exterior bearing transverse wrinkles and growth lines but lacking septal grooves. The major septa are mostly thin, evenly disposed, and long. Some of them, especially the counter septum, reach to the axis of the corallite, but the majority terminate inward just short of the rather indefinite axial column. No fossulae are developed. The minor septa are short, being confined to the dissepimental zone, or they may not be present. In some specimens the outer parts of the septa tend to weaken, becoming discontinuous or disappearing. The inner parts may be somewhat thickened by stereoplasm. The dissepimental zone is moderately wide, and the inner margin, which is even or uneven, is not thickened to form a well-marked wall. Individual dissepiments range in size from very small to large, their surfaces convex toward the interior of the coral and sloping steeply downward. In transverse sections, the dissepiments appear very irregular in position, mostly running obliquely rather than normal to the septa. Lonsdaleoid structure is developed in the dissepimental zone where the septa disappear. The tabulae are very numerous, uneven, and anastomosing. They slope gently or with moderate steepness upward from their outer edges toward the axis. An axial column consisting of irregular vertical lamellae and upturned inner margins of the tabulae is observed, but there is no clearly defined median lamella or somewhat evenly disposed radiating lamellae, as in *Dibunophyllum*.

Genotype.—*Neokoninckophyllum vesiculosum* Fomitchev, Middle or Upper Carboniferous, U. S. S. R.

Discussion.—A number of genera having characters more or less closely similar to those of *Neokoninckophyllum* have been described. Perhaps most nearly related is *Dibunophyllum* Thomson and Nicholson (1876, p. 457), which occurs most commonly in Lower Carboniferous strata but is known also from Pennsylvanian rocks of North America (Newell, 1935, p. 343) and has been reported from the Permian. *Dibunophyllum* is distinguished by the presence of a well-developed column that in transverse section exhibits a weblike structure; vertical lamellae diverge radially from points distributed along a median lamella and these are intersected by steeply up-arched inner parts of the tabulae or similar platforms called tabellae. The axial column of *Dibunophyllum* may be outlined by a fairly distinct wall and is commonly differentiated clearly both in transverse and longitudinal sections. This genus may comprise the stock from which *Neokoninckophyllum* was derived, but at present the phylogenetic relationships of coral genera of this type are very doubtful.

Koninckophyllum Thomson and Nicholson (1876, p. 297) and *Lophophyllum* Edwards and Haime (1850, p. lxvi) are closely related genera described from Lower Carboniferous rocks of western Europe that bear resemblance to *Neokoninckophyllum* in several features. The first two genera mentioned, which may be synonyms, have been discussed by us (Moore and Jeffords, 1941, p. 80; Jeffords, 1942, p. 202) previously. Longitudinal sections of corals assigned to any of the three genera show no diagnostic features by which one can be separated from the others. Transverse sections, however, reveal differences; the column of *Lophophyllum* and *Koninckophyllum* is relatively dense and shows a distinct elongation in the plane of the counter and cardinal septa, whereas the columnar structure of *Neokoninckophyllum* is open and rather indefinite, and if a median lamella is distinguishable, it is not prominent.

Yuanophyllum Yu (1931, p. 27), described from Lower Carboniferous rocks of China, has a prominent dissepimental zone, up-arched anastomosing tabulae, long septa, and a rather indefinite axial column, in all of these features being much like the corals that here are assigned to *Neokoninckophyllum*. Longitudinal sections of Yu's genotype and of our specimens show no significant distinctions. *Yuanophyllum* differs from *Neokoninckophyllum* in having a large cardinal fossula and in the twisting of some of the long septa in the axial region, in the manner of *Clisiophyllum*.

Bothrophyllum Trautschold (1879, p. 30), from Carboniferous rocks of the U. S. S. R., generally resembles *Neokoninckophyllum* in the form of the large corallites, characters of the dissepimental and tabulate areas, and the presence of numerous long septa. The column of *Bothrophyllum* is a large, irregular structure of dibunophyllid type, differing from that of *Neokoninckophyllum* in the relative prominence of the median and radiating lamellae. Also, the septa of *Bothrophyllum* are commonly much thickened.

There is little need for comparison of *Neokoninckophyllum* with other genera, although a number of these have some features that correspond to characters of Fomitchev's genus. *Arachnolasma* Grabau (1922, p. 59) is probably a junior synonym of *Dibunophyllum*, and differs from *Neokoninckophyllum* as does *Dibunophyllum*. *Rodophyllum* Thomson (1874, p. 557) has an irregular columnar structure that is composed essentially of crowded, steeply arched parts of the tabulae. *Axophyllum* Edwards and Haime (1850, p. lxxii) is not now precisely defined, but seemingly the presence of a dense column and well-marked septal grooves on the theca differentiate it from *Neokoninckophyllum*. Prominent radial lamellae distinguish the column of *Carcinophyllum* Thompson and Nicholson (1876, p. 70). *Pseudozaphrentoides* Stuckenberg (1904, p. 90) and *Siphonophyllia* Scouler (1844, p. 187) lack an axial column.

Occurrence.—Upper Carboniferous; U. S. S. R. and North America.

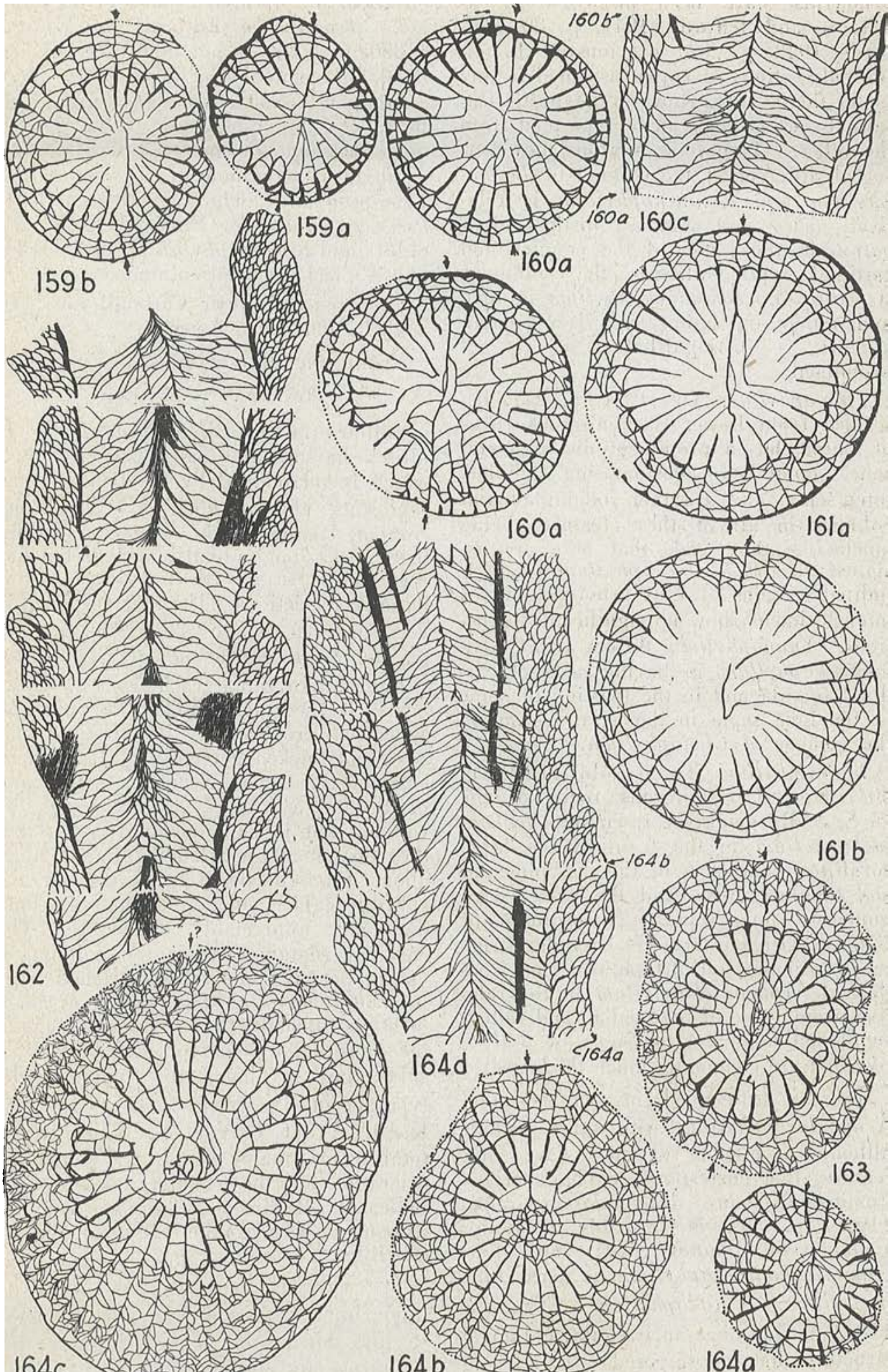
NEOKONINCKOPHYLLUM SIMPLEX, n.sp.

Text figs. 149, 150, 156

Solitary medium-sized cylindrical corallites having a broad shallow calyx, which is surrounded by the band of dissepiments and intruded by the broad column, comprise this species. The thin theca lacks longitudinal markings but has fine transverse growth lines and a few minor constrictions. The type specimen is 28.2 mm. in length and 19.3 mm. in maximum diameter at the calyx.

Long major septa reach from the theca nearly to the column. They are thin and somewhat crooked in the dissepimental zone and thicken perceptibly at the inner edge of this zone. Near the apex many of the septa are extended to join the column, but in subsequent growth stages they do not attain a length of more than about three-fourths the radius of the corallite. The counter septum is long and not appreciably thickened. The cardinal septum reaches the column in youth but is relatively shortened during later growth. The septal arrangement is difficult to interpret owing to the poor development of alar pseudofossulae, but in the mature part of the type specimen it seems to be as follows: K 10? A 8 C 8 A 11 K. This gives a total of 41 major septa, and some acceleration of the counter quadrants is indicated. Rudimentary minor septa are present only near the calyx of mature corallites.

The wide peripheral zone is formed by large uneven dissepiments, which slope steeply downward. The innermost dissepiments are slightly thickened to form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a poorly defined inner wall. Numerous thin tabulae rise gently to the axial column. Close to the inner wall there is an irregular zone of more or less horizontal anastomosing tabulae, which give way to more distinct arched tabulae joining the thin median lamella of the column. These tabulae are seen in transverse sections as curved bars between the septa on the axial side of the inner wall.

In longitudinal section the column is indicated by axial junction of the tabulae and the vertical trace of the median lamella. Cross sections show a distinct but very thin median lamella that is attached to the counter and cardinal septa. A few wavy radiating lamellae meet the median lamella at different points. Most of the lamellae seem to be axial extensions of the septa. In transverse section the intersection of tabulae with these lamellae produces a very uneven cobweb appearance. A shallow cardinal fossula is indicated by shortening of the thin cardinal septum and poorly developed septa on either side and by indentation of the inner wall bounding the dissepimental zone.

Discussion.—This species can be distinguished readily from *Neokoninckophyllum arcuatum*, n.sp., by its very large unequal dissepiments and poorly developed inner wall. In transverse sections the dissepiments are more or less parallel and not closely packed, and have a herringbone pattern, as in *N. arcuatum*. The median lamella is more persistent, but the radiating lamellae and tabulae of the axial column are less complex. *N. gracile*, n.sp., also has parallel dissepiments, as seen in transverse section, and a very simple column. *N. simplex* differs in having a broader and less well-defined dissepimental zone, more highly arched tabulae, and more numerous septa.

Occurrence.—Hale formation, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore, one-quarter of a mile south of Keough quarry, Fort Gibson, Oklahoma (Univ. Kansas loc. 7130).

Material studied.—Two well-preserved specimens of this species were sectioned for study.

Type.—University of Kansas, specimen no. 7130-21a.

NEOKONINCKOPHYLLUM ARCUATUM, n.sp.

Text figs. 157, 162–164

The corals placed in this species are large cylindrical forms having a thin theca and a deep flat-bottomed calyx that is surrounded by the broad dissepimental zone and intruded by a low sharp axial column. The surface of the corallites is rough, owing to irregularly spaced expansions and deep transverse depressions. Fine growth lines are present but septal markings are not seen on the surface of the theca. The type specimen is 13.4 mm. in diameter at the calyx and 61 mm. in length. The largest specimen has a diameter of 24 mm. near the calyx; it is a fragment of the corallite, its length being 38 mm.

Long major septa reach nearly to the axis. They are thin in the dissepimental zone, thicken at the inner edge of this zone, and thin out halfway through the axial tabular zone. The counter septum is long and extends to the column in young growth stages. The cardinal septum reaches the edge of the column in lower parts of the corallite but becomes relatively shortened during growth. Other

Figs. 159–164. Sections of Marble Falls clisiophyllid corals, x3, belonging to the genus *Neokoninckophyllum* Fomitchev. Transverse sections are oriented with the cardinal septum at bottom; protosepta indicated by small arrows. Longitudinal sections are mostly at right angles to the plane of the cardinal and counter septa; positions of transverse sections indicated by small italic figures. (159) *N. gracile*, n.sp., the type specimen, no. KU7994–21a, from the Marble Falls limestone at Marble Falls, Texas; (160) specimen no. KU7994–21c, from the same locality as fig. 159 (the lower transverse section numbered 160a is an error for 160b); (161) specimen no. KU7994–21b, from the same locality as fig. 159. (162) *N. arcuatum*, n.sp., specimen no. P4022, from the Marble Falls limestone near Smith Crossing on Llano River, 4.8 miles southeast of London, Kimble County, Texas; (163) specimen no. P7234h, from the same locality as fig. 162; (164) type specimen, no. P7234b, from the same locality as fig. 162.

major septa are approximately equal in length. There are 26 major septa in the type specimen and larger corals may have as many as 30 septa. Minor septa are thin and extend two-thirds through the dissepimental zone.

A peripheral zone of very fine dissepiments reaches nearly half the distance to the axis in adult portions of the corallite. Close to the apex, dissepiments are confined to a narrow band. The axial edge of this zone is thickened to form an inner wall. Numerous anastomosing tabulae rise gently from the inner wall and turn abruptly upward at the column. In longitudinal sections the column is seen to be composed of the thickened vertical extensions of the tabulae. Transverse sections of the type specimen show a long median lamella in the counter-cardinal plane and a few short radiating lamellae that meet the median lamella at different points. In other specimens a median lamella is not differentiated. Some of the lamellae seem to be thinned extensions of the septa.

Discussion. — These long cylindrical corals are distinguished from those called *Neokoninckophyllum simplex* by their more complex axial column, small regular dissepiments, and more highly arched tabulae. The broad dissepimental zone and arched tabulae also serve to separate this species from *N. gracile*, n.sp. The numerous tabulae, broad dissepimental zone, and cylindrical shape of these corals are features found also in species of *Pseudozaphrentoides*, but the arched tabulae and axial column make it possible to separate them readily.

Occurrence.—Middle part of the Marble Falls limestone (Big Saline beds), Bendian, Lower Pennsylvanian (Upper Carboniferous); collected by F. B. Plummer, on the north side of Llano River about 600 feet east of the mouth of Big Saline Creek, 4.8 miles S. 45° E. of London, Kimble County, Texas (loc. 134–T–2).

Material studied.—Seven well-preserved specimens of this species were sectioned for study.

Type.—The University of Texas, Bureau of Economic Geology, specimen no. P–7234b.

NEOKONINCKOPHYLLUM GRACILE, n.sp.

Text figs. 158–161

Solitary cylindrical or very slightly tapering corals that have a moderately deep calyx and thin theca are included in this species. The exterior is marked by fine growth lines and irregular wrinkles. Septal grooves are lacking. The incomplete type specimen is 19.1 mm. in length and 12.3 mm. in maximum diameter. The largest corallite is 15.4 mm. in diameter at the calyx.

The long major septa extend nearly to the axis. They are thin in the peripheral dissepimental zone, thicken abruptly at the inner edge of this zone, and become attenuated toward the axis. The cardinal and counter septa are extended as a median lamella across the axial region. A few other septa may be extended to or nearly to this lamella. Minor septa remain short. Fossulae are not recognized. Regularly spaced dissepiments occur in a peripheral band, which increases in thickness towards the calyx. The innermost dissepiments are thickened to form a distinct inner wall. Numerous, almost vesicular, anastomosing tabulae rise gently toward the axis. In transverse section they appear as curved bars irregularly intersecting the septa. The thin median lamella is joined in the axial region by tabulae to form a simple column. In the transverse sections of most specimens the column consists of a median lamella, irregularly arranged tabulae, and the radiating axial portions of a few septa.

Discussion.—This species is characterized by its simple column, narrow dissepimental zone, and very anastomosing tabulae. It may be distinguished from *Neokoninckophyllum arcuatum*, n.sp., by its smaller size, simple axial column, and the appearance of the dissepiments in transverse section. In sections of *N. gracile*, the dissepiments are mostly parallel, whereas they have a distinctly herringbone arrangement in *N. arcuatum*. The relative narrow dissepimental zone, prominent median lamella, and strong inner wall separate *N. gracile* from the Morrowan coral, *N. simplex*, n.sp. The external markings of the theca and the dissepimental zone of these corals is similar to that found in *Pseudozaphrentoides* *lepidus*, n.sp., and other species of that genus. *Neokoninckophyllum gracile* is most easily distinguished by comparison of the longitudinal sections. It has a definite axial column whereas species of *Pseudozaphrentoides* have no axial structure.

Occurrence.—Marble Falls limestone, Bendian, Lower Pennsylvanian (Upper Carboniferous); collected by J. D. Ewers from the Marble Falls type section along Colorado River below the steel highway bridge, Marble Falls, Burnet County, Texas (Univ. Kansas loc. 7994).

Material studied.—Four well-preserved corallites and other fragmentary specimens were sectioned for study.

Type.—University of Kansas, specimen no. 7994–21a.

NEOKONINCKOPHYLLUM sp. A

Text figs. 165a-d

The single specimen comprising this form is a large corallite that is conical in the lower one-third but cylindrical in the upper portions. The very thin theca bears fine growth lines and sharp wrinkles, but septal markings are not seen on the unweathered surface. The poorly preserved calyx seemingly is broad and flat, except for the low axial boss. The coral is 51 mm. in length and 20.6 mm. in diameter at the calyx. The maximum diameter, 15 mm. below the top of the calyx, is 25.1 mm.

The major septa extend slightly over half the distance to the axis and are approximately equal in length, except for the shortened cardinal septum, which

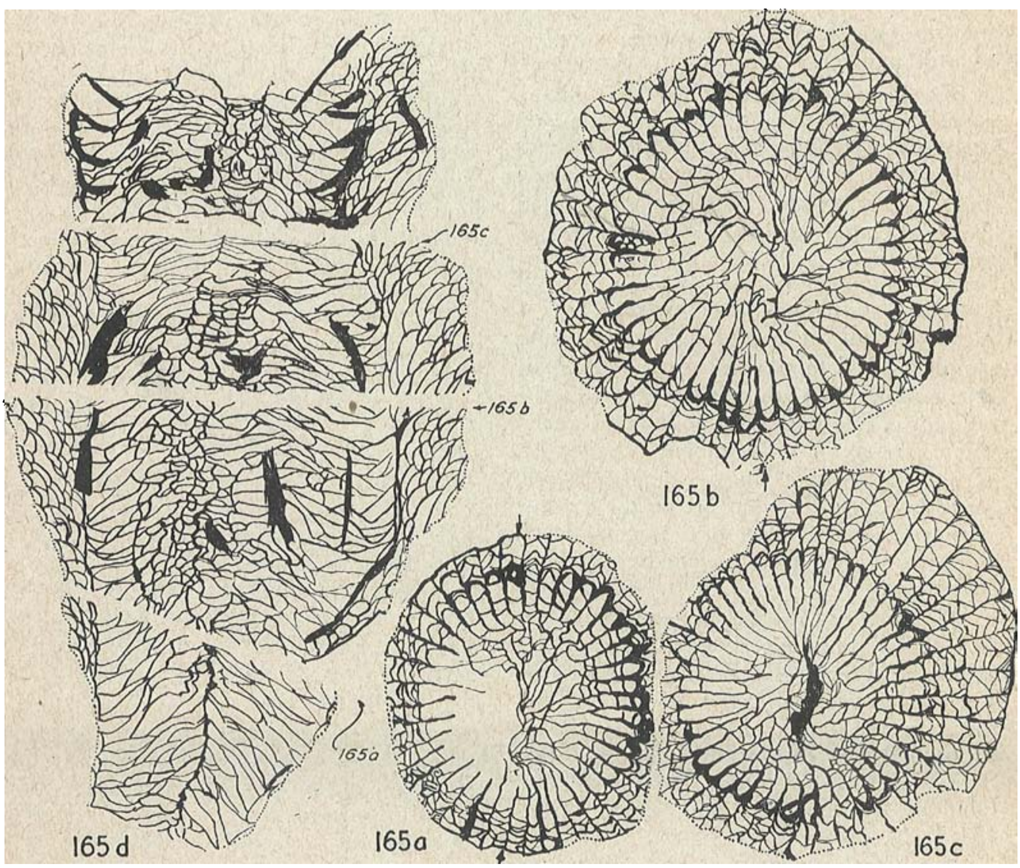

Fig. 165. Sections of *Neokoninckophyllum*, sp. A, x2.5. Specimen no. P7234d, from the Marble Falls limestone near Smith Crossing on Llano River, 4.8 miles southeast of London, Kimble County, Texas (loc. 134–T–2).

lies in a weak fossula. Throughout the corallite, the septa are thin in the dissepimental zone but thicken abruptly at the inner border of that zone. This feature, together with the thickening of the innermost dissepiments, forms a distinct inner wall. Transverse sections show the inner edges of some of the septa to be extended as wavy lamellae into the axial region. There are 46 long major septa and alternating short minor septa that extend only to the first dissepiments.

The peripheral band consists of relatively large unequal dissepiments that are developed oblique to the septa. The outer tabulate zone contains thin, somewhat anastomosing tabulae, which are horizontal or rise gently to the broad axial region. A broad column is formed by the irregularly disposed curved lamellae and closely spaced anastomosing tabulae. No thickened median lamella is recognized nor do lamellae join each other in any regular manner.

Discussion.—This specimen is from the same locality as corals called *Neokoninckophyllum arcuatum*, n.sp., and approaches that species in the nature of the septa and dissepiments. *N.* sp. A is separated from the latter species by its larger size and the type of its axial column. This broad column consists of many curved lamellae and numerous tabulae, but it lacks the distinct median lamella and simple arched tabulae of *N. arcuatum.* It is possible that this difference in the column is due merely to individual variation. *N.* sp. A differs from *N. simplex*, n.sp., *N. gracile*, n.sp., and *Dibunophyllum? inauditum*, n.sp., in the greater diameter of its column, the poor development of its median lamella, and its larger size.

Occurrence.—Middle part of the Marble Falls limestone (Big Saline beds), Bendian, Lower Pennsylvanian (Upper Carboniferous); collected by F. B. Plummer, on the north side of Llano River about 600 feet east of the mouth of Big Saline Creek, 4.8 miles S. 45° E. of London, Kimble County, Texas (loc. 134–T–2).

Material studied.—One large well-preserved corallite, which was sectioned, was available for study of this form (Univ. Texas, Bureau of Economic Geology, specimen No. P–7234d).

Family PORPITIDAE, n.fam.

Relatively small discoid to low conical solitary corallites are included in this family. The calyx is shallowly concave, to convex, showing edges of the septa strongly to very weakly defined or in part lacking trace of septa. A thin theca, generally wrinkled concentrically, is present. Some of the major septa may meet axially but there is no column. A tetrameral pattern of the corallite is commonly well developed. A cardinal fossula is more or less distinct; alar pseudofossulae may be present or absent. Tabulae and dissepiments are not observed. Range, Silurian to Pennsylvanian.

Discussion. — This family comprises specialized corallites of distinctive form that seem to be only rather distantly related to most other Rugosa. The assemblage has long been designated by the family name Palaeocyclidae (Dybowski, 1873), but this term cannot longer be used inasmuch as *Palaeocyclus* Edwards and Haime (1849) has been shown by Lang, Smith, and Thomas (1940, pp. 94, 104) to be an objective junior synonym of *Porpites* Schlotheim (1820). We propose the name Porpitidae to take the place of the invalidated designation Palaeocyclidae. Seemingly, no other family name, based on a genus included in this assemblage, has been published.

Genus CUMMINSIA, n.gen.

The normal form of corallites belonging to this new genus is that of a thick disc, but very gerontic individuals may be taller than wide. The base is nearly flat in most individuals; many specimens, however, have an irregular convex base that may be low conical or rounded. All corallites are distinguished by strongly marked wrinkles of the theca that are arranged concentrically around the subcentral small scar of attachment. At the periphery of the corallite the theca may be built upward more or less vertically, but only in rare individuals is the rim of the theca as high as the summits of the septa; typically the septa rise well above the thecate portion of the corallite.

The major septa are grouped in well-defined quadrants that are outlined by the very deep cardinal fossula, the slightly elongate, elevated counter septum, and the two alar pseudofossulae. The boundaries of the quadrants diverge from an excentric point located on the counter-cardinal line toward the counter side. The cardinal fossula is extraordinarily conspicuous owing to its steep sides and depth, especially in the central part of the corallite where a space near the terminus of the counter septum may be accented as an elongate pit. The cardinal septum, which is very short, is seen at the outer extremity of the cardinal fossula. The metasepta of the cardinal quadrants approach the fossula at a strong angle. The alar pseudofossulae are narrow and not appreciably deepened, but they are clearly marked by the strong angle between the long alar septa and the short septa of the counter quadrants. The counter quadrants are distinctly but not strongly accelerated. Extremely short minor septa are present or absent. Tabulae and dissepiments are lacking. Deposition of stereoplasm in layer on layer over the calyx produces gerontic types of corallites.

Genotype. — *Hadrophyllum aplatum* Cummins, Smithwick shale, Bendian, Lower Pennsylvanian (Upper Carboniferous); San Saba County, Texas.

Discussion.—The Smithwick corals that are here assigned to the new genus *Cumminsia,* named for the early investigator of Carboniferous and Permian rocks in Texas who first described these fossils, are not properly classifiable as belonging to *Hadrophyllum* Edwards and Haime (1850, p. lxvii). The genotype of *Hadrophyllum,* which is *H. orbignyi* Edwards and Haime (Pl. 14, figs. 12a, b), from Upper Devonian rocks of Indiana and Kentucky, resembles the type of *Cumminsia* only superficially. *Hadrophyllum* is a thick discoid coral, like *Cumminsia,* but it lacks the prominent, concentrically wrinkled theca that terminates upward as a sharply marked rim; the base of *Hadrophyllum orbignyi* is rather evenly rounded and this is true also of the periphery of the corallite, which lacks a rim separating theca from calyx. The cardinal fossula of *Hadrophyllum* is prominent, as in *Cumminsia,* but it is not deeply excavated and it is divided by a long slender cardinal septum. Most significant is the branching pattern of septa in each quadrant and the junction of the main septa near the center of the calyx. Alar pseudofossulae are absent in *Hadrophyllum orbignyi,* inasmuch as a majority of the septa of the counter quadrants are joined to the alar septa so as to make a pinnate pattern of branching. All these features—not to mention the flatness of the calyx of *H. orbignyi,* formed by low thin septa, as contrasted with the stoutly upraised septa of *Cumminsia aplata*—serve to distinguish *Hadrophyllum* from this new genus.

Cumminsia is distinguished from *Microcyclus* Meek and Worthen (1868, Pl. 14, figs. 14a, b, 15) by numerous characters, most important of which are the greater thickness of the corallite in *Cumminsia,* pronounced irregularity of the basal theca, absence of a broad central area lacking in septa, and the presence of a deep cardinal fossula. The septa of *Microcyclus* are much more evenly disposed radially than in *Cumminsia* and well-developed minor septa joined to adjacent major septa commonly occur. *Dipterophyllum* Roemer (1883), which is based on *Zaphrentis glans* White (Pl. 14, figs. 13a, b), from Lower Mississippian rocks, as genotype, resembles *Cumminsia* in the prominence of its deep cardinal fossula, distinct alar pseudofossulae, moderately long counter septum, and in the bulging elevation of the septa above the margin of the theca; it differs from the new genus here discussed in the form of the corallite, which is distinctly conical, and the apical region coming to a sharp point.

Occurrence. — Mississipian, Osagian; Kentucky; Bendian, Lower Pennsylvanian (Upper Carboniferous); central Texas. The species called *Hadrophyllum romingeri* Bassler (1937, p. 198, pl. 32, figs. 14–18), from the New Providence shale at Button Mold Knob, near Louisville, Kentucky, is a typical representative of *Cumminsia.*

CUMMINSIA APLATA (Cummins)

Pl. 14, figs. 16–23

Hadrophyllum aplatus [sic] CUMMINS, 1891, Texas Geol. Survey, 2nd Ann. Rept., p. 552, figs. 60, 61.

Hadrophyllum aplatum Cummins, BASSLER, 1937, Jour. Paleont., vol. 11, p. 200, pl. 32, figs. 19, 20.

This species is represented by discoidal to top-shaped corallites which become more or less cylindrical in gerontic stages. The base of typical specimens is nearly flat, but has an elevated point of attachment, called a peduncle, on the counter side of the center. This base is covered by theca bearing numerous concentric lines and ridges parallel to the periphery and having the peduncle as their center. In the more elongate forms the theca of the sides is marked by sharp ridges normal to and interrupting the poorly developed septal grooves. Weathered specimens show the septal grooves more distinctly. The specimens are mostly 20 to 25 mm. in diameter and 6 to 12 mm. in thickness. One specimen reaches a length of 29 mm.

The short cardinal septum lies in a deep fossula, which is deepest at the axis in most specimens, and rises abruptly against the axial end of the long counter septum. The septa are arranged in four groups that are separated by the two alar pseudofossulae, the cardinal fossula, and the strong counter septum. The last-formed septa are very short; these are located in the cardinal quadrants on either side of the cardinal septum and in the counter quadrants on the counter side of the alar septa. The progressively older septa in each quadrant, which are those going towards the counter septum from the cardinal and alar septa, increase in size and length. The counter septum and the alar septa are the longest and most prominent septa. Individual major septa are thin straight plates extending from the periphery to the edge of the fossula, where they enter a raised ridge of stereoplasm surrounding the fossula. The septal formula of a typical specimen is K 7 A 5 C 5 A 7 K. This indicates distinct acceleration of the counter quadrants. The alar pseudofossulae are formed on the counter side of the alar septa by the shortened immature septa. These pseudofossulae become inconspicuous in very advanced periods of growth.

Discussion.—The material available for study includes about 250 corallites, and seems to indicate wide individual variation. Most of the differences, however, are due to the gradual change of characteristics during growth. Many specimens agree closely with Cummins' original description and illustrations; associated with these are forms that grade toward the smallest, most immature individuals, on the one hand (Pl. 14, figs. 16–18), and the large cylindrical gerontic specimens, on the other (Pl. 14, fig. 21).

Cumminsia aplata is most closely related to the coral described as *Hadrophyllum romingeri* Bassler (1937, p. 198), from Lower Mississippian rocks of Kentucky. Indeed, this species seems to be assignable to *Cumminsia* without question. It is distinguished from *C. aplata* by its less sharply elevated peduncle, longer cardinal septum, and less well-developed counter septum. These two species agree in the small number of strong straight major septa, very poorly developed minor septa, large deep cardinal fossula, conspicuous alar pseudofossulae, and the merging of the septa in a stereozone around the fossula. *C. aplata* differs from *Microcyclus discus* Meek and Worthen (1868, p. 420) in the longer strongly developed major septa, deeply incised cardinal fossula, and well-developed alar pseudofossulae (Pl. 14, figs. 14a, b, 15).

Occurrence.—Smithwick shale, Bendian, Lower Pennsylvanian (Upper Carboniferous). The specimens were collected by F. B. Plummer in San Saba County, Texas, at the following localities: just south of the road fork, 1.1 miles southwest of Bend; along Colorado River, 1½ miles southwest of Bend; on Bend-Chappel road, 2 miles southwest of Bend (all descriptions apply to loc. 205–T–13); west of big tank in the Ellis pasture, 10½ miles S. 80° W. of San Saba courthouse (loc. 205–T–50); northwest of new tank on south side of escarpment, northwest part of Leonard ranch, 4.6 miles S. 33° E. of Richland Springs (loc. 205–T–79); tank east of Jack Wood's house, Gibbons' ranch, 7.5 miles S. 25° W. of Richland

Springs (loc. 205-T-71). Other specimens were collected by R. C. Moore 1 mile southwest of Bend.

Material studied.—About 250 specimens were available for study. Most of these are completely weathered from the concealing matrix and nearly all are excellently preserved.

Suborder TABULATA Edwards and Haime

This suborder embraces colonial corals that form hard parts consisting of loosely connected or closely packed tubes. The relatively thick walls of the tubes are intersected by pores or they are imperforate. Septa are extremely reduced or lacking, but the tubes are intersected commonly by tabulae, which may be very numerous. Dissepiments are lacking. Range, Ordovician to Cretaceous.

Discussion.—The origin and affinities of genera classed in the suborder Tabulata have long been problematical. Most forms included in the group seem to be somewhat closely related to the Hexacoralla, which are common in Mesozoic and younger deposits but not recognized in Paleozoic rocks. As a group, the Tabulata are differentiated from the Rugosa by the weakness or absence of septa, common occurrence of mural pores, average small size of the corallites and uniformly compound habit of growth. The Tabulata are regarded as a subdivision of the order Madreporaria.

Family FAVOSITIDAE Edwards and Haime

Massive or branching tabulate corals comprise this family. The corallites are invariably closely packed together and accordingly the tubes have a polygonal cross section. The walls of the tubes are perforated by pores. Septa are represented by low ridges or rows of short spines, or they are absent. Tabulae are commonly very numerous and they are regular or very irregular; in some genera many of the tabulae may be incomplete. Range, Ordovician to Permian.

Genus MICHELINIA de Koninck, 1842

Compound tabulate corals having highly variable form of the colonies, bearing a concentrically wrinkled holotheca at the base, and composed of closely packed prismatic corallites of moderately coarse size, are included in the genus *Michelinia.* The calices are deep, nearly smooth-sided polygonal depressions that vary considerably in size, and they are separated from one another only by the narrow, even crests of the walls that divide the corallites. These walls are very thin in some species but they attain a thickness of 1 mm. or slightly more in others; the walls are not excessively thickened in any specimens belonging to the genus, however. Irregularly spaced mural pores that commonly are visible to the unaided eye intersect the walls, both crossing them transversely so as to form direct connections between adjacent corallites and in places running in the plane of the walls. The corallite tubes contain numerous complete and incomplete tabulae; these may be so abundant and so arranged as to resemble vesicles. Very short septal spines or low striate longitudinal markings are seen on the walls of the corallites, but there are no true septa.

Genotype. — *Calamopora tenuisepta* Phillips, Lower Carboniferous, England.

Discussion.—This genus has been regarded by a few students of the corals as a junior synonym of *Pleurodictyum* Goldfuss (1829), which was described on the basis of molds of a very thick-walled colonial coral having the general aspect of *Favosites* or *Michelinia.* The genotype of *Pleurodictyum,* which is *P. problematicum* Goldfuss, has very numerour large mural pores that extend through the thick walls perpendicularly and tabulae are not closely spaced. These features, together with the thickened walls and low discoidal form of the corallum, seem to differentiate *Pleurodictyum* from *Michelinia* rather clearly. *Michelinia* differs from *Striatopora* in lacking the greatly thickened exterior "rind" of the corallum that is formed by laminated deposits of stereoplasm on the walls and in the calices of the corallites.

Occurrence. — Devonian to Permian; Europe, Asia, Australia, North America.

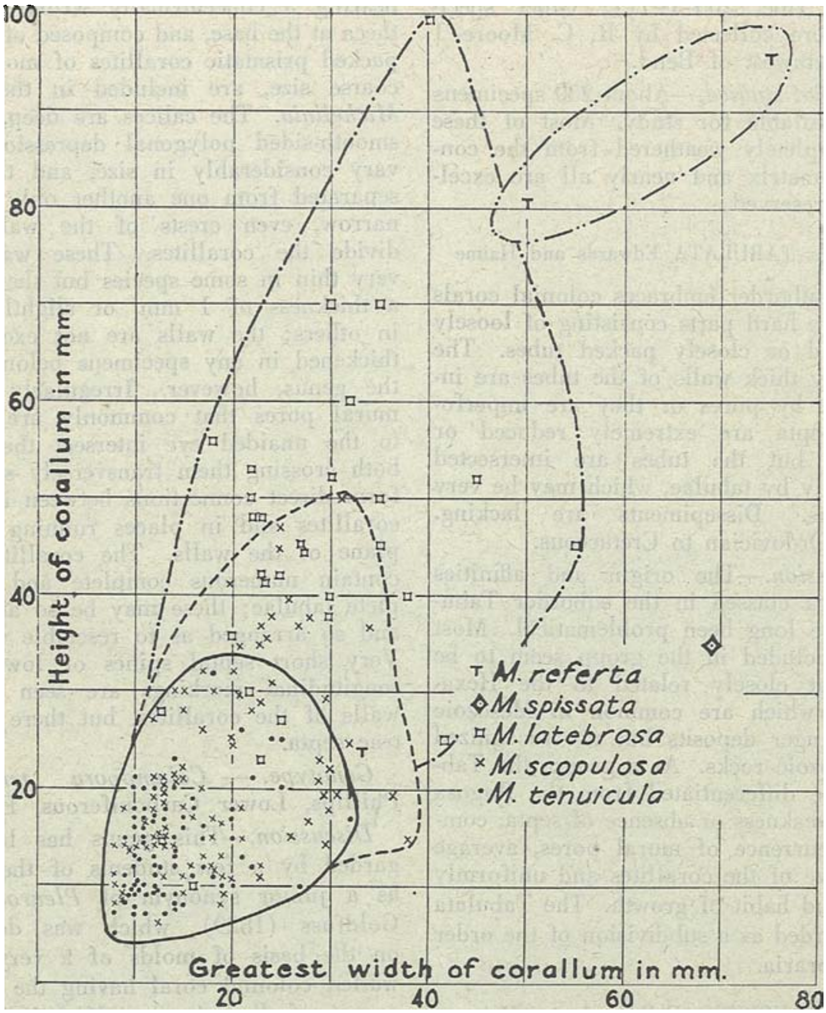

Fig. 166. Diagram showing form ratios of coralla representing Hale, Brentwood, Wapanucka, and Marble Falls species of *Michelinia.*

MICHELINIA EXILIMURA Mather

Michelinia exilimura MATHER, 1915, Denison Univ. Bull., Jour. Sci. Labs., vol. 18, p. 96, pl. 2, figs. 2, 2a. Morrowan, near Choteau, Mayes County, Oklahoma.

not *Michelenia* [sic] *exilimura* Mather MORGAN, 1924, Oklahoma Bur. Geol., Bull. 2, pl. 35, fig. 2. "Upper Caney shale," southern Oklahoma.

This is a robust species that may attain a diameter of 125 mm., according to Mather. The type specimen is 70 by 75 mm. in width and 50 mm. in height. The corallites are unusually thin-walled and attain a diameter of 6 mm. The tubes are crossed by curved tabulae, 5 to 7 occurring in a space equal to the diameter of the corallite. Mural pores are small and not abundant.

Discussion.—We have found no specimens in our fairly large collection from Oklahoma and Arkansas that seem to be assignable to *Michelinia exilimura.* Judging by Mather's illustrations and description, this species is most like the upper Marble Falls and Smithwick specimens from Texas that are described here as *M. referta,* n.sp., in which the tabulae are much more crowded and the corallites a little larger in greatest diameter. The specimen from Lower Pennsylvanian beds called "upper Caney shale" in NE. ¼ sec. 29, T. 3 N., R. 7 E., Oklahoma, does not belong to *M. exilimura*, according to our view, but is assigned here to *M. latebrosa*, n.sp.

Occurrence.—The only records yet published are those of Mather's specimens, from two localities in Morrowan beds, near Choteau, Oklahoma.

Type.—University of Chicago, Walker Museum.

MICHELINIA SPISSATA, n.sp.

Text figs. 170, 180

The corallum of this species is ovoid in shape, wider than high; the type is 70 mm. in greatest width and 40 mm. high. The corallites attain a diameter of 5 mm. and their apertures are mostly rounded, rather than sharply polygonal, owing to thickening of walls at angles of the tubes. The walls range in thickness from 0.45 to 1.3 mm., the average being about 1 mm. Mural pores, 0.13 to 0.17 mm. in diameter, are very numerous, at many places being spaced 0.5 mm. apart or less. Stout curved tabulae are abundant but not extremely crowded; most of them are incomplete; arched gently upward, and joined together so as to form a coarse vesiculose structure.

Discussion.—The chief distinguishing features of *Michelinia spissata*, n.sp., are the uniformly thick walls, abundant mural pores, and numerous, fairly evenly spaced, arching tabulae. This species differs from *M. referta*, n.sp., in the smaller size of the corallites, thicker walls, much more prominent mural pores, and stouter, more regular and less crowded tabulae. It is distinguished from *M. latebrosa*, n.sp., and *M. scopulosa*, n.sp., by its larger corallites, thicker walls, and more numerous mural pores.

Occurrence. — Brentwood limestone, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore at "Acorn Cut" on railroad, 2 miles northwest of Brentwood, Arkansas (sec. 23, T. 14 N., R. 30 W.).

Type.—University of Kansas, specimen no. 720.

MICHELINIA SCOPULOSA, n.sp.

Pl. 14, figs. 10, 11; text figs. 174–178, 183, 184

Michelinia eugeneae White, MATHER [part], 1915, Denison Univ. Bull., Jour. Sci. Labs., vol. 18, p. 96, pl. 1, figs. 17, 17a, pl. 2, fig. 1; from the Brentwood limestone near Brentwood and Fayetteville, Arkansas, and Sawney Hollow, Oklahoma, and from Kessler limestone, near Fort Gibson, Choteau, Hulbert, and Gore, Oklahoma. MORGAN [part], 1924, Oklahoma Bur. Geol., Bull. 2, pl. 35, figs. 1, 1a; from the Wapanucka limestone, SE. ¼ sec. 8, T. 1 N., R. 7 E., Oklahoma.

Small coralla of extremely variable growth form are included in this species. Most specimens show the presence of a well-developed, strongly wrinkled holotheca at the base of the colony, and the irregular construction of corallites above the holotheca produces coralla that mostly exceed 15 mm. in height and greatest width and that in few specimens are more than 30 mm. across in any direction. Globose, subconical, cylindrical, explanate, and shapes that cannot be indicated clearly by a single adjective are almost equally common. The corallites are small and comparatively thin-walled; their greatest diameter is about 3 mm. and although many calices attain this size, none exceed it by as much as 0.5 mm. The walls are straight or gently curved and they may be angulated, but they are not minutely flexuous; their thickness ranges from 0.3 to 0.8 mm., the average being less than 0.5 mm. The summits of the walls, which form the dividing lines between adjoining calices, are sharp-crested and slightly denticulate in well-preserved specimens. The depth of the calices is equal to the diameter of the corallites, or somewhat less, and the walls may show faint closely spaced longitudinal markings and the openings of a few mural pores. The pores range in diameter from 0.08 to 0.26 mm.; they are common in the peripheral parts of colonies but less so in the axial region. Thin tabulae, some of which are incomplete and branching from other tabulae, are closely spaced in the corallites, 10 to 12 commonly occurring in a distance of 5 mm. along the tube.

An interesting specimen of subhemispherical form that is questionably referred to this species (figs. 184a–d) differs from normal examples in having no observed tabulae. Accordingly the calices have unusual depth (fig. 175).

Discussion.—This coral, which is abundant in Morrowan beds of northeastern Oklahoma and seemingly less common in other areas, has been identified as *Michelinia eugeneae* White, which was described from Pennsylvanian rocks of indeterminate horizon or horizons in Indiana and Illinois. White (1884, p. 119, pl. 23, figs. 14–16) published illustrations of the exterior of three specimens, each so different from the others as to indicate at once either that the species is surprisingly variable not only in growth form but size of corallites, or that more than a single species was represented in the specimens studied and figured by White. No illustrations of the internal structure of *M. eugeneae* were given by the author. During the last half-century, almost any Pennsylvanian *Michelinia* has been assigned to *M. eugeneae,* and it has even been reported (Yakovlev, 1903, p. 7, pl. 1, figs. 3, 5) from the Donetz Basin in the U.S.S.R., and a variety of the species has been described from Mississippian rocks. Until critical study is given to type material, *M. eugeneae* is an unrecognizable species.

Michelinia scopulosa most closely resembles *M. tenuicula,* n.sp., which occurs in the same rocks and area as the species here considered and which is also characterized by small coralla of highly variable shape. *M. scopulosa* is most readily distinguished from associated specimens of *M. tenuicula* by the larger diameter that is attained by many of its corallites. The walls surrounding the calices of *M. tenuicula* are somewhat thicker than in *M. scopulosa,* their crests blunter, and the sides more prominently marked by fine spinose ridges. In examination of large collections, there are few specimens that offer difficulty in seeming to combine characters belonging to the two forms. Numerous specimens that have been sectioned show that the walls of *M. tenuicula* are proportionally a little thicker, less regular, and marked by more numerous mural pores, and the tabulae are generally distinctly more crowded.

Comparison of the dimensions of coralla identified as belonging to this species and others from Lower Pennsylvanian rocks is shown graphically in figure 166. This indicates that the size of colonies assigned to *M. scopulosa* overlaps the range of *M. tenuicula,* but the latter does not attain the dimensions observed in many specimens of the former. The size of coralla is not in itself a definitive character ordinarily, but in conjunction with other features it aids in identification of a species.

Occurrence.—Morrowan, Lower Pennsylvanian (Upper Carboniferous); found at several localities in northeastern Oklahoma and northwestern Arkansas. The species is especially common in beds classed as belonging to the Hale formation, at the spillway below Greenleaf reservoir (near cen. sec. 10, T. 13 N., R. 20 E.), southeast of Braggs, Oklahoma,

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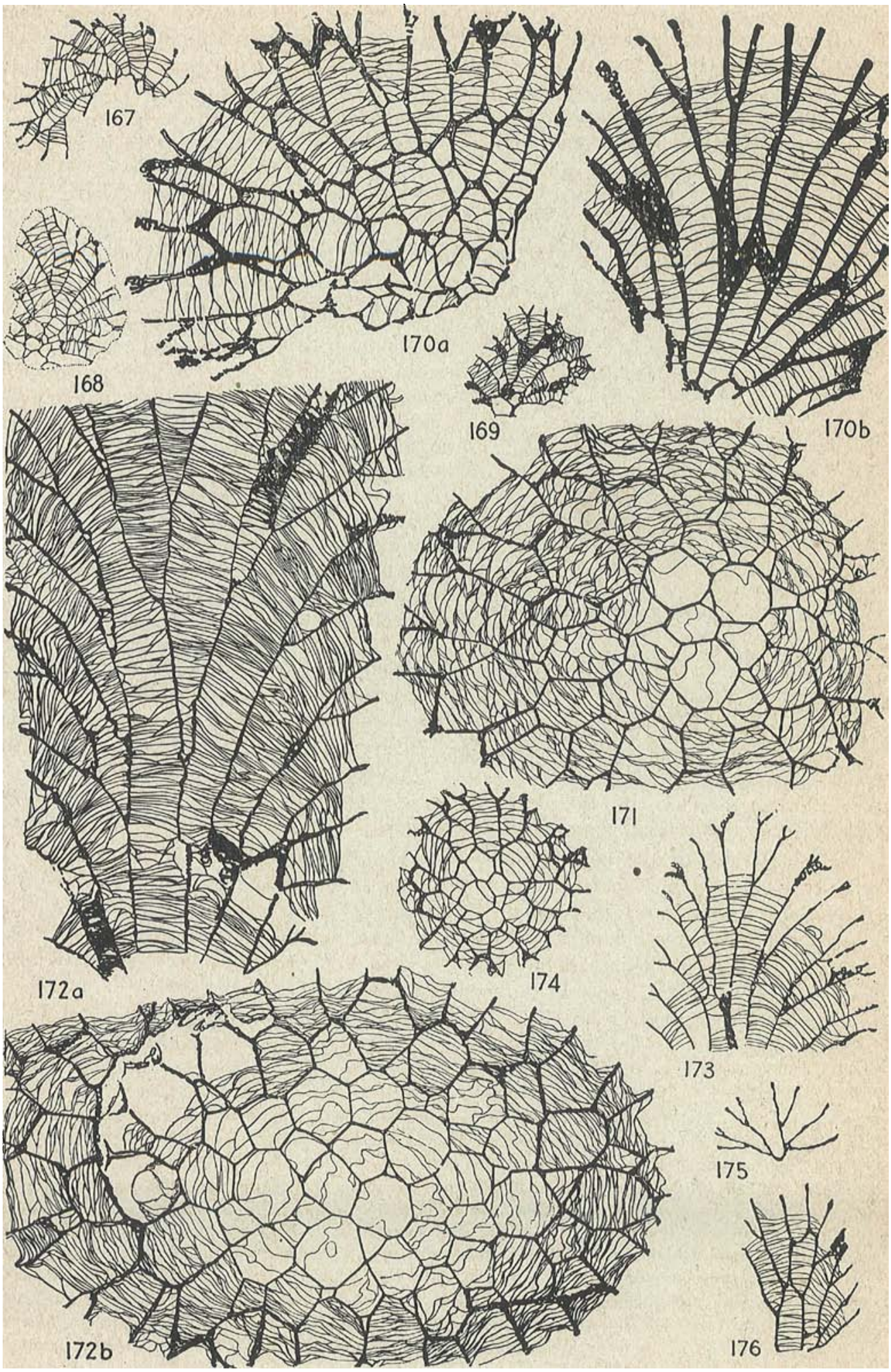
Figs. 167–176. Sections of Hale, Brentwood, Wapanucka, Otterville, Smithwick, and Marble Falls favositid corals, x1.5, all belonging to the genus *Michelinia* deKoninck. (167) *M. tenuicula,* n.sp., specimen no. KU7744–21g, from the Hale formation near Keough quarry, north of Fort Gibson, Oklahoma; (168) specimen no. KU7744–21h, from the same locality as fig. 167; (169) type specimen, no. KU7385–25k, from the Hale formation at Greenleaf Lake, southeast of Braggs, Oklahoma. (170) *M. spissata,* n.sp., type specimen, no. KU720, from the Brentwood limestone at Acorn Cut, south of Fayetteville, Arkansas. (171) *M. referta,* n.sp., specimen no. KU7511—23a, from the (?) Marble Falls limestone on Turkey Roost Creek, 10 miles almost due south of Richland Springs, San Saba County, Texas; (172) type specimen, no. P11782, from the Smithwick shale near tank east of Jack Wood's house, 7.5 miles south-southwest of Richland Springs, San Saba County, Texas (loc. 205–T–71). (173) *M. latebrosa,* n.sp., specimen no. KU7142–21c, from the Otterville limestone about 5 miles north of Ardmore, Oklahoma. (174) *M. scopulosa,* n.sp., specimen no. KU7385–25n, type specimen, from same locality as fig. 169; (175) specimen no. KU7385–25L, from the same locality as fig. 169; (176) specimen no. KU7385–25m, from the same locality as fig. 169.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and near Keough quarry (sec. 36, T. 16 N., R. 19 E.), about 2 miles north of Fort Gibson, Oklahoma.

Type.—University of Kansas, specimen no. 7385–25n, from the Hale formation at Greenleaf reservoir; collected by R. C. Moore and L. R. Laudon.

MICHELINIA TENUICULA, n.sp.

Text figs. 167–169, 181

Michelinia eugeneae White, MATHER [part], 1915, Denison Univ. Bull., Jour. Sci. Labs., vol. 18, p. 96; Morrowan beds, northeastern Oklahoma.

Colonies belonging to this species are very irregular in shape and most of them are very small, ranging in height or width to about 30 mm. as a maximum; most specimens have a greatest measurement across the corallum of less than 20 mm. A strongly wrinkled holotheca covers the base and generally it has a roughly circular margin; a common feature is the occurrence of outlying patches or strips of epitheca separated from the base by the calices of a number of corallites. The maximum size attained by the corallites is 2 mm. The walls between the tubes range in thickness from 0.18 to 0.85 mm., which is about the same as in *Michelinia scopulosa,* n.sp., but the walls seem thicker because of their bluntly pointed crests between calices and because of the small size of the corallites. The walls have slightly uneven edges as seen in section. They are perforated by numerous mural pores having a diameter of 0.12 to 0.15 mm. Thin tabulae, complete and incomplete, mostly arched gently upward, are numerous, 10 to 14 occurring in 3 mm. The sides of the calices of well-preserved specimens bear longitudinal rows of minute spines.

Discussion.—This species is not likely to be confused with any other except *Michelinia scopulosa,* which is associated with it and which resembles it in irregularity of form and small size. Distinctions between these species have been noted under discussion of *M. scopulosa.* It is probable that examples of *M. tenuicula* were included by Mather (1915, p. 96) in *M. eugeneae* White, although none were figured by him; certainly they were contained in his collection. It is interesting to note that specimens of *M. tenuicula* are greatly outnumbered by colonies of *M. scopulosa* in collections from the Greenleaf reservoir locality in northeastern Oklahoma, whereas the reverse is true at the Keough quarry locality, which is about 15 miles northwest of Greenleaf reservoir.

Occurrence.—Hale formation, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore, L. R. Laudon, and University of Kansas students at spillway below Greenleaf reservoir (cen. sec. 10, T. 13 N., R. 20 E.) and near Keough quarry (sec. 36, T. 16 N., R. 19 E.), both in northeastern Oklahoma.

Type.—University of Kansas, specimen no. 7385–25k, from Greenleaf reservoir.

MICHELINIA LATEBROSA, n.sp.

Text figs. 173, 179

?*Michelenia* [sic] *exilimura* Mather, MORGAN, 1924, Oklahoma Bur. Geol., Bull. 2, pl. 35, fig. 2; "Upper Caney shale," NE. ¼ sec. 29, T. 3 N., R. 7 E., Oklahoma.

This species is described on the basis of about 75 specimens from the Jolliffe

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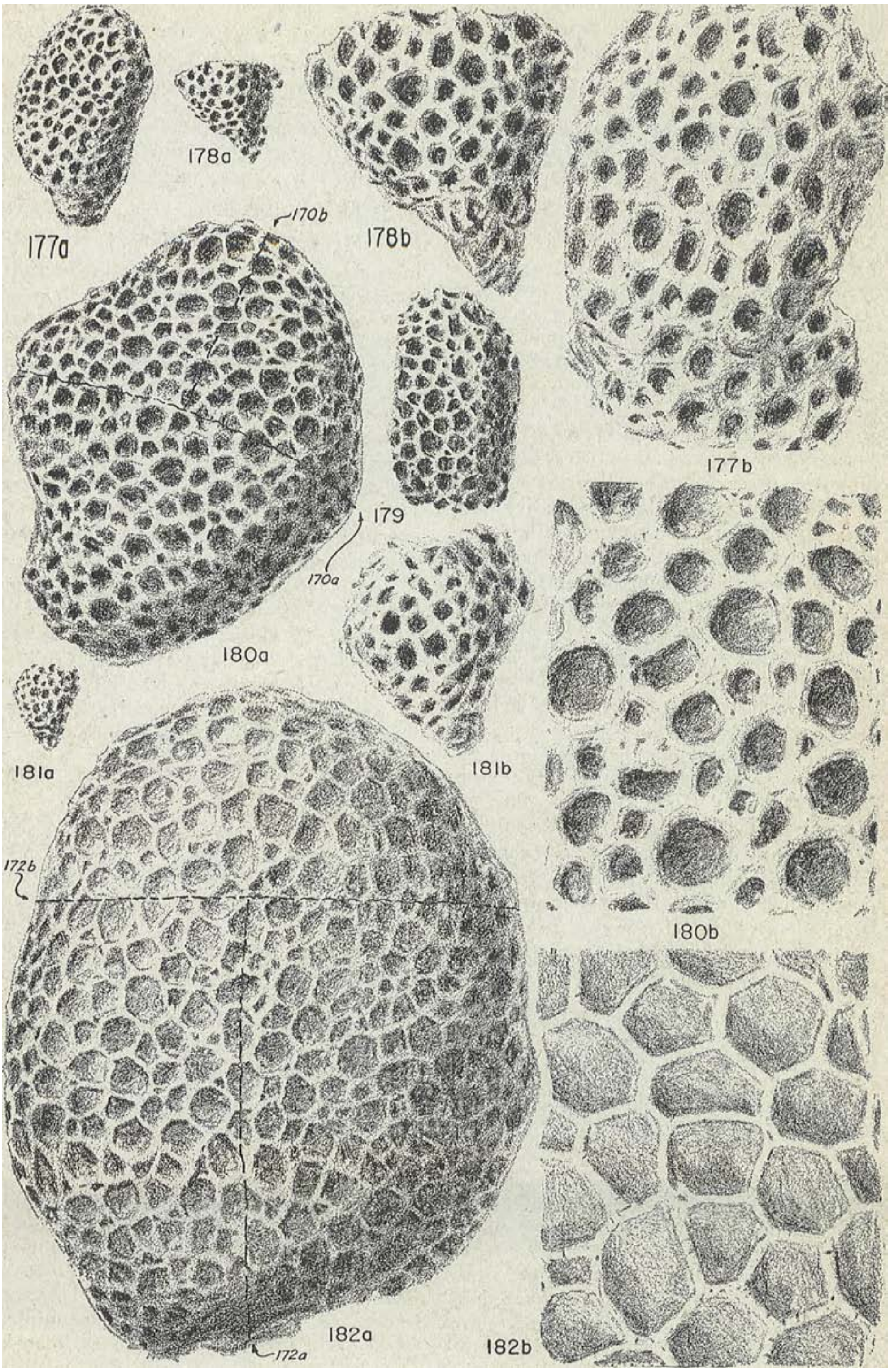
Figs. 177–182. Exterior views of Hale, Brentwood, Otterville, and Smithwick favositid corals belonging to the genus *Michelinia* deKoninck. (177) *M. scopulosa,* n.sp., type specimen, no. KU7385–25n, from the Hale formation at Greenleaf Lake, southeast of Braggs, Oklahoma; 177a, x1; 177b, x2.5; (178) specimen no. KU7744–26a, from the Hale formation at Keough quarry, north of Fort Gibson, Oklahoma; 178a, x1; 128b, x2.5. (179) *M. latebrosa,* n.sp., x1, type specimen, no. KU71421, from the Otterville limestone on U.S. highway no. 77 about 5 miles north of Ardmore, Oklahoma. (180) *M. spissata,* n.sp., type specimen, no. KU720, from the Brentwood limestone at Acorn Cut, south of Fayetteville, Arkansas; 180a, x1; 180b, x2.5. (181) *M. tenuicula,* n.sp., type specimen, no. KU7385–25k, from the same locality as fig. 177; 181a, x1; 181b, x2.5. (182) *M. referta,* n.sp., type specimen, no. P11782, from the Smithwick shale on Gibbons' ranch, 7.5 miles south-southwest of Richland Springs, San Saba County, Texas (loc. 205–T–71); 182a, x1; 182b, x2.5.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and Otterville limestones of southern Oklahoma, and several additional specimens from the Marble Falls limestone of Texas and Morrowan strata of northwestern Arkansas and northeastern Oklahoma. The coralla are variable in shape and size but they tend to be subcylindrical, higher than wide, and they are intermediate between robust species, such as *Michelinia referta*, n.sp., and *M. spissata*, n.sp., and the common diminutive species of Morrowan age, *M. scopulosa*, n.sp., and *M. tenuicula* n.sp. The largest observed specimen has a height of 108 mm. and a greatest width of 40 mm.; average specimens measure about 50 mm. in height and 25 to 30 mm. in width. The colonies generally come to a point at the base, but only one or two specimens show the presence of small areas covered by holotheca; virtually the entire surface of the corallum is normally occupied by calices. The corallites are regular, bounded by straight or gently curved walls of moderate thickness (0.22 to 0.60 mm., average 0.45 mm.), and attaining a diameter of 4 mm. at full size; numerous calices 3.5 to 4 mm. in diameter are seen at the surface of specimens belonging to this species, and the calices are characterized by depth that commonly exceeds the width. Mural pores ranging in diameters from 0.09 to 0.25 mm. are widely spaced and generally not abundant in any part of the coralla as examined in sections, but longitudinal rows of pores, spaced about 0.4 mm. apart, may be seen on the side walls of calices. Tabulae are fairly strong, mostly complete, rather evenly spaced, 6 or 7 in 5 mm.

Discussion.—This species most closely resembles *Michelinia scopulosa*, which is extremely common in Morrowan deposits of northeastern Oklahoma. The latter species is characterized by distinctly smaller coralla (fig. 166) that are highly erratic in form and they bear a prominent holotheca; the corallites attain a greatest diameter of only slightly more than 3 mm. and the average size of the calices is perceptibly smaller than *M. latebrosa*. The tabulae of *M. scopulosa* generally are more crowded and more irregular than in the species here described. The sections of a *Michelinia* from a sandy limestone classed as belonging in the upper part of the "Caney shale" north of the Arbuckle Mountains in southern Oklahoma, identified by Morgan (1924, p. 194) as *M. exilimura* Mather, show characters like those of *M. latebrosa* and may represent this species; the corallites are much smaller than in *M. exilimura*.

Occurrence.—This species is abundant in parts of the Jolliffe and Otterville limestones, Morrowan, Lower Pennsylvanian (Upper Carboniferous), near Ardmore, Oklahoma. The collections studied were obtained chiefly from outcrops along U. S. highway No. 77 about 5 and 7 miles north of Ardmore. Two specimens, presumably from middle Marble Falls limestone (Bendian) on Honey Creek, about 7 miles southwest of Mason, Texas (loc. 159–T–1) are referred to this species. Two specimens from the Brentwood limestone at outcrops along U. S. highway No. 71 near Woolsey, Arkansas, correspond to the Jolliffe and Otterville specimens except for their slightly thicker walls.

Type.—University of Kansas, specimen no. 71421, from the Otterville limestone, 5 miles north of Ardmore, Oklahoma.

MICHELINIA REFERTA, n.sp.

Text figs. 171, 172, 182

Large ovoid coralla composed of relatively large thin-walled prismatic corallites having very abundant flexuous to vesiculose tabulae are included in this new species. The height of observed colonies exceeds the width, but the growth form seems to be massive rather than ramose. The corallites have an average diameter of about 5.7 mm. but there are many tubes measuring up to 7 mm. across. The thickness of the walls ranges from 0.25 to 1 mm., the average being about 0.4 mm. The thin walls are perforated by a few widely spaced small mural pores; the outer parts of the coralla, which commonly have slightly thicker walls, possess more numerous pores, 0.1 to 0.22 mm. in diameter. Tabulae having a thickness of 0.03 mm. or less are crowded. They are irregularly curved and many incomplete tabulae are joined together so as to make a vesicular structure.

Discussion.—The size of the coralla, large diameter of the corallites, relatively thin walls, and numerous fine tabulae belonging to this species are characters common to *Michelinia exilimura* Mather, from Morrowan beds in northeastern Oklahoma. *M. referta* has corallites a little larger than those of Mather's species and tabulae that are much more closely crowded and irregularly vesiculose. The latter character mainly distinguishes the Texas coral.

Occurrence.—(?)Marble Falls limestone, Bendian, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore, on Turkey Roost Creek, southwest of San Saba, Texas (loc. 205–T–84 or Univ. Kansas loc. 7511); also collected by F. B. Plummer and R. C. Moore on King Creek, about 1300 ft. southwest of King Springs, Jym Sloan ranch, 12.9 miles S. 74° W. of courthouse at San Saba, Texas (loc. 205–T–65 or Univ. Kansas loc. 7079), Smithwick shale, Bendian; collected by F. B. Plummer near tank east of Jack Wood's house, Gibbons' ranch, 7.5 miles S. 25° W. of Richland Springs, San Saba County, Texas (loc. 205–T–71).

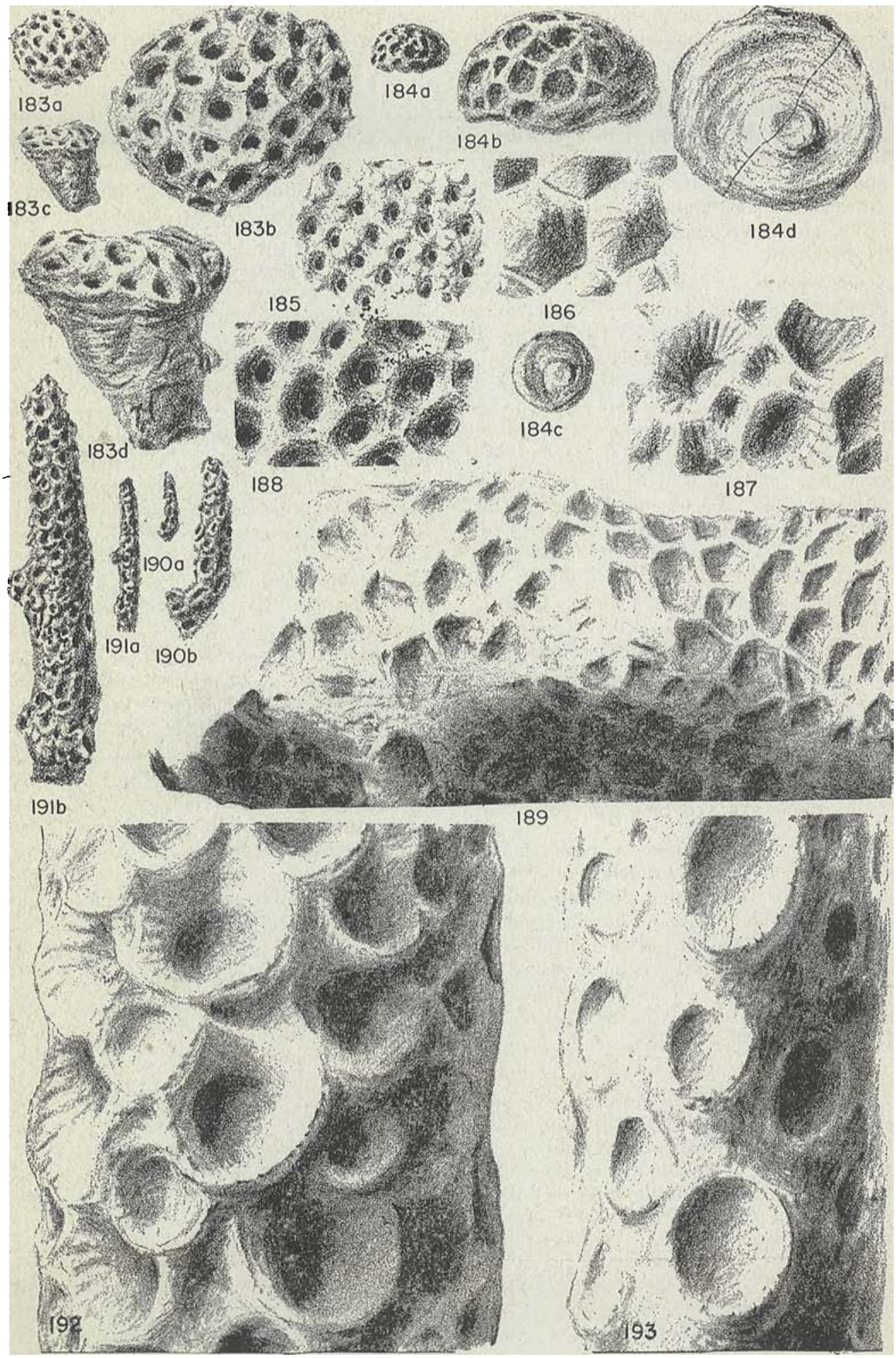
Type.—The University of Texas, Bureau of Economic Geology, specimen no. P–11782, from the Smithwick shale (loc. 205–T–71).

Genus STRIATOPORA Hall, 1851

This genus comprises colonial corals that build irregular branches of varying size, the corallum being divisible into an immature axial region characterized by relatively thin-walled polygonal tubes and a mature peripheral region marked by thick deposits of stereoplasm that constrict and tend to fill the apertures. The walls of corallites in the immature region are intersected by a few widely spaced mural pores that generally are small and inconspicuous. In the peripheral region the walls are greatly thickened by successive laminae of calcareous tissue that slope downward from the midline of the wall toward the open space of the corallite tubes, constricting and rounding them or filling them. The surface of well-preserved coralla shows crater-like depressions of somewhat even or quite uneven size marked longitudinally by grooves and ridges. The interspaces between the depressions vary in width, and they range from rounded to angular in vertical profile. Complete or incomplete tabulae are numerous both in the immature and mature regions.

Genotype.—*Striatopora flexuosa* Hall, Hamilton, Middle Devonian, New York.

Discussion.—Corals of this general type are a subject of considerable taxonomic uncertainty. The structural nature of the immature portion of the corallites is closely comparable with that of *Favosites*, and some investigators have been inclined to doubt the value of thickened walls in the peripheral region as generically important. Most students agree, however, that these corals are quite distinct from *Favosites* and *Michelinia*, which lack pronounced thickening of the walls near the surface and which commonly have numerous large mural pores. The genera *Thamnopora* Steininger (1831), *Striatopora* Hall (1851), and *Pachypora* Lindström (1873) have been introduced for peripherally thick-walled favositid corals, and partly because of a lack of satisfactorily definite information on characters of the type species of these genera, partly because of doubt as to the classificatory importance of some observed characters, and partly because of the diversity of fossils seemingly belonging in the group, different species have been assigned to one genus or another on rather insecure grounds. According to Hill (1937, p. 56) and Lang, Smith, and Thomas (1940, p. 92), studies of the genotypes of *Thamnopora* and *Pachypora* indicate convincingly that the latter is a junior synonym of the former. The walls of the corallites in *Thamnopora* are thick in the immature region, as well as in the still thicker-walled mature region, tabulae are rather widely spaced, and mural pores are reported to be large. The genotype of *Thamnopora*, which is *Alveolites cervicornis* Blainville, has closely spaced diminutive corallites only slightly more than 1 mm. in diameter and walls of the axial region nearly as thick as those near the surface. Illustrations of this species bear little resem-


183a
184a
184b
183c
183b
184d
185
186
183d
184c
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187
190a
191a
190b
191b
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193

blance to those of Pennsylvanian corals here assigned to *Striatopora*.[5]

Occurrence.—Species belonging to *Striatopora* seem to include corals ranging from Silurian to Permian.

STRIATOPORA OKLAHOMENSIS (Snider)

Text figs. 188, 189, 195–197

Pachypora oklahomensis SNIDER, 1915 (July), Oklahoma Geol. Survey, Bull. 24, p. 72, pl. 3, figs. 7, 8. ?Morrowan (reported from the "Mayes" formation, northwest of Grove, northern Delaware County, Oklahoma).

Pachypora carbonaria MATHER, 1915 (December), Denison Univ. Bull., Jour. Sci. Labs., vol. 18, p. 94, pl. 1, figs. 15, 16. Brentwood limestone, Morrowan, near Brentwood, Arkansas, and near Fort Gibson and Chotcau, Oklahoma.

Irregular ramose colonies of tabulate corals having a strongly thickened peripheral region and thin-walled immature region are referred to this species. The coralla have an ovoid transverse section, 15 to 40 mm. in diameter, the average being about 20 mm. The colonies branch irregularly at intervals of 50 mm. or more. A large incomplete corallum (fig. 197), collected near Hulbert, Oklahoma, measures 150 by 300 mm. and consists of numerous branches. The surface is marked by the rounded depressions of small calices, which average 2 to 3 mm. in width; in well-preserved specimens the interspaces between calices are seen to be fairly sharp crested but commonly these spaces are worn to a rounded form. The corallites are closely packed and have a polygonal cross section. The walls are thin in the immature region but extremely thick near the surface of the corallum. Mural pores are not common. Complete or incomplete tabulae, the latter joined to the former, are numerous, both in the immature and mature regions; commonly there are 3 or 4 tabulae in a space equal to the diameter of the corallite.

Discussion.—Study of the figures and descriptions for "*Pachypora*" *oklahomen-*

[5]A paper by John W. Wells (New tabulate corals from the Pennsylvanian of Texas: Jour. Paleont., vol. 18, no. 3, pp. 259–262, pls. 40, 41, May, 1944) published long after the manuscript of the present report was submitted for printing, contains excellent illustrations of the exterior of the genotype of *Striatopora* but no figures showing internal structure. Adequate representation of structural features belonging to this coral (*S. flexuosa*) is much needed. All the Pennsylvanian specimens figured by Wells, which he classes as representing four species of *Striatopora*, differ markedly from the Lower Pennsylvanian forms here assigned to this genus in that walls of corallites in the axial region are notably thicker in Wells' specimens, and (except in *S. moorei*) the axial region comprises only a small fraction of the branches. Whether the corals described by Wells and those here referred to *Striatopora* are congeneric and are properly assigned to Hall's genus based on *S. flexuosa* may well be questioned.

Figs. 183–193. Exterior views of Hale, Brentwood, and Marble Falls favositid corals. (183) *Michelinia scopulosa*, n.sp., specimen no. KU7744–26b, from the Hale formation at Keough quarry, north of Fort Gibson, Oklahoma; 183a, top of corallum, x1; 183b, same, x2.5; 183c, side view of corallum showing holotheca, x1; 183d, same, x2.5. (184) *M. scopulosa?*, n.sp., specimen no. KU7385–25L, from the Hale formation at Greenleaf Lake, southeast of Braggs, Oklahoma; 184a, side view of corallum, x1; 184b, same, x2.5; 184c, bottom of corallum showing holotheca and peduncle, x1; 184d, same, x2.5, the position of the section shown in fig. 175 being indicated. (185) *Striatopora immota*, n.sp., part of the surface of type specimen, no. P9364, x2.5, from the Brentwood limestone about 1.5 miles northeast of Fayetteville, Arkansas. (186) *S. religiosa*, n.sp., part of the surface of type specimen, no. P12201a, showing the narrow crest along walls between corallites, x2.5, from the upper Marble Falls limestone, 5 miles south-southwest of Hall, San Saba County, Texas (loc. 205–T–87); (187) specimen no. P12196, x2.5, showing distinct septal ridges in calices, from the same locality as fig. 186. (188) *S. oklahomensis* (Snider), specimen no. P9618, part of the surface, x2.5, showing nature of calices, from the Brentwood limestone, near Woolsey, Arkansas; (189) specimen no. P12201, x2, from the same locality as fig. 188. (190) *Acaciapora subcylindrica* (Mather), n.gen., specimen no. KU7385–26h, from the Hale formation at Greenleaf Lake, southeast of Braggs, Oklahoma; 190a, x1; 190b, x.2.5; (191) specimen no. KU7385–26b, from the same locality as fig. 190; 191a, x1; 191b, 2.5; (192) specimen no. KU7385–26f, part of surface, x13.5, showing projecting rims of calices and their partially overlapping nature. (193) *A. venusta*, n.sp., part of type specimen no. P11222, x13.5, showing the fairly even rims of the calices and broad interspaces, from the base of the Marble Falls limestone on Wallace Creek, 10 miles southwest of San Saba, Texas (loc. 205–T–43).

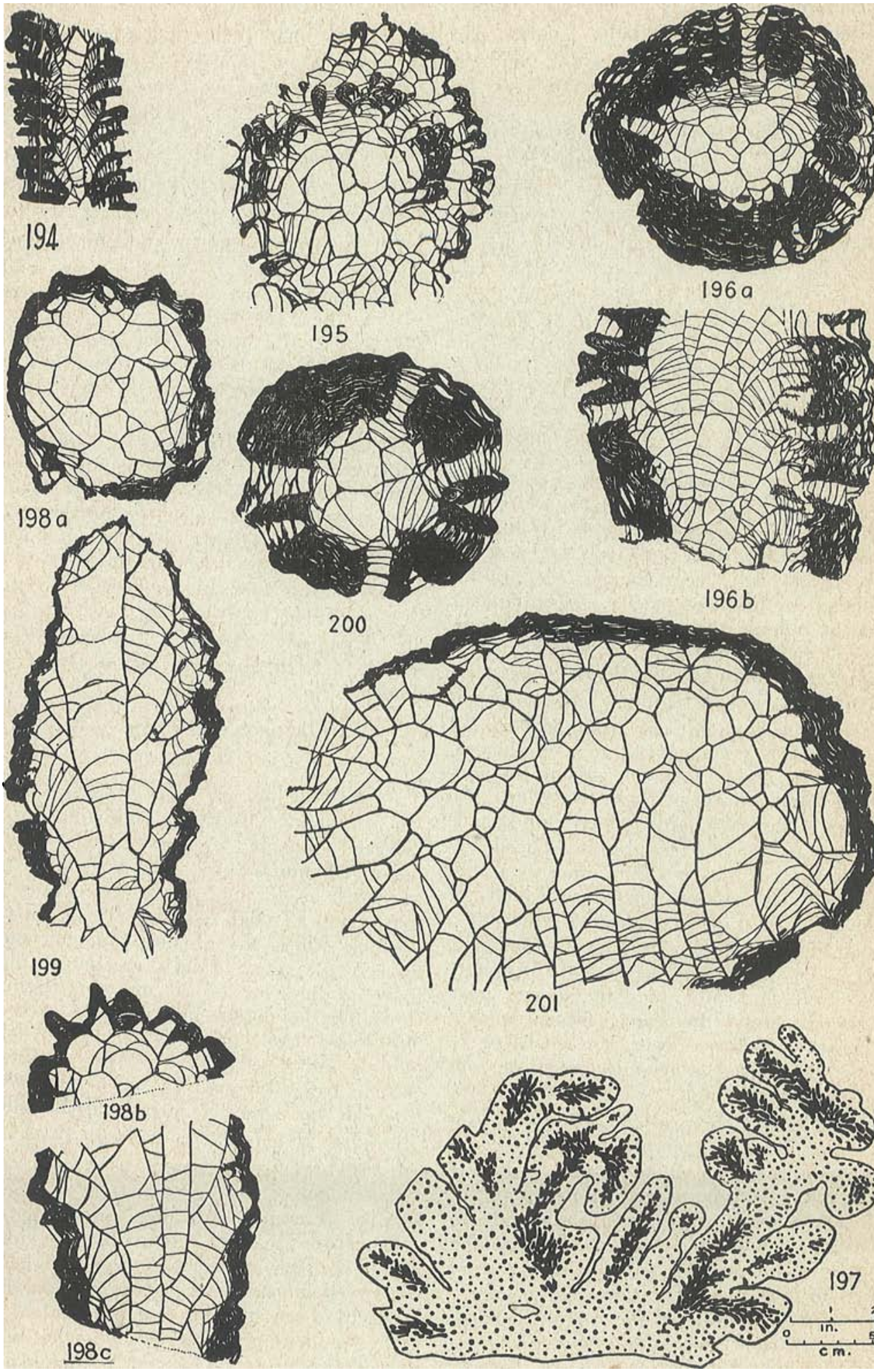
sis Snider and "*P.*" *carbonaria* Mather indicates no significant basis for distinction, and, accordingly, these species are here regarded synonymous. "*P.*" *oklahomensis* was reported to be in the "Mayes" formation, of presumed Chesterian age. The locality from which the types were collected on Grand River in northern Delaware County, Oklahoma (SE. 1/4 sec. 10, T. 25 N., R. 23 E.) and which is the only place where Snider found the fossil, is in an area mapped as Chesterian by Snider (1915, map facing p. 16) but corrected on the state geological map of Oklahoma (Miser, 1926) by classification as Morrowan. Thus, the true age of *Striatopora oklahomensis* is, with little doubt, Pennsylvanian (Morrowan) and not Mississippian. No specimens of *Striatopora* are known from recognized Chesterian deposits anywhere in this region. The date of Snider's paper is a few months earlier than that of Mather's description of "*P.*" *carbonaria,* based on specimens also obtained from Morrowan strata in northeastern Oklahoma and northwestern Arkansas. Although no figures of the internal structure of Snider's species are given, external characters of *S. oklahomensis* and *S. carbonaria* seem to be the same. The slightly wider spacing of tabulae in *S. caneyana* Morgan, from the "upper Caney" (Lower Pennsylvanian) of southern Oklahoma, may be a valid basis for distinction from *S. oklahomensis,* but this is doubtful in view of the observation that specimens assigned to *S. oklahomensis* have a range of variation of the tabulae extending in the direction of wide spacing as far as the condition in *S. caneyana.*

If "*Pachypora*" *carbonaria* Mather is not actually a junior synonym of *Striatopora oklahomensis* (Snider), the Brentwood species can not be named *Striatopora carbonaria,* because White (1865) had earlier described a Burlington (Lower Mississippian) coral as *Striatopora carbonaria.* Mather's specific name would thus become a homonym. The Mississippian and Pennsylvanian species mentioned seem to be congeneric with little doubt.

Striatopora oklahomensis differs from *S. religiosa,* n.sp., from the Marble Falls limestone, in having smaller corallites, both average and maximum, more closely spaced tabulae, and generally a less robust growth of the colonies. The peripheral zone of most specimens of *S. oklahomensis* is much thickened, whereas a majority of the Texas specimens that have been observed have a relatively thin peripheral thickened zone. This distinction has doubtful significance, however.

Occurrence.—This species occurs abundantly in the Brentwood limestone, Morrowan, Lower Pennsylvanian (Upper Carboniferous), of northwestern Arkansas and less commonly in Morrowan strata of northeastern Oklahoma. Specimens from these rocks have commonly been identified as *Pachypora carbonaria* Mather. The only specimens of *Striatopora oklahomensis* previously reported are Snider's type and associated fossils from the "Mayes"

Figs. 194–201. Sections of Marble Falls, Smithwick, Brentwood, and Hale favositid corals, x1.5 (except fig. 197). (194) *Striatopora immota,* n.sp., type specimen, no. P9364, from the Brentwood limestone, 1½ miles northeast of Fayetteville, Arkansas; a longitudinal section through the mid-portion of a branch. (195) *S. oklahomensis* (Snider), no. KU7999–21a, from Morrowan beds in Ash Canyon, San Andres Mtns., sec. 28, T. 19 S., R. 4 E., New Mexico; (196) specimen no. P9616, from the Brentwood limestone near Woolsey, Arkansas; transverse and longitudinal sections showing thick peripheral zone; (197) specimen no. KU7364, from the Hale formation, 2 miles southeast of Hulbert, Oklahoma; reduced-scale sketch of a large corallum on a slab of limestone; some of the branches weathered so as to show the thin-walled inner part of the corallites. (198) *S. religiosa,* n.sp., type specimen, no. P12201a, from the upper Marble Falls limestone, 5 miles south-southwest of Hall, San Saba County, Texas (loc. 205–T–87); transverse and longitudinal sections showing the large diameter of the corallites and wide spacing of the tabulae; (199) specimen no. P12201b, from the same locality as fig. 198; (200) specimen no. P12201c, from the same locality as fig. 198; transverse section of a specimen having an unusually thick peripheral zone; (201) specimen no. P12197a, a large specimen from the same locality as fig. 198.


194
195
196a
198a
200
196b
199
201
198b
198c
197
0 1 2
in.
0 5
cm.

formation, classed as Chesterian, Upper Mississippian, at a single locality, as already mentioned; the age of Snider's fossils is thought almost certainly to be Morrowan.

Type.—The type specimens of both "*Pachypora*" *oklahomensis* and "*P.*" *carbonaria* are deposited in Walker Museum, University of Chicago. The specimen here illustrated was collected by F. B. Plummer from the Brentwood limestone on U. S. highway No. 71 near Woolsey, Arkansas, a few miles south of Fayetteville (Univ. Texas, Bureau of Economic Geology, specimen no. P–9616).

STRIATOPORA IMMOTA, n.sp.

Pl. 14, fig. 5; text figs. 185, 194

Small branching coralla having a relatively thick peripheral zone of dense stereoplasm and characterized by diminutive corallites that are unconstricted by thickened walls near the surface are included in this new species. The diameter of the colonies ranges from about 7 mm. at the growing tip of a branch to an observed maximum of 20 mm.; the average size is about 13 mm. The two specimens now available are a slightly curved unbranched fragment 42 mm. in length, the type, and a fragment about 50 mm. long having parts of three branches. The surface has a roughly pitted appearance owing to the rather closely spaced depressions of the corallite apertures and the elevated nodose interspaces, which are rounded in transverse profile rather than sharp-crested. The apertures range in diameter from slightly less than 1 mm. to 1.6 mm., and the interspaces have approximately the same measurements; about 5 apertures occur in a space of 10 mm., measured diagonally in directions of closest spacing.

The axial thin-walled portion of the coralla in the examples studied has a diameter of only 2 or 3 mm., whereas the dense peripheral region has a radial thickness of 4 or 5 mm. The corallites are polygonal in cross section in the axial region and the walls here are thin, 0.04 to 0.08 mm. The tubes curve evenly outward so as to meet the surface perpendicularly, and here the cross section is subcircular. Tabulae are closely spaced, fairly stout, and they include both complete and incomplete platforms, the latter invariably joined to other tabulae. Mural pores ranging from 0.08 to 0.25 mm. are fairly common in the thickened zone.

Discussion.—The size and surface characters of *Striatopora immota* readily distinguish it from *S. oklahomensis*, for the latter is a much coarser and more robust species. Whether or not the very small diameter of the axial zone is a character of specific importance is uncertain, but other internal features, such as the small size of the corallites and their lack of constriction in the peripheral zone, serve to mark this form.

Occurrence. — Brentwood limestone, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by F. B. Plummer from outcrops 1½ miles northeast of Fayetteville, Arkansas, on State highway No. 45, and on U. S. highway No. 71 about 8 miles north of Woolsey, Arkansas.

Type.—The University of Texas, Bureau of Economic Geology, specimen no. P–9364, from the locality northeast of Fayetteville.

STRIATOPORA RELIGIOSA, n.sp.

Text figs. 186, 187, 198–201

Coralla belonging to this species have an irregular cylindrical branching form, average diameter of the branches being about 25 mm. Some specimens measure as much as 40 mm. across the colony in parts not affected by widening at bifurcations, where the greatest diameter may exceed 70 mm.; small specimens may have a diameter of 20 mm. or slightly less. The height of some colonies exceeds 100 mm. The surface is marked by the closely appressed calices of the corallites, which are polygonal in outline, variable in size, moderately deep, and bounded by sharp-crested ridges. A majority of the calices have a diameter of 4 mm. or slightly more; the largest attain a diameter of 8 mm. and calices measuring 6 mm. across are fairly common. The sides of the calices are steep and in the best-preserved parts of the coralla they are seen to bear regular longitudinal low ridges and intervening grooves that are spaced two in 1 mm. on the average (fig.

187). The bottom of some calices, especially the larger ones, is flat or gently convex, and this part, formed by the topmost tabula of the corallite, meets the sides of the calyx at a sharp angle.

The internal structure of colonies, as shown by transverse and longitudinal sections, is characterized by the strongly marked differentiation of an axial immature zone and a peripheral mature zone. The tubes of corallites in the axial region are decidedly thin-walled and slightly uneven. They are pierced sporadically by moderately large mural pores that intersect the walls perpendicularly. New corallites are introduced at the angles between large tubes. Tabulae are common but they are widely spaced in the immature region; they may be very closely spaced in the peripheral region. Most of the tabulae are complete, extending across the tubes in a direction that is normal or obliquely inclined to the walls; some tabulae are arched upward or sag downward. Incomplete tabulae may branch from the complete ones. The mature region is characterized by a dense deposit of laminated stereoplasm that shows considerable variation in thickness in different coralla. In some specimens, like the type, the thickness of peripheral dense material is only 3 or 4 mm. (fig. 198), but it may be twice as great (fig. 200).

Discussion.—This species is more robust than *Striatopora oklahomensis* (Snider) and the inferred synonymous species, *S. carbonaria* (Mather). Colonies of *S. oklahomensis* range in diameter from about 15 to 25 mm. and the maximum width of the corallites is about 4 mm. (or rarely 5 mm.), whereas colonies of *S. religiosa* have a diameter of 20 to 40 mm. and corallites range to 8 mm. in width. Tabulae are much more widely spaced in the immature zone of *S. religiosa* than in *S. oklahomensis.*

Occurrence.—Common in the upper Marble Falls limestone, Bendian, Lower Pennsylvanian (Upper Carboniferous); collected by F. B. Plummer on Gibbons' ranch 5 miles south-southwest of Hall, San Saba County, Texas (loc. 205–T–87).

Type.—The University of Texas, Bureau of Economic Geology, specimen no. P–12201a.

Genus ACACIAPORA, n.gen.

Slender branching subcylindrical tabulate corals are assigned to this new genus. The corallites grow upward in the axial region, curve gently outward radially in all directions and meet the surface obliquely; their transverse outline is polygonal in the axial region but it changes to ovoid near the surface, apertures being generally elongate in the direction of growth. The calices are bordered by a rim that is most strongly elevated on the lower side, making the plane of the rim nearly normal to the axis of the corallite. Interspaces between the calices, variable in width, are formed by dense stereoplasm. The walls of the corallites are stout but not strongly thickened, although the filling of interspaces in the peripheral region may seem to constitute such thickening. The walls are perforated by more or less numerous mural pores. Shelf-like incomplete tabulae having a free edge project into the tubes of the corallites (figs. 202, 203); seemingly complete tabulae shown in longitudinal sections may actually belong to incomplete tabulae that are so intersected that the free margin is missed.

Genotype. — *Michelinia subcylindrica* Mather, Hale formation, Morrowan, northeastern Oklahoma.

Discussion.—The tabulate corals of the general type of this new genus that occur in Carboniferous and Permian strata of different parts of the world have been variously assigned to *Favosites* Lamarck (1816), *Thamnopora* Steininger (1831), *Michelinia* de Koninck (1841), *Trachypora* Edwards and Haime (1851), *Striatopora* Hall (1851), *Cladopora* Hall (1851), *Pachypora* Lindström (1873), and *Heterocoenites* Gerth (1921). All these genera, except *Michelinia* and *Heterocoenites*, are based on Silurian or Devonian genotypes, and considerable room for question exists as to the validity of reported occurrences of a majority of the genera named in Upper Carboniferous and Permian strata. It is true that structural differences between middle and late Paleozoic favositids seem partly quantitative rather than qualitative, involving such matters as distribution and amount of wall thickening, and these are difficult to evaluate precisely. Whether or not the tabulate corals were far less progressive in evolutionary changes than rugose corals, the appearance of at least a number of generically distinguishable groups is reasonably expectable in rocks that are many millions of years younger than Silurian or Devonian. The broadening of generic concepts that is necessary in order to include some of the Permian tabulates in a Silurian genus, for example, serves little useful purpose, and besides tending to make confusion, it is likely to obscure significant stratigraphic implications of these fossils.

Favosites, Michelinia, and *Pachypora* are distinguished from other genera mentioned in the essentially right-angled attitude of the distal part of the corallites with respect to the surface of the corallum; the polygonal apertures are divided by ridges of approximately uniform height. These statements apply also to the genotypes of *Thamnopora* and *Striatopora* although the corallite tubes may not be quite normal to the surface. *Trachypora, Cladopora,* and *Heterocoenites* are ramose tabulate corals in which the corallites reach the surface obliquely, and commonly the lower rim of the apertures is somewhat extended so as to make the plane of the calyx margin nearly normal to the axis of the tube.[6] The corallites of *Cladopora* are closely spaced at the surface, as well as in the axial region, and as a result the apertures are semicircular or crescentic in outline and partly overlap one another in a manner suggestive of shingles; the walls are not distinctly thickened in the peripheral region and they are not marked by septal ridges. *Trachypora* is distinguished by thick walls of the axial region and excessive thickening of the peripheral region; the apertures of corallites are separated by interspaces, which in the genotype species are very broad, and the sides of the ovoid calices lack septal ridges. *Heterocoenites* has considerably thickened walls, like *Trachypora,* but is characterized by strongly defined septal ridges on sides of the calices. A few complete tabulae occur in the corallite tubes of *Cladopora, Trachypora,* and *Heterocoenites,* and all have well-defined mural pores.

Acaciapora is distinguished from all the genera mentioned in the nature of its tabulae, most of which, if not all, are platforms reaching only part way across the corallite and having a free edge. The appearance of the exterior may resemble that of *Cladopora* or *Trachypora,* but internal features serve readily to distinguish *Acaciapora* from these genera.

Occurrence.—Morrowan, Pennsylvanian (Upper Carboniferous); Oklahoma and Texas.

ACACIAPORA SUBCYLINDRICA (Mather)

Pl. 14, figs. 7–9; text figs. 190–192, 202

Michelinia subcylindrica MATHER, 1915, Denison Univ. Bull., Jour. Sci. Labs., vol. 18, p. 97, pl. 1, fig. 18. Morrowan strata, near Fort Gibson, Oklahoma.

This species is represented in our collections by more than 200 well-preserved specimens, some of which attain a height of 30 mm. Most of the colonies are slender straight branches about 3 mm. in diameter, but some are curved and several show bifurcations of the branches. The greatest observed diameter of a corallum is 6 mm.; a few fragments having a diameter of only 2 mm. are contained in the collection. None of our specimens show a "base small and conical, covered with a wrinkled, concentrically striated epitheca," as reported by Mather (1915, p. 97), but numerous examples before us show the attachment of coralla to other fossils. Seemingly, this species grew upward or outward from almost any foreign object, such as a brachiopod, bryozoan, crinoid column, or blastoid, offering a foothold. Possibly some colonies were unattached. The terminal growing tips of colonies are rounded and here the diameter is commonly about 2 mm. The apertures are rather closely crowded on most specimens, each newly added calyx seeming slightly to encroach on neighbors next below them (fig. 192), but this appear-

[6] The figures of *Striatopora flexuosa* Hall, genotype of *Striatopora,* in a recent paper by John W. Wells (Jour. Paleont., vol. 18, pp. 259–262, pls. 40, 41, 1944) also show elevated lower rims of the corallite apertures. A distinctly oblique attitude of the distal part of the corallites is suggested.

ance is due mainly to elevation of the semicircular lower part of the rims of the calices. Distinct interspaces occur between some of the apertures, and on parts of coralla or on a few whole colonies the interspaces are evident. The sides of very well-preserved calices show faint septal grooves and ridges but commonly these are not seen. The rims are more or less distinctly denticulate. The depth of calices commonly exceeds the diameter of the corallite tubes. The largest calices have a diameter of 1.5 mm.; they are mostly 1.0 mm. or smaller.

Transverse sections of a branch show that the thickness of walls of the axial region is about the same as that of the peripheral zone, although interspace areas are solid stereoplasm interrupted only by mural pores. The tubes of the axial region are subpolygonal in section. The tubes expand evenly as they grow upward and outward, as shown in longitudinal sections. The most striking feature of the corallites is the nature of the incomplete tabulae, which are attached to one side of the tube or another and reach part way across. Two to four tabulae in the space of 1 mm. may be present in this species. Longitudinal sections (fig. 202) may show seemingly unattached portions of tabulae in the central part of corallite tubes; these represent intercepts of tabulae that join the walls along a line that lies entirely outside the plane of the longitudinal section. The occurrence of such "floating" segments of tabulae in the sections indicates that the free margin of at least some tabulae is convex to the tabula, not concave, and the opening between the tabula and adjacent wall is crescentic. Attention may be called to the alternating arrangement of the incomplete tabulae attached to opposite walls of some corallite tubes (fig. 202).

Discussion. — This interesting small coral is readily distinguished from associated species of *Michelinia,* such as *M. tenuicula,* n.sp., and *M. scopulosa,* n.sp., by the slender branching form of the colonies and the diminutive size of the calices. Superficially the apertures of *Acaciapora subcylindrica* resemble the openings of the tubes of *Michelinia,* but they are obliquely disposed and rounded in outline, rather than normal to the surface and distinctly polygonal in shape. This species has about the same growth form and size as the Texas species, *Acaciapora venusta,* n.sp., but it is differentiated by more closely spaced apertures and a rougher surface appearance.

Occurrence.—Hale formation, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore and L. R. Laudon at spillway below Greenleaf reservoir (cen. sec. 10, T. 13 N., R. 20 E.), near Braggs, Oklahoma, and near Keough quarry (sec. 36, T. 16 N., R. 19 E.), about 2 miles north of Fort Gibson, Oklahoma.

Type.—University of Chicago, Walker Museum. Figured specimens, University of Kansas, specimens nos. 7385–26b, f, g, h.

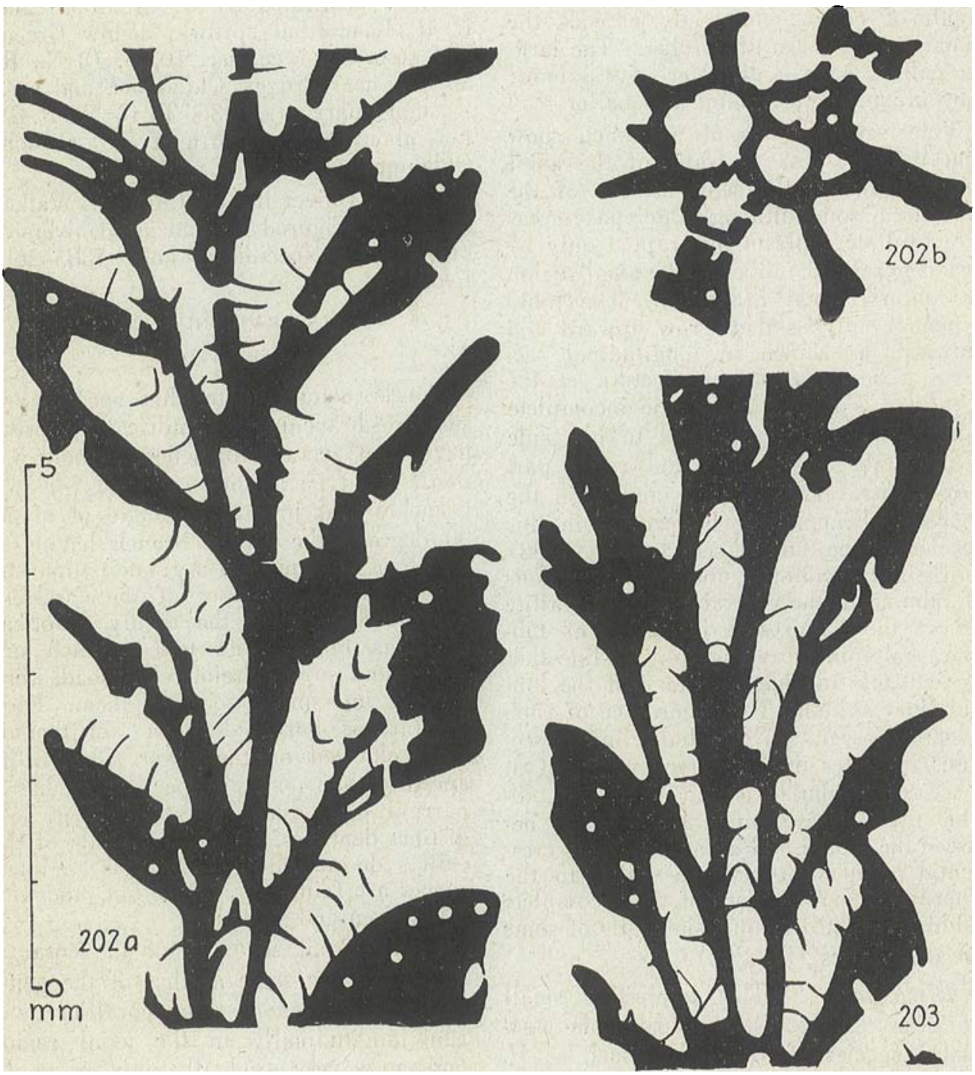
ACACIAPORA VENUSTA, n.sp.

Text figs. 193, 203

Corals belonging to this species are slender branching cylindrical growths having an average diameter of about 3.5 mm. The type specimen consists of two branches that join at an angle of about 90 degrees, the longer branch having a length of 37 mm. and a greatest diameter of 4 mm. The surface of the corallum is characterized by the evenly elliptical openings of corallite tubes, which are distributed so that relatively broad, very distinct interspaces separate them. Each aperture is bordered by a rim that is more elevated on the lower side of the aperture than on the upper, and it has a narrow crest that bears more or less distinct denticles. The inner walls of the calices do not show septal ridges. Interspaces are faintly granulose but otherwise fairly even and smooth.

The internal structure of the coral is essentially the same as that of the genotype of *Acaciapora.* The corallite tubes run longitudinally in the axial region and curve very gradually outward to the surface, intersecting it at a very oblique angle. The walls range in thickness from 0.10 to 0.30 mm. and they are perforated by fairly numerous mural pores, 0.07 to 0.12 mm. in diameter. The corallites bear more or less numerous incomplete tabulae that project into the tubes and have a free margin. Many of these tabulae diverge from the wall at a rather steep angle and in longitudinal section resemble thorny spines of the acacia.

Discussion.—Distinction of *Acaciapora venusta* from *A. subcylindrica* is based chiefly on surface characters. The apertures of the Texas species are more regularly elliptical and more widely spaced than in the genotype and the surface of the corallum as a whole is more even. Internally, the corallite tubes of *A. venusta* seem to have a longer immature portion parallel to the axis of the corallum and to curve outward slightly more gradually than in *A. subcylindrica.*



Figs. 202–203. Sections of *Acaciapora,* n.gen., from the Hale and Marble Falls formations, x13.5. (202) *Acaciapora subcylindrica* (Mather), specimen no. KU7385–26g, from the Hale formation at Greenleaf Lake, southeast of Braggs, Oklahoma; 202a, longitudinal section showing the incomplete tabulae and large mural pores; 202b, transverse section. (203) *A. venusta,* n.sp., type specimen, no. P11222, from the base of the Marble Falls limestone on Wallace Creek, 10 miles southwest of San Saba, Texas (loc. 205–T–43); longitudinal section showing the strongly oblique attitude of the tubes.

Occurrence.—Four well-preserved colonies are now known from the base of the Marble Falls limestone, Morrowan, Lower Pennsylvanian (Upper Carboniferous); collected by F. B. Plummer and R. C. Moore in an outcrop west of Wallace Creek road, about 10 miles southwest of San Saba, Texas (loc. 205–T–43).

Type.—The University of Texas, Bureau of Economic Geology, specimen no. P–11222.

Family AULOPORIDAE Nicholson

Small tubular corallites of trumpet-like or cylindrical form comprise colonies belonging to this family. The tubes have a creeping habit, attached to foreign objects throughout growth, or most of the branching tubes may be erect, free structures. Tabulae are common or lacking. Range, Ordovician to Permian.

Genus CLADOCHONUS McCoy, 1847

Pyrgia Edwards and Haime, 1851, Arch. Mus. Hist. Nat. Paris, vol. 5, pp. 159, 310.
Monilopora Nicholson and Etheridge, 1879, Geol. Mag., n.s., dec. 2, vol. 6, p. 293.

The corallum characteristic of this genus comprises colonies of erect trumpet-shaped corallites that branch in opposite directions at short regular distances. The theca is marked only by delicate growth lines. The base of the colony is formed by a ring of corallites that commonly encircles a crinoid stem, and branches of corallites extend outward from the attached ring. Each corallite touches another only at the place of branching, which is located at the point where the parent corallite begins to form its expanded calyx. The offshoot corallite first builds a slender tube that grows at an angle to the axis of its predecessor and directed nearly opposite to the calyx opening of the latter. The newly formed corallite also gives off a branch and develops a large oblique calyx. The corallum thus consists of many zigzag corallites. The walls are very thick and the central hollow portion is small. Tabulae and septal spines are lacking, but longitudinal ridges may appear in the calices.

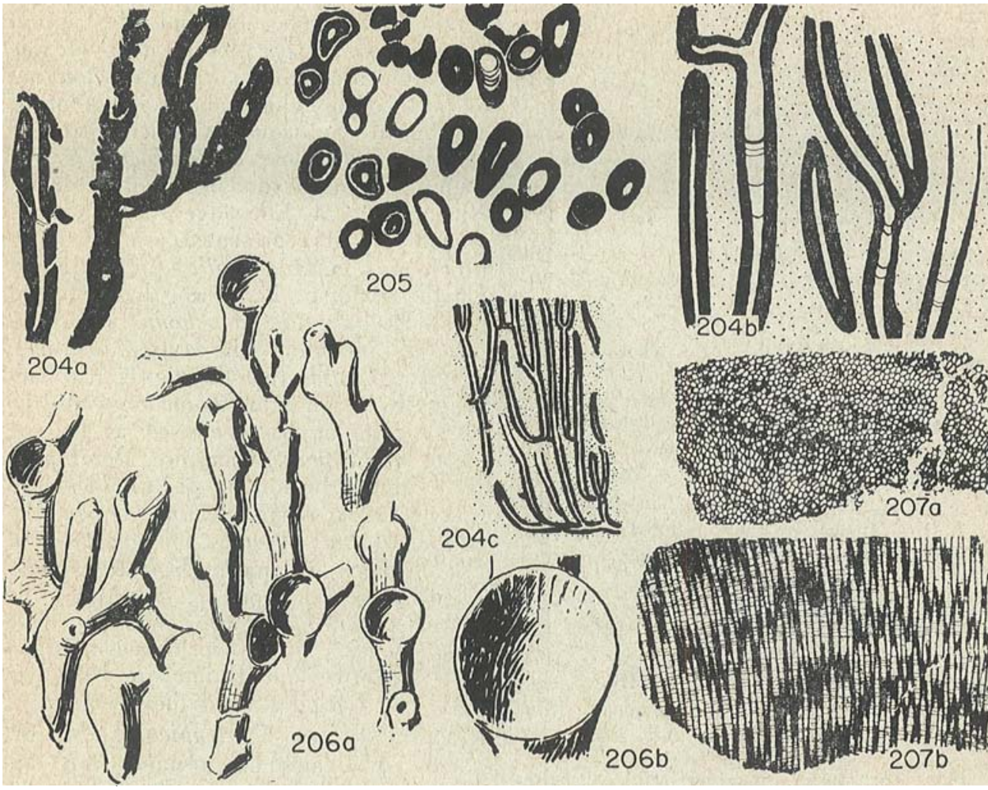
Genotype. — *Cladochonus tenuicollis* McCoy (1847, p. 227, Pl. 11, fig. 8), Lower Carboniferous, Australia.

Discussion.—The original description of *Cladochonus* by McCoy in 1847 was based on branching corallites belonging to parts of a colony above its point of attachment. Subsequently, when a ring of corallites like those of *Cladochonus* was found growing around a crinoid column, Nicholson and Etheridge (1879) concluded that it represented a new genus, which they named *Monilopora.* Hill and Smyth (1938, p. 127), who have studied corals assigned to *Cladochonus* and *Monilopora*, including the types of these genera, conclude that the zigzag branches generally assigned to *Cladochonus* are the distal parts of bases classed as belonging to *Monilopora.* Therefore, *Monilopora* is a junior synonym of *Cladochonus.* Girty (1925) regarded *Jania crassa* McCoy (1844, p. 197) as the genotype of *Cladochonus,* and inasmuch as this species is also the genotype of *Monilopora* he placed *Monilopora* in synonymy with *Cladochonus.* Girty overlooked the fact that Edwards and Haime in 1850 (p. lxxvi) had legally fixed the genotype of *Cladochonus* as *C. tenuicollis* McCoy, which invalidates his argument on taxonomy, although conclusions as to the synonymy of these genera are the same.

Pyrgia is regarded by Nicholson (1879, pp. 19, 219–225) and by Hill and Smyth (1938, p. 126) as a junior synonym of *Cladochonus*, inasmuch as *P. michelini* Edwards and Haime (1851, p. 310), the genotype, seems to be based on individual corallites broken from a *Cladochonus* colony.

Cladochonus is very different from all other tabulate corals except *Aulopora* Goldfuss (1829, p. 82). *Aulopora* consists of a number of prostrate tubes that are attached by the entire lower portion to a foreign object. The individual tubes expand gradually to the calices, nearly all of which open in a single direction. The definitely zigzag arrangement of the branches of *Cladochonus* distinguish it from *Aulopora.*

Occurrence.—Middle and Upper Devonian of North America and Germany; Lower Carboniferous of North America, western Europe, U.S.S.R., and eastern Australia; Upper Carboniferous of North America and U.S.S.R.; and Permian of



Figs. 204–207. Springoporid and auloporid corals from the Marble Falls and Smithwick formations, and a chaetetid. (204) *Multithecopora paucitabulata*, n.sp., section of part of type specimen, no. KU79999e, from the Marble Falls limestone north of Onion Creek, Fowler ranch, about 3 miles southeast of Marble Falls, Burnet County, Texas (loc. 27–T–16); 204a, b, longitudinal sections of tubes, partly through the central cavity, showing the very thick-walled structure and locally distributed slightly concave tabulae, x2.5; 204c, specimen showing branching of tubes, x0.75; (205) specimen no. KU7753, from the Marble Falls limestone, 5 miles southeast of Rochelle, McCulloch County, Texas; transverse sections of tubes. (206) *Cladochonus texasensis*, n.sp., part of type specimen, no. USGS2612–22, from the Smithwick shale about 1 mile southwest of Bend, Texas; 206a, several corallites showing form and character of branching, x1; 206b, a calyx showing faint septal ridges, x3. (207) *Chaetetes eximius*, n.sp., type specimen, no. KU7744–26, from the Hale formation at Keough quarry, north of Fort Gibson, Oklahoma; 207a, transverse section, x2.5; 207b, longitudinal section, x2.5.

Timor, China, Yugoslavia, and Western Australia.

CLADOCHONUS FRAGILIS Mather

Pl. 14, figs. 1–3

Cladochonus fragilis MATHER, 1915, Denison Univ. Bull., Jour. Sci. Labs., vol. 18, p. 98, pl. 1, figs. 3–5. MORGAN, 1924, Oklahoma Bur. Geol., Bull. 2, p. 190, pl. 31, fig. 3.

This species consists of funnel-shaped corallites developed alternately and directed in opposite directions from the almost solid connecting tube so as to give a zigzag appearance to the branch. The theca is thin in the upper part of the individual corallites but thickens in the lower smaller portions. The outer surface of the colony is smooth. None of the Oklahoma corallites studied reveal the nature of the calyx, but specimens from Texas show a few well-preserved calices that bear low but distinct septal ridges, spaced 0.15 to 0.12 mm. apart. The deep part of the calices is laterally constricted so as to form a pit about 0.3 mm. in width and 1.3 mm. in length; the mid-portions of the long sides of this pit bulge inward, constricting the narrow depression. According to observations on specimens from northeastern Oklahoma, the corallites expand rapidly from a connecting tube 1 mm. in diameter to 3.0 mm. at the calyx; the length of nearly complete corallites ranges from 6.8 to 8 mm. Corallites from Texas (Pl. 14, figs. 1–3) have a diameter of 1.5 mm. in the young part and they measure 2.3 to 2.8 mm. at the calyx; one specimen (Pl. 14, fig. 2) shows 6 corallites in 26 mm., and another (Pl. 14, fig. 1) has 4 corallites in 20 mm., but the length of individual corallites is 6 to 8 mm.

A base of a colony belonging to this genus and presumed to be conspecific is attached to a crinoid columnal, forming a ring around it. From this more or less disc-like base broken stubs of the zigzag branches extend horizontally in all directions. Several of the imperfect calices have a diameter of about 3 mm.

Discussion.—The fragmentary branches here reported from Morrowan beds of northeastern Oklahoma agree in form and diminutive size with those described by Mather (1915, p. 98) but they are larger than his specimens. He records the average length of individual corallites as 3 mm. and the average diameter of the calyx as 1.5 mm. This agrees with the illustration of one of the types (Mather, 1915, pl. 1, fig. 3) but not with those of other types (*idem*, figs. 4, 5), which are indicated to have a length of about 5 mm. and a calyx diameter of 2 mm. Mather's specimens came from localities 1.5 and 2 miles, respectively, north of Fort Gibson, Oklahoma, the latter collecting place being Keough quarry where our specimen of a part of the colony above the base was obtained. Despite differences in measurements, there is little doubt that our specimens belong to *Cladochonus fragilis*. Mather did not find a *Cladochonus* basal ring. Our specimen showing this part of the colony comes from about the same horizon as that of the Keough quarry fossils; it was collected a few miles southeast of Fort Gibson at the dam below the Greenleaf Lake reservoir.

Cladochonus fragilis resembles *C. tenuicollis* McCoy, the genotype, in the general arrangement and shape of the corallites along the branch but has a much thickened lower portion and shorter intervals between buds. The connecting tubes of the Morrow species are much more delicate and shorter than those of *C. americanus* Weller (1909, p. 275) described from the Fern Glen formation, Lower Mississippian, of Missouri.

Occurrence.—Hale formation, Morrowan, Lower Pennsylvanian (Upper Carboniferous); the free branches were collected by R. C. Moore, one-quarter of a mile south of Keough quarry, Fort Gibson, Oklahoma (Univ. Kansas, specimens nos. 7130–22), and the attached base was found at the east end of the dam, Greenleaf Lake, cen. sec. 10, T. 13 N., R. 20 E., southeast of Braggs, Oklahoma (Univ. Kansas, specimen no. 7385–27a). Three well-preserved fragments of corallites are from the basal part of the Marble Falls limestone in eastern San Saba County, Texas; they were collected by R. C. Moore on the Chappel-Cherokee road, 1½ miles south of Cherokee Crossing (loc. 205–T–49 or Univ. Kansas loc. 7149). Two well-preserved fragments of coralla were collected by R. C. Moore from the lower Marble Falls limestone at loc. KU7171 southwest of San Saba, Texas.

Material studied.—One base of a *Cladochonus* colony attached to a crinoid columnal and four free branches were available for study.

CLADOCHONUS TEXASENSIS, n.sp.

Pl. 14, fig. 4; text figs. 206a, b

Description of this species is based on a corallum consisting of numerous subparallel branches and containing some scores of unusually well-preserved corallites. The colony is embedded in an ellipsoidal concretionary nodule having dimensions of about 150 by 100 by 60 mm.; it is made up of fine silt cemented by calcium carbonate. Parts of the nodule that are hard and brittle can be broken very cleanly from around corallites, but preparation of the fossil in this way inevitably causes breakage of the rims of calices and hardly permits obtaining parts of the colony sufficiently large for satisfactory study. One part of the nodule, slightly softer than the rest, was selected for preparation by removing the matrix; this work was done under a binocular microscope and it was found possible to uncover several branches almost entirely. The base of the colony, showing mode of attachment, was not discovered, however.

The corallites of this species are robust trumpet-shaped structures having very thick walls, such as characterize the genus *Cladochonus.* The immature part of each individual is subcircular in cross section and its diameter is very uniformly 4.0 to 4.2 mm.; the thickness of the walls in this region is about 1.5 mm. and the inside diameter of the tube 1.0 mm. or slightly smaller. The calices are directed alternately in opposite directions, their nearly circular rim lying in a plane that is almost parallel to the direction of growth of the branch and 3 to 4 mm. distant from the mid-line of the branch. The distance between corresponding parts of successive calices, such as their centers or distal margins, is about 13 mm. The budding that gives rise to a new corallite is initiated at a point opposite the proximal edge of the parent corallite. In parts of the colony every second or third corallite gives off two new individuals, instead of a single one, and this produces a bifurcation of the branch. Low but distinct septal ridges are observed in some of the calices, the spaces between them ranging from 0.45 to 0.60 mm. The exterior of the corallites is delicately marked by unevenly spaced, slightly flexuous growth lines and small transverse corrugations; in the vicinity of the points of bifurcation of the corallites these growth lines curve upward distinctly. Faint longitudinal corrugations are observed on many corallites and in addition there are very fine longitudinal striae; the spacing of the corrugations corresponds to that of the septal ridges, which is about 0.5 mm.

Discussion.—This species is much more robust than *Cladochonus fragilis* Mather, and the exterior of the corallites differs from that of the more delicate form in having distinct transverse and longitudinal markings. *C. texasensis* may be distinguished from *C. bennetti* Beede, which occurs in higher parts of the Pennsylvanian section of the midcontinent region, by the dimensions and surface markings of the corallites.

Occurrence.—Upper part of the Marble Falls formation, Bendian, Lower Pennsylvanian (Upper Carboniferous); collected by P. V. Roundy, U. S. Geological Survey, on the south bank of Colorado River, 6 feet above river level, about 1 mile southwest of Bend, San Saba County, Texas (April, 1919).

Type.—U. S. Geological Survey, specimen no. 2612–22a.

Family SYRINGOPORIDAE Edwards and Haime

Colonies assigned to this family are composed of cylindrical tubes growing more or less parallel and joined to one another at intervals by lateral processes. The walls are thick and they bear only slight traces of septa or none at all. Tabulae, which commonly are funnel-shaped, are numerous to sparse. Range, Ordovician to Permian.

Genus MULTITHECOPORA Yoh, 1927

Compound coralla consisting of thick-walled tubular corallites, joined together by only a few connecting processes, are designated by this name. The corallites grow in a subparallel position and they are somewhat variable in distance from one another; mostly, the interspaces between corallites are one to three times that of the diameter of the corallites. The outer surface of the tubes is wrinkled transversely so as to make a rather rough exterior. The walls of the tubes are characterized by excessive thickness, except in the distal region where they are one-half or less of the ordinary thickness. The diameter of the interior of the tubes is normally one-third to one-fourth of the outside diameter, but the interior of some tubes is only one-fifth of the outside diameter. The walls are concentrically laminated. Septa are lacking but the interior of the corallites is intersected locally by thin down-curved complete tabulae. The corallites reproduce by lateral budding, the young individual growing laterally a short distance from the parent and then turning abruptly upward parallel to it.

Genotype.—*Multithecopora penchiensis* Yoh, Carboniferous of Chihli and Fengtien provinces, China.

Discussion.—This genus is distinguished from *Syringopora* Goldfuss by its entire lack of traces of septa, by the unusual thickness of the corallite walls, and by characters of the tabulae. The comparatively large tubes of *Syringopora* contain numerous tabulae of steep funnel-shaped and irregular form, and cross-wise tubes, or stolons, connecting the corallites, occur at frequent intervals. *Kuweichowpora* Chi, a syringoporoid Lower Carboniferous coral from China, resembles *Multithecopora* in having rare connections between the corallites and in lacking traces of septa; it differs in having numerous regularly spaced funnel-shaped tabulae that surround an open central tube.

Occurrence.—Carboniferous; China and Texas.

MULTITHECOPORA PAUCITABULATA, n.sp.

Text figs. 204, 205

Colonies belonging to this species consist of nearly parallel tubes growing subvertically, the interspaces being about equal to the diameter of the tubes on the average. The type specimen is wider than high, measuring more than 200 mm. transversely and about 50 mm. in greatest height; the base of the corallum is preserved, showing the recumbent tubes and regularly spaced budding of upcurving tubes in this region, but the upper surface is weathered in such manner as to indicate that it lies some distance below the original top of the corallum. The corallites are cylindrical and nearly uniform in diameter, ranging from 2 to 2.5 mm.; their outer surface is marked by transverse wrinkles, which are not very prominent, but otherwise the tubes are smooth and straight. At the base of the colony the corallites curve gently from a horizontal to a vertical position; branches given off higher in the colony grow laterally from the parent for a short distance and then curve abruptly upward. The walls of the tubes are uniformly thick except in their distal extremities where the outside diameter of the corallite remains constant but the inside diameter gradually increases until the wall is reduced to a feather edge. The normal thickness of the walls is about 0.85 mm. and the inside diameter of the tubes is about 0.35 mm. Tabulae are not observed except in thin-walled parts of corallites near the apertures and in places just below the points of budding. Here, thin complete tabulae intersect the tubes approximately at right angles, the central part of the tabulae being curved evenly downward, however. These tabulae, with concave surface upward, are closely crowded for a short distance in some tubes but only a few rather widely spaced ones occur in others. As already noted, the long thick-walled parts of tubes seem to be devoid of tabulae.

Discussion.—This coral from the Marble Falls limestone corresponds in all observed structural features with the described and illustrated characters of the genotype of *Multithecopora,* including the localized distribution of the downcurved tabulae which leaves "remaining parts of the tubes entirely hollow" (Yoh, 1927, p. 291). The dimensions of *M. penchiensis* and *M. paucitabulata* are almost identical, both as to the thickness of walls of the tubes, their outside and inside diameters, and average spacing of the corallites. The exterior of the Chinese corals is more corrugated than that of the species here described, but otherwise there seems to be little basis for distinction, unless the distal thinning of the walls and expansion of the inside diameter of the tubes near the apertures, which is not mentioned by Yoh, may serve to differentiate the Texas species. *M. paucitabulata* does not closely resemble any described North American syringoporoid coral. It differs markedly from such a form as *Syringopora multattenuata* McChesney in the structure and distribution of the tabulae and the stolonal connections between the tubes.

Occurrence.—Upper part of the Marble Falls limestone, Bendian, Lower Pennsylvanian (Upper Carboniferous); collected by J. D. Ewers, 4900 feet north of Onion Creek, on east side of Fowler ranch, 3.1 mile S. 45° E. of the steel highway bridge over Colorado River at Marble Falls, Burnet County, Texas (loc. 27–T–16). A corallum doubtfully assigned to this species was collected by M. H. Wallace, of the University of Kansas, from the

Marble Falls limestone at a locality about 5 miles southeast of Rochelle, Texas (Univ. Kansas loc. 7752). This specimen (Univ. Kansas, specimen no. 7753) agrees with the type of *Multithecopora paucitabulata*, except that the corallites are much less regular in arrangement.

Type.—The University of Texas, Bureau of Economic Geology, specimen no. 31649. A small part of the type is retained in collections of the University of Kansas (specimen no. KU–79999e).

Family CHAETETIDAE Edwards and Haime

Very small closely packed parallel tubes of prismatic form compose the massive colonies belonging to the family Chaetetidae. The walls are relatively thick, imperforate, and not divided in any way along a median plane. Septa are lacking but in some tubes lateral projections called pseudosepta may occur. Tabulae are more or less numerous; they include both complete and incomplete horizontal platforms. Range, Ordovician to Cretaceous.

Discussion.—The Chaetetidae are a puzzling group of fossils which have been interpreted varyingly as anthozoans, alcyonarians, hydrozoans, bryozoans, and calcareous algae. Whatever their taxonomic status may be, question is not to be raised on the stratigraphic usefulness of these fossils or on the interesting nature of research as to their paleoecologic significance. Field observations in study of Lower Pennsylvanian rocks of many areas have emphasized the desirability of close attention to the nature and sedimentational environment of chaetetid remains. In this paper the known occurrences of *Chaetetes* in the Marble Falls limestone and Smithwick shale of Texas are only reported and described very incompletely.

The Chaetetidae generally have been assigned to the ill-defined tabulate division of the coelenterates, but a great number of species that were assigned to *Chaetetes* in early papers now are placed in bryozoan genera. The differences between some tabulate corals and bryozoans are not easily established. A study by Peterhans (1929) of genera assigned to the family Chaetetidae (*Chaetetes* Fischer, *Chaetetopsis* Neumayr, *Diplochaetites* Weissermel, *Blastochaetetes* Dietrich, *Bauneia* Peterhans—all but the first of post-Paleozoic age) leads him to conclude that the genera of this family show closer affinity to trepostome bryozoans than to corals. The small size of the tubes, lack of symmetry, and variability of the microscopic structure in different chaetetids separate them from the Alcyonaria and the Zoantharia. The Chaetetidae lack mural pores, as do these bryozoans, and they have unsymmetrical tubes, as in many cyclostome and trepostome bryozoans, but the diameter of the tubes is much greater than in bryozoans, the walls are a little thicker, and pseudosepta are present. A similar mode of reproduction is found in both the bryozoans and the Alcyonaria.

The characters of *Chaetetes* and related genera are not sufficiently well understood to permit definite classificatory placement at this time. The much larger size of the corallites of the tabulate corals with respect to the bryozoans is a criterion that has been widely used to separate these groups. Carboniferous species of *Chaetetes* can be separated readily from known species of bryozoans in this way, and accordingly have been placed in the Coelenterata.

Genus CHAETETES Fischer, 1829

Massive colonies of small closely packed prismatic tubes comprise this genus. Colonies occur as small irregular, moundlike or disc-like masses, or as large reefs. The polygonal tubes are approximately equal in diameter and have thin complete or incomplete tabulae. The tabulae of each tube are independent and not connected to those of the adjacent tubes; they are not necessarily at the same level in different tubes. Weathered specimens may show a concentric layering within a colony. An axial column, septa, and mural pores are lacking. The amalgamate thecal wall of adjoining tubes may be incomplete due to partial fission so as to give the appearance of a septum (pseudoseptum). The diameter of the tubes varies from 0.1 mm. to 0.8 mm., and the wall thickness from 0.04 mm. to 0.10 mm. Reproduction is by division. A holotheca is present only at the base.

Genotype. — *Chaetetes cylindraceus* Fischer, Lower Carboniferous, U.S.S.R. *C. radians* Fischer (1830, expl. pl. 36, fig. 3) was selected as genotype by Edwards and Haime (1850, p. lxi), but it is not one of the genosyntypes.

Discussion.—This genus occurs commonly in the Pennsylvanian strata of North America as large colonies or widespread reefs. *Chaetetes* differs from *Tetradium* Dana (1848, p. 701) in the simple division and lack of an axial column and septa. *Bauneia* Peterhans (1927) is similar to *Chaetetes* in the structure of the wall and form of the corallites, but is distinguished by reproduction by both gemmation and division. *Beaumontia* Edwards and Haime (1851, p. 154) has been put in the same family as *Chaetetes* but differs greatly in the larger size and perforate walls. *Chaetetides* was proposed by Strand (1928, p. 34) as a new name for *Chaetetes* Fischer (1837, p. 159), if this should be found to differ from the earlier *Chaetetes* Fischer von Waldheim (in Eichwald, 1829, p. 197), but it does not seem to be a useful generic name.

Occurrence.—Carboniferous and Permian of Asia, Australia, North America, and Europe, and reported from the Mesozoic of Europe.

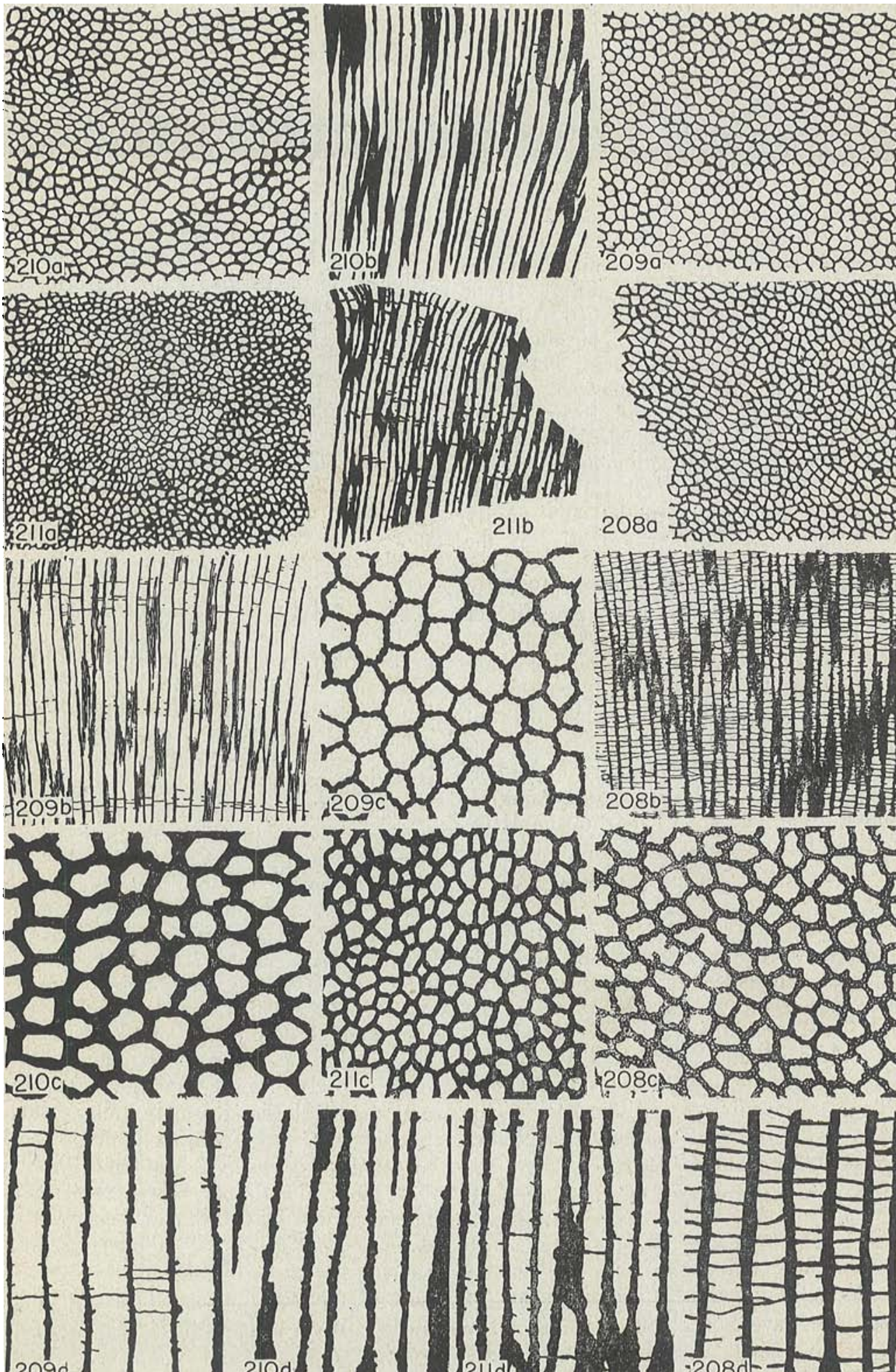
CHAETETES EXIMIUS, n.sp.

Text figs. 207, 208

Large massive colonies of fine prismatic tubes are included in this species. The holotheca is not indicated on any of the specimens and all are merely fragments of large colonies, so that they do not show the true shape of the colony. The tubes are evenly spaced throughout the mass. The largest specimen measures about 300 mm. by 110 mm.

In transverse sections the tubes are seen to be 5- or 6-sided polygons approximately equal in size. Pseudosepta, which develop where division is incomplete, are moderately numerous. The diameters of the tubes average about 0.3 mm. The walls are mostly 0.07 mm. in thickness. Examined in transverse section under strong magnification, the walls are seen to be swollen slightly so as to have a somewhat beaded appearance, about two beads occurring on each straight side of the tubes. Longitudinal sections show the slightly uneven thecal walls and numerous extremely fine flat tabulae. These tabulae are mostly complete, but some project from one or both sides without reaching entirely across the tube. Only rarely do tabulae join each other. The distribution of the tabulae is not uniform, but nearly all tubes have 6 tabulae to each millimeter. The thickness of the tabulae is very much less than that of the walls, measuring 0.008 to 0.01 mm.

Discussion.—Most American Pennsylvanian species of *Chaetetes* have been referred to *C. milleporaceus* Edwards and Haime (1851, p. 272) (incorrectly called *C. milleporaceous* by some authors). This species was characterized as a coral forming large masses and having strong walls, very long capillary-like corallites, and unequal polygonal calices about 0.25 mm. in diameter. The tabulae were described as complete, very closely spaced, 40 in a distance of 10 mm., and not corresponding in position in adjacent corallites. The occurrence was given as Carboniferous of Cumberland Mountains, Tennessee, and on the Ohio at Newburg, near Evansville, Indiana. Further information and illustrations of the internal structure of authentic examples seem to be lacking. Fossils from many localities and widely scattered stratigraphic units have been assigned to *C. milleporaceus*, but it is not certain which, if any, are truly conspecific. *C. milleporaceus* is not now recognizable. *C. eximius* seems to differ from the original description of *C. milleporaceus* in having many incomplete tabulae, more closely crowded complete tabulae, and slightly larger prismatic tubes. Comparison of *C. eximius* with topotype specimens of *C. schucherti* Morgan (1924, p. 174) from the Homer limestone of Oklahoma shows that the new species here described differs in the distinctly closer spacing of the tabulae, smaller tubes, and lack of the peculiar macula-like arrangement of tubes in parts of *C. schucherti*. *C. eximius* differs from specimens of *Chaetetes* from the Fort Scott, Pawnee, and


210a
210b
209a
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208a
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208d

Altamont limestones of southern Kansas in its more numerous and finer tabulae.

Occurrence.—The type material is from the Hale formation, Morrowan, Lower Pennsylvanian (Upper Carboniferous), at Keough quarry, 2½ miles north of Fort Gibson, Oklahoma, collected by R. H. King (Univ. Kansas loc. 7744). Other specimens were collected by R. C. Moore from the Hale limestone, along State highway No. 51, 3 miles west of Tahlequah, Oklahoma (Univ. Kansas loc. 7964), and by F. B. Plummer from the upper Marble Falls limestone on Colorado River one-fourth mile southwest of Bend, San Saba County, Texas (loc. 205–T–1), and from Gibbons' ranch, 2.6 miles S. 7° W. of Hall, San Saba County, Texas (loc. 205–T–102).

Material studied.—Large well-preserved specimens were available from each of the above localities. Abundant material from other formations was compared with the Morrowan species.

Type.—University of Kansas, specimen no. 7744–26, from Keough quarry, north of Fort Gibson, Oklahoma.

CHAETETES FAVOSUS, n.sp.

Text figs. 209, 210

Large colonies of subcylindrical form and evenly rounded at the top characterize this species. The fine prismatic tubes are very long and nearly straight, as examined in a hand specimen, but in the whole colony they are seen to curve radially so as to intersect the surface at right angles. The type specimen has a transverse diameter of about 250 mm. and originally reached a height of more than 800 mm. Whether or not this dominance of upward growth, as compared to expansion laterally, is important in distinguishing colonies belonging to this species is not known, but several similar growth forms were observed at the place near Bend, Texas, where the type was obtained. The colonies are separated from one another somewhat widely, that is, by some tens or scores of feet, and the growth form may depend largely on ecologic factors.

Transverse sections of *Chaetetes favosus* are distinguished by the even outlines and comparatively thin walls of the prismatic tubes; resemblance to an extremely fine-textured honeycomb is marked. The diameter of the tubes is little greater in one direction than another. Pseudosepta are rare. The thickness of the walls is very uniformly about 0.06 mm. and the diameter of the tubes averages 0.3 mm.; few tubes have a diameter as small as 0.25 mm. or, excepting sections of tubes just below points of fission, as large as 0.35 mm. The walls have a faintly beaded apparance. Longitudinal sections reveal an unusually wide spacing of tabulae and small number of these partitions. Short projections from the wall, representing incomplete tabulae, are much more numerous than complete tabulae, but in parts of the type specimen both types of diaphragms are nearly lacking. Many of the intercepts of incomplete tabulae are disposed in pairs, occurring at the same height and projecting toward one another from opposite sides of a tube; these tabulae seem to be centrally perforated platforms, like diaphragms of the trepostomatous bryozoan genus *Tabulipora.* Other incomplete tabulae consist

Figs. 208–211. Sections of *Chaetetes* from the Hale and Marble Falls formations. (208) *C. eximius,* n.sp., type specimen, no. KU7744–26, from the Hale formation, Keough quarry, north of Fort Gibson, Oklahoma; 208a, transverse section, x5; 208b, longitudinal section, x5; 208c, transverse section, x15; 208d, longitudinal section, x15. (209) *C. favosus,* n.sp., type specimen, no. KU4809, from the top of the Marble Falls limestone near Bend, Texas; 209a, transverse section, x5; 209b, longitudinal section, x5; 209c, transverse section, x15; 209d, longitudinal section, x15; (210) specimen no. P8622, from the Marble Falls limestone in northeastern Kimble County, Texas (loc. 134–T–8); 210a, transverse section, x5; 210b, longitudinal section, x5; 210c, transverse section, x15; 210d, longitudinal section, x15. (211) *C. subtilis,* n.sp., type specimen, no. P8605, from the Marble Falls limestone, northeastern Kimble County, Texas (loc. 134–T–8); 211a, transverse section, x5; 211b, longitudinal section, x5; 211c, transverse section, x15; 211d, longitudinal section, x15.

of short projections that have only a smooth wall opposite to them. A few specimens assigned to this species are so lacking in tabulae that it is necessary to search in order to find a few. It is true that tabulae are zonally distributed to some extent, being more abundant in all tubes at a given level than elsewhere, but this observation does not alter the described peculiarity of this species. Examination of any part of a colony shows a relative paucity of tabulae.

Discussion.—The distinguishing features of *Chaetetes favosus*, according to our study, which has included comparison of forms from many Pennsylvanian rocks, are the general uniformity in size and shape of the tubes, comparative thinness of the walls, and wide spacing of the tabulae. These characters serve to separate this species very readily from *C. eximius*, n.sp., and from most of the forms of *Chaetetes* observed in Des Moinesian strata. The Altamont limestone of Kansas contains a species that resembles *C. favosus* in having almost no tabulae, but the walls of the tubes are thicker, and size and shape of the tubes are less regular, and the form of the colonies seems to differ.

Occurrence.—Top of the Marble Falls limestone, Bendian, Lower Pennsylvanian (Upper Carboniferous); collected by R. C. Moore from widely exposed beds slightly above water level on the south side of Colorado River southwest of Bend, San Saba County, Texas (loc. 205–T–1 or Univ. Kansas loc. 4809). Several specimens from the middle Marble Falls limestone were collected by F. B. Plummer from east bank of Llano River, 1 mile south of Shell pipe line and 4000 feet east of the abandoned Bierschwale ranch headquarters, northeastern Kimble County, Texas (loc. 134–T–8); others were collected by F. B. Plummer from the upper Marble Falls along an old ranch road 1600 feet northeast of Cress Springs, or 11 miles southwest of Mason, Mason County, Texas (loc. 159–T–17). Four fragments referred to this species were also collected by N. F. Drake from the Marble Falls limestone on the first bend of Colorado River north of Nabor's Creek, Mills County, Texas.

Type.—University of Kansas, specimen no. 4809; part of type specimen deposited in collections of the Bureau of Economic Geology (Univ. Texas, Bureau of Economic Geology, specimen no. 31650, from near Bend, Texas.

CHAETETES SUBTILIS, n.sp.

Text figs. 211a-d

Description of this species is based on two lots consisting of rather small portions of colonies. Accordingly, the shape and dimensions of the masses from which the fragments were taken are not known to us. The largest fragment is about 25 by 20 mm. The specimens differ so markedly from other examples of *Chaetetes* that we venture to describe them as a new species.

The distinctive structural character of this species is the unusually small size of the tubes. Transverse sections indicate an average diameter of the tubes amounting to 0.15 mm.; many tubes measure only 0.10 mm. from wall to wall and some are as little as 0.05 mm. in diameter. The shape and size of the tubes are more irregular than in most examples of *Chaetetes*, but only a few tubes of very uneven cross section have a greatest diameter exceeding 0.30 mm. The walls are 0.03 to 0.06 mm. in thickness, the average being 0.05 mm. Tabulae are widely spaced. They seem to be relatively more abundant than in *C. favosus*, n.sp., but in some tubes there are no complete tabulae in distances of 5 or 6 mm. The tubes are fairly straight and regular in direction of growth.

Discussion. — This species is distinguished from *Chaetetes favosus*, n.sp., *C. eximius*, n.sp., and all other forms known to us by the small size of the tubes. The shape and arrangement of the tubes is more irregular than in either of the species just mentioned.

Occurrence.—Marble Falls limestone, Bendian, Lower Pennsylvanian (Upper Carboniferous); collected by F. B. Plummer from east bank of Llano River, 1 mile south of Shell pipe line and 4000 feet east of the old Bierschwale ranch headquarters (now Morgan ranch) (loc. 134–T–8), northeastern Kimble County, Texas.

Type.—The University of Texas, Bureau of Economic Geology, specimen no. 8605.

SUBORDER DOUBTFUL

Family PALAEACIDAE, n.fam.

Fossils having the characters of the genus *Palaeacis* Haime are included in this family. Range, Mississippian to Permian.

Discussion.—The great uncertainty in classification of *Palaeacis* in any established family group, in conjunction with the distinctive peculiarities, considerable stratigraphic range, and recognition of more and more species, makes desirable the erection of a separate family. Several undescribed Pennsylvanian representatives are known, of which two are given in this paper.

Genus PALAEACIS Haime, 1857

Sphenopterium MEEK and WORTHEN, 1860, Acad. Nat. Sci. Philadelphia, Proc., p. 447.

This genus comprises rather small solitary or colonial supposed corals that are distinguished by lack of distinct septa in the round or somewhat polygonal calices, the presence of pores in the walls and floor of the calices and opening on the outer surface of the fossil, and the spongelike structure of the calcareous hard parts generally. The calices are shallow or deep, and their interior surface is comparatively smooth or very uneven. Some specimens bear distinct furrows and low ridges running longitudinally from the rim of the calyx toward the floor; several pores are located along the grooves. Other specimens entirely lack a suggestion of even rudimentary septa and the pores are irregularly disposed. Interspaces between the calices are marked by fine anastomosing low ridges and granules, and there are small pores at intervals in the grooves between the ridges. Sections of these fossils show the presence of a labyrinthine pattern of fine canals that lead to the pore openings on the exterior and in the calices; in well-preserved specimens they also show the arrangement of diverging bundles of very fine calcite fibres or prisms. The lower part of the fossil is pointed, rounded or expanded and shows commonly a scar of attachment.

Genotype. — *Palaeacis cuneiformis* Haime, Salem limestone, Meramecian, Mississippian (Lower Carboniferous); Spergen Hill, Indiana.

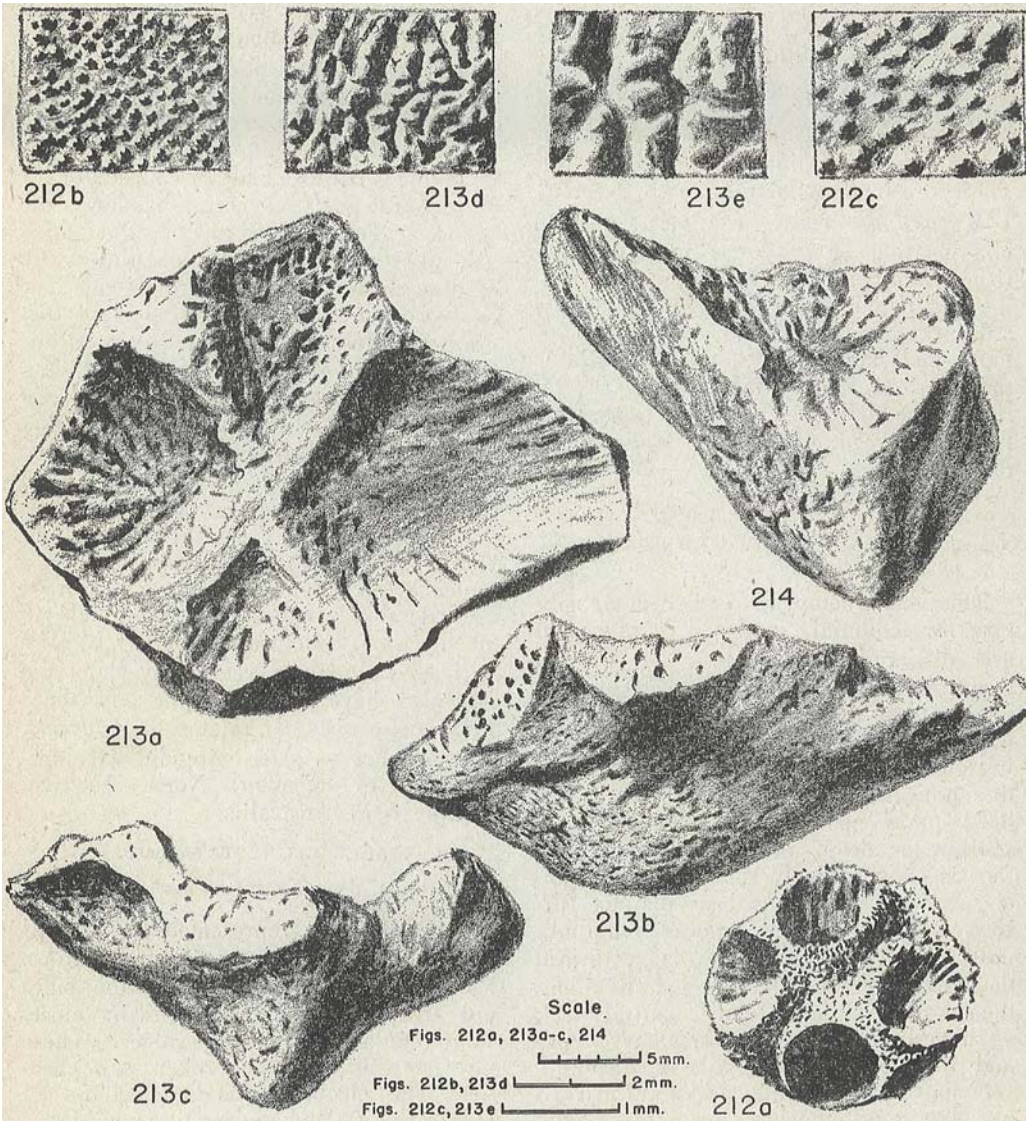
Discussion.—No other late Paleozoic fossils closely resemble *Palaeacis*. Specimens belonging to the genus are strikingly unlike contemporaneous types of undoubted corals, and the structure of their hard parts suggests that of some sponges. The absence of observed spicules like those of sponges and the nature of the calices, which have no resemblance to the oscula of sponges, suggest that *Palaeacis* does not belong to the Porifera, although Meek and Worthen (1866, p. 146) report that A. E. Verrill, a specialist on the corals, concluded that this genus probably belongs with the sponges. Several undoubted corals, such as *Actinacis* Orbigny (Cretaceous, Tertiary), *Heptastylis* Frech (Triassic), and *Spongiomorpha* Frech (Triassic), have a spongy intercalicinal structure traversed by irregular canals that corresponds to to the wall structure of *Palaeacis*. The Archaeocyathidae of very early Paleozoic age also have porous septa and theca and may be distantly related to *Palaeacis*.

Occurrence. — Mississippian (Kinderhookian) to Permian; North America, Europe, Asia, Australia.

PALAEACIS TESTATA, n.sp.

Pl. 14, figs. 6a, b; text figs. 212a-c

This species is represented by a small corallum consisting of five corallites. The holotheca is covered on the sides and areas between the calices by close-set irregular labyrinthic ridges. These may be continuous or broken into granules. The specimen was attached over a wide area of the base and it rises higher and more steeply on one side than the other. Apertures of the calices are circular and raised above the surface. The interior of the deep calices is marked by poorly developed vertical grooves. These grooves are not pronounced and their number is not determined. Pore openings seem confined to these grooves. The large individual calices are 4.5 mm. in diameter and 3.7 mm. in depth. The entire corallum is 8.8 mm. in height and 6.3 mm. in maximum diameter.



Figs. 212–214. Exterior views of species of *Palaeacis* from the Smithwick shale. (212) *P. tes-tata,* n.sp.; 212a, upper surface of type specimen, no. P7823a, x2.7, from 3 miles east of Rochelle, Texas (loc. 153–T–6), showing the circular deep calices; 212b, part of the surface of *P. testata,* x7.5, showing strongly elevated, sharp-pointed granules; 212c, same, x15. (213) *P. walcotti,* n.sp.; 213a–c, top, side, and end views of the type, no. USGS647m, x2.7, from Honey Creek, Llano County, showing shape of the corallum and the shallow calices; 213d, part of the surface of this specimen, x7.5, showing irregular grooves and ridges; 213e, same, x15. (214) End view of another specimen of *P. walcotti,* x2.7, specimen no. USGS647n, from the same locality as the type.

Discussion.—This species differs from most described species of *Palaeacis* in the irregularly formed corallum and large area of attachment. The anastomosing external ridges mostly are composed of elongated granules, rather than elongated ridges, as in *P. axinoides* Smyth (1929, p. 126). The Smithwick species also lacks the wedgelike shape of the corallum and numerous member corallites of *P. axinoides*. *P. testata* can be distinguished from *P. depressa* (Meek and Worthen, 1866, p. 146) by the basal area of attachment, greater depth of the corallum, and irregular shape.

Occurrence. — Smithwick shale, Bendian, Lower Pennsylvanian (Upper Carboniferous); collected by F. B. Plummer, 3 miles east of Rochelle, McCulloch County, Texas (loc. 153–T–6).

Material studied.—One well-preserved complete corallum was available for study.

Type.—The University of Texas, Bureau of Economic Geology, specimen no. P–7823a.

PALAEACIS WALCOTTI, n.sp.

Text figs. 213, 214

The coralla belonging to this species are unusually large, inasmuch as only two or three among all described forms belonging to *Palaeacis* rival it in magnitude. The colonies are composed typically of four corallites disposed around a center, the two largest calices being located commonly on the long axis of the corallum and two smaller calices being placed opposite one another on the short transverse axis of the corallum. The dividing walls between the calices are narrow and together they form a more or less regular cross. The outline of the calices is rounded on the outer sides but somewhat angulated at the point where the depressions come most closely together; measurements of the diameter of the calices are slightly or very distinctly greater in directions pointing radially from the center of the corallum than at right angles to these directions. The cups are very shallow, the greatest depth amounting to only one-third or one-fourth of the greatest diameter. The sides are marked by irregular sharp ridges and furrows running normal to the rim of the calices and converging toward the center; they form a pattern like that of very short, evenly disposed septa. The grooves between the septa-like ridges contain round pits that in many places encroach on the ridges and deflect them; the pits connect with irregular canals that traverse the otherwise dense skeletal mass of the coralla. The lower surface of a colony has the form of a rather uneven four-sided inverted pyramid having rounded edges; the dominance of one transverse axis of the pyramid over the other, and much sharper curvature of the surface along this dominant axis, are modifications that almost obliterate the suggestion of inverted pyramid, however. Some specimens resemble a very broad-beamed boat. A small scar of attachment is observable at the lowermost point of of all but one of the specimens. The outer surface bears a characteristic pattern of very uneven grooves and ridges.

The type specimen has a height of 12.5 mm., a greatest length of 30.5 mm. (incomplete), and a transverse measurement of 24 mm.; the larger calices of this specimen are 15.5 mm. by 12 mm. across and 3.5 to 4 mm. in depth. Four other specimens in the collection range in height from 17.5 to 21.5 mm., in greatest width from 20 to 31.5 (all incomplete), and in width at right angles to the longer measurement from 17 (incomplete) to 25 mm.

Discussion.—This large species differs so strikingly from *Palaeacis testata*, n.sp., in shape, size, surface markings, and characters of the calices that detailed comparison is needless. Drawings of the two forms at the same scale (figs. 212–214) illustrate their contrasting characters. *P. walcotti* somewhat closely resembles an undescribed species from an unrecorded horizon in upper Des Moinesian or lower Missourian rocks of Palo Pinto County, Texas; this new species is represented by two excellently preserved specimens belonging to the U. S. National Museum. Differences in surface marking, shape of the corallum, and characters of the calices serve readily to separate the Palo Pinto County specimens from *P. walcotti*, however. The new species here described is approximately matched in size by two

Pennsylvanian species from Iowa, called *P. cymba* Seebach and *P. umbonata* Seebach, and the first-mentioned form consists typically of four corallites arranged like those of *P. walcotti*. The coralla of *P. cymba* is more compressed laterally, the calices seemingly deeper and the exterior smoother than the Texas species. *P. tubifer* Gerth, from Permian rocks of Timor, is a species that attains length and width approximately equal to the dimensions of *P. walcotti* but it differs radically in the shape of the corallum and other features.

Occurrence.—The locality records accompanying these fossils read: "Llano quadrangle, Texas—Texas Carboniferous (Honey Creek section). C. D. Walcott, Oct. 5, 1884." This outcrop lies on Slaughter ranch about 10 miles southeast of Llano, Llano County, Texas. Because the specimens are associated with very numerous examples of *Cumminsia aplata* (Cummins), which elsewhere is unknown except in the Smithwick shale, it seems reasonable to conclude that the Honey Creek strata yielding *Palaeacis walcotti* belong to the Smithwick.

Type.—U. S. Geological Survey, specimen no. 647m.

REGISTER OF LOCALITIES

Arkansas

P–9364. Brentwood limestone, 1½ miles northeast of Fayetteville, on State highway No. 45, F. B. Plummer, collector. (*Lophophyllidium conoideum*, n.sp., *Chaetetes eximius*, n.sp.)

P–10500. Brentwood limestone, one-fourth mile east of Brentwood.

KU–720. Brentwood limestone, at Acorn Cut, south of Fayetteville; R. C. Moore, collector. (*Michelinia spissata*, n.sp.)

KU–4625. Brentwood limestone, NE. ¼ sec. 21, T. 14 N., R. 30 W. (Winslow quadrangle); R. C. Moore, collector. (*Lophophyllidium coaptum*, n.sp.)

KU–5441. Brentwood limestone. Hale Mountain, 1 mile south of Morrow. R. C. Moore, collector. (*Lophophyllidium angustifolium*, n.sp.)

KU–6968. Brentwood limestone, 4 miles north of Winslow. (*Striatopora oklahomensis* (Snider).)

KU–7206. Brentwood limestone, on U.S. highway No. 71, near Woolsey; R. C. Moore and F. B. Plummer, collectors. (*Lophophyllidium metum*, n.sp., *Michelinia latebrosa*, n.sp., *Lophotichium vescum*, n.sp., *?Barytichisma callosum*, n.sp., *Striatopora oklahomensis* (Snider).)

New Mexico

7999. "Derry" formation, Morrowan, 6 feet above Mississippian. Ash Canyon, between Ash Can Springs and Jose M. Pappa Tank, San Andres Mountains. SW. ¼ NE. ¼ sec. 28, T. 19S. R. 4 E.; A. L. Bowsher, collector. (*Striatopora oklahomensis* (Snider).)

Oklahoma

KU–976. Jolliffe limestone, on U.S. highway No. 77, about 7 miles north of Ardmore; R. C. Moore, collector. (*Michelinia latebrosa*, n.sp.)

KU–1221. Wapanucka limestone, just west of Clarita; R. C. Moore, collector. (*Lophophyllidium minutum* Jeffords.)

KU–2747. Wapanucka limestone, on Coal Creek, in sec. 15, T. 1 N., R. 7 E., about 15 miles southeast of Ada, Pontotoc County; R. C. Moore, collector. (*Stereocorypha annectans*, n.sp.)

KU–4520. Hale formation, at Keough quarry, about 2½ miles north of Fort Gibson; R. C. Moore, collector. (*Lophophyllidium blandum*, n.sp., *L. metum*, n.sp., *Lophamplexus captiosus*, n.sp., *L.* sp. A, *L.* sp. B, *Michelinia tenuicula*, n.sp., *M. scopulosa*, n.sp., *Acaciapora subcylindrica* (Mather), *Amplexocarinia corrugata* (Mather).)

KU–5564. Hale formation. Keough quarry, about 2½ miles north of Fort Gibson (sec. 36, T. 16 N., R. 19 E.); R. C. Moore, L. R. Laudon, R. H. King, collectors. (Same as KU–4520.)

KU–7060. Wapanucka limestone, near Limestone Gap, sec. 30, T. 2 N., R. 13 E. Atoka County; R. C. Moore, collector. (*Stereocorypha spissata*, n.sp., *Lophophyllidium minutum* Jeffords.)

KU–7096. Hale formation. N. line sec. 22, T. 16 N., R. 20 E., south of Hulbert; R. C. Moore, collector. (*Amplexocarinia corrugata* (Mather), *Striatopora oklahomensis* (Snider).)

KU–7130. Hale formation, about one-fourth mile south of Keough quarry, north of Fort Gibson; R. C. Moore, collector. (*Neokoninckophyllum simplex*, n.sp.)

KU–7134. Wapanucka limestone, 1 mile south and 1 mile east of Hartshorne, in stone quarry; R. C. Moore, collector. (*Lophophyllidium ignotum*, n.sp., *L.* sp. A.)

KU–7142. Otterville limestone. On U.S. highway No. 77, 5 miles north of Ardmore; R. C. Moore, collector. (*Michelinia latebrosa*, n.sp.)

KU–7151. Wapanucka limestone, on State highway No. 61, 1 mile west of Wapanucka. (*Lophophyllidium idonium*, n.sp.).

KU–7364. Hale formation, 2 miles southeast of Hulbert; R. C. Moore, collector. (*Striatopora oklahomensis* (Snider).)

KU–7385. Hale formation. At spillway below Greenleaf Lake, southeast of Braggs (cen. sec. 10, T. 13 N., R. 20 E.); R. C. Moore, L. R. Laudon, R. H. King, A. L. Bowsher, collectors. (*Lophophyllidium angustifolium*, n.sp., *L. exile*, n.sp., *L. minutum* Jeffords, *L.* sp. A, *Lophotichium vescum*, n.sp., *L. improcerum*, *L. densum*, n.sp., *L.* sp. A, *Lophamplexus captiosus*, n.sp., *L.* sp. B, *Amplexocarinia corrugata* (Mather), *Pseudozaphrentoides nitellus*, n.sp., *Michelinia tenuicula*, n.sp., *M. scopulosa*, n.sp., *Acaciapora subcylindrica* (Mather), *Cladochonus fragilis* Mather.)

KU–7744. Hale formation. Near Keough quarry, 2½ miles north of Fort Gibson; R. C. Moore and L. R. Laudon, collectors. (*Lophotichium vescum*, n.sp., *L. amoenum*, n.sp., *Dibunophyllum? inauditum*, n.sp., *Michelinia tenuicula*, n.sp., *M. scopulosa*, n.sp., *Hapsiphyllum crassiseptatum*, n.sp., *Amplexocarinia corrugata* (Mather), *Pseudozaphrentoides nitellus*, n.sp., *Chaetetes eximius*, n.sp.)

KU–7964. Hale formation, on State highway No. 51, 3 miles west of Tahlequah. (*Chaetetes eximius*, n.sp.)

Texas

Burnet County

27–T–10. Marble Falls limestone (upper). Outcrop on north bank of Colorado River near Millsite Bluff above the bridge, Marble Falls (bed 14, of stratigraphic section;[7] F. B. Plummer, collector. The same beds on opposite side of bridge constitute the type locality for *Neokoninckophyllum gracile*, n.sp., and both *Amplexocarinia corrugata* (Mather) and *Pseudozaphrentoides lepidus*, n.sp., are recorded from this exposure. (See map, fig. 1, in preceding paper by F. B. Plummer.)

27–T–16. Marble Falls limestone (upper). About 4900 feet from Onion Creek on electrical transmission line, 3.1 miles S. 45° E. of bridge over Colorado River at Marble Falls; F. B. Plummer and J. D. Ewers, collectors. Type locality for *Multithecopora paucitabulata*, n.sp. (See map, fig. 1, in preceding paper by F. B. Plummer.)

USGS–2402. Marble Falls limestone (upper). North bank of Colorado River just below bridge at Marble Falls. Black muddy limestone 75 to 85 feet below top of Carboniferous limestone. Lot 38. G. H. Girty, collector, Sept. 20, 1910.

USGS–2404. Marble Falls limestone (upper). South bank of Colorado River opposite locality 2402. Near top of Marble Falls limestone as exposed here. Lot 34. G. H. Girty, collector, Sept. 19, 1910.

USGS–2404a. Marble Falls limestone (upper). Same as loc. 2404 but from bed 15 to 20 feet higher in the section. Lot 35. "*Campophyllum* and *Echinocrinus* abundant." G. H. Girty, collector, Sept. 19, 1910.

KU–7994. Marble Falls limestone (upper). Along Colorado River below steel bridge at Marble Falls (essentially same as 27–T–10); J. D. Ewers, collector. Type locality for *Neokoninckophyllum gracile*, n.sp.

KU–8093. Marble Falls limestone (upper). Banks of Colorado River near steel highway bridge at Marble Falls (same is 27–T–10); R. C. Moore and J. D. Ewers, collectors.

[7]Plummer, F. B., The Carboniferous rocks of the Llano region of central Texas: Univ. Texas Pub. 4329, in press.

Kimble County

134–T–2. Marble Falls limestone (middle), zone of *Neospirifer cameratus*, Big Saline member. North side of Llano River at Smith Crossing just east of mouth of Big Saline Creek, 4.8 miles S. 45° E. of London. Type locality for *Neokoninckophyllum arcuatum*, n.sp.; *N.* sp. A is described from this exposure. (See fig. 15 in following paper by H. J. Plummer.)

134–T–6. Marble Falls limestone, upper part of Big Saline member. On Big Saline Creek, 1.6 miles N. 67° W. of old Pfluger ranch house, 3.2 miles S. 37° E. of London. Type locality for *Pseudozaphrentoides lepidus*, n.sp. (See fig. 15 in following paper by H. J. Plummer.)

134–T–S. Marble Falls limestone (middle). East bank of Llano River 1 mile south of Shell Company pipe line and 4000 feet east of abandoned Bierschwale ranch headquarters (now Morgan ranch); F. B. Plummer, collector. Type locality for *Chaetetes subtilis*, n.sp. *Chaetetes favosus*, n.sp., is also found in these beds. See fig. 15 in following paper by H. J. Plummer.)

Lampasas County

USGS–2429. Marble Falls limestone (upper). "San Saba quadrangle. In creek bottom 2.5 miles west of Nix on road to Bend. J. A. Taff, E. O. Ulrich, and J. W. Beede," collectors. (See Pl. 11 in preceding paper by F. B. Plummer.) Type locality for *Empodesma imulum*, n.sp.

Llano County

USGS–647. Smithwick shale. Honey Creek, Llano quadrangle, C. D. Walcott, collector, Oct. 5, 1884. This exposure lies somewhere on the Slaughter ranch, about 10 miles southeast of Llano. It has yielded about 150 specimens of *Cumminsia aplata* (Cummins), which is characteristic of the Smithwick. This is the type locality for *Hapsiphyllum retusum*, n.sp., and *Palaeacis walcotti*, n.sp.

McCulloch County

153–T–6. Smithwick shale. About 3 miles east of Rochelle, in gully 0.9 of a mile south of the San Saba-Brady highway (see Pl. 11). Type locality for *Palaeacis testata*, n.sp. *Cumminsia aplata* (Cummins) is very rare in these shales.

153–T–81. Marble Falls limestone (upper). At old road crossing on southwest side of Brady Creek, 2 miles southeast of Brady courthouse (see Pl. 11); F. B. Plummer, collector. *Lophophyllidium conoideum*, n.sp., is recorded here.

153–T–85. Marble Falls limestone, Big Saline member with fusulines. Spillway at Shropshire Lake, 3.3 miles S. 62° E. of courthouse at Brady (see Pl. 11). Type locality for *Rodophyllum texanum*, n.sp.

KU–7752. Marble Falls limestone, big Saline member; 3.4 miles S. 20° E. of Rochelle (also recorded as 5 miles southeast of Rochelle); Maurice Wallace, collector.

Mason County

159–T–1. Marble Falls limestone (middle). Bank of Honey Creek about a quarter mile upstream (northwest) from bridge on Mason-White's Crossing road, 2 miles in direct line north-northeast of White's Crossing, or 7 miles southwest of Mason. *Michelinia latebrosa,* n.sp., is recorded from here.

159–T–17. Marble Falls limestone (upper). Along ranch road on White ranch, about 1600 feet northeast of Cress Spring and 11 miles southwest of Mason, or 2½ miles west-southwest of White's Crossing on Llano River. *Chaetetes favosus,* n.sp., occurs at this locality.

KU–7125. Marble Falls limestone (middle). On Honey Creek, about 7 miles southwest of Mason (same as 159–T–1); R. C. Moore, collector.

San Saba County

205–T–1. Marble Falls limestone and shale. Extensive high bank of hard limestone ("*Nautilus* limestone") at the base overlain by more than 40 feet of black shale lies between the San Saba-Bend road and Colorado River from about one-half to three-quarters of a mile southwest of Bend on the south side of McAnelly's Bend of the Colorado (see Pl. 11). This is the type locality for *Paracaninia? sana,* n.sp., *Cladochonus texasensis,* n.sp., and *Chaetetes favosus,* n.sp.; *Chaetetes eximius,* n.sp., and *C. subtilis,* n.sp., are also recorded from this exposure.

205–T–4. Marble Falls limestone (lower). On San Saba-Llano road 4 miles by road south of San Saba (same as KU–6885, KU–7132) (see Pl. 11). Type locality for *Lophophyllidium extumidum,* n.sp., accompanied by *L. idonium,* n.sp., and *Barytichisma crassum,* n.sp.

205–T–13. Smithwick shale. Steep banks along small creek across Bend-Chappel road close to its junction with the San Saba-Bend road, 1.1 miles southwest of Bend (see Pl. 11). *Cumminsia aplata* (Cummins) is common in this well-known exposure.

205–T–16. Marble Falls limestone (middle). Bank of Rough Creek just east of San Saba-Bend highway, about 5 miles in direct line northwest of Bend (same as USGS–2619) (see Pl. 11). *Barytichisma callosum,* n.sp., is recorded from this outcrop.

205–T–40. Marble Falls limestone (lower). Prominent exposure of Barnett shale (Mississippian) overlain by Marble Falls limestone on east side of San Saba-Llano highway 5.2 miles by road south of San Saba courthouse (see Pl. 11). Type locality for *Barytichisma repletum,* n.sp., accompanied by *Amplexocarinia corrugata* (Mather).

205–T–43. Marble Falls limestone (lower). West of Wallace Creek road, 10.2 miles S. 45° W. of San Saba courthouse, or 0.8 of a mile north of Indian monument (same as KU–7171); F. B. Plummer, collector (see Pl. 11). Type locality for *Stereocorypha annectans,* n.sp., *Barytichisma crassum,* n.sp., *B. callosum,* n.sp., and *Acaciapora venusta,* n.sp.

205–T–49. Marble Falls limestone (lower). Basal strata lying on Barnett shale (Mississippian) on Chappel-Cherokee road, in valley of Hollow Creek, 1¼ miles by road south of Cherokee Creek crossing or 2¾ miles in direct line south-southwest of Chappel (same as KU–7149 (see Pl. 11). *Cladochonus fragilis,* n.sp., occurs here.

205–T–50. Smithwick shale. Ellis pasture, west of big cattle tank, 2 miles northeast of Maxwell Crossing on San Saba River, one-half mile east of Sloan School, or 10½ miles S. 80° W. of San Saba courthouse (see Pl. 11); F. B. Plummer, collector. Type locality for *Zaphrentoides excentricus,* n.sp., accompanied by *Cumminsia aplata* (Cummins).

205–T–65. Marble Falls limestone (lower). Top of hill on road to King Spring, Sloan ranch, one-half mile southeast of San Saba river, or 1 mile southwest of Walnut Springs, south of ranch gate (same as KU–7079) (see Pl. 11). *Michelinia referta,* n.sp., and *Amplexocarinia corrugata* (Mather) have been found in these strata.

205–T–71. Smithwick shale. Tank on Gibbons' ranch east of Jack Wood's house, 1 mile due west of Hackberry Mill, or 7.5 miles S. 25° W. of Richland Springs (see Pl. 11). Type locality for *Hapsiphyllum tumidum,* n.sp., and *Michelinia referta,* n.sp., accompanied by *Cumminsia aplata* (Cummins).

205–T–79. Smithwick shale. Along gully south of cattle tank, 1 mile north-northeast of Baker Spring and northwest of Baker ranch house, or 4.6 miles S. 33° E. of Richland Springs (see Pl. 11). *Zaphrentoides excentricus,* n.sp., and *Cumminsia aplata* (Cummins) are recorded from these shales.

205–T–84. Marble Falls limestone (lower). Near Turkey Roost Creek, Jym Sloan's ranch, one-half mile due east of Heron Bluff, 1¾ miles south-southwest of Walnut Springs, 1¼ miles south of Maxwell Crossing on San Saba River, or 10 miles almost due south of Richland Springs (same as KU–7511) (see Pl. 11). *Stereocorypha annectans,* n.sp., and *Michelinia referta,* n.sp., have been found in this outcrop.

205–T–87. Marble Falls limestone (upper). About 5 miles south-southwest of Hall, 1½ miles northeast of Treasure Cavern, and 1½ miles east of the western boundary of the county (see Pl. 11). Type locality for *Striatopora religiosa,* n.sp.

205–T–92. Marble Falls limestone (lower). Excavation for caliche about one-quarter mile northeast of Jack Sloan's rock house and 2.2 miles northwest of Maxwell Crossing on San Saba River; 6.8 miles due south of Richland Springs (same as KU–7085) (see Pl. 11). Contains abundant crinoid fragments and ramose bryozoa. F. B. Plummer and R. C. Moore, collectors. *Lophophyllidium adapertum,* n.sp., is very abundant in these shales.

205–T–102. Marble Falls limestone (upper). On Gibbons' ranch 2.6 miles S. 7° W. of Hall (see Pl. 11). *Chaetetes eximius,* n.sp., is recorded from this exposure.

205–T–165. Marble Falls limestone (middle). On San Saba-Chappel road, 1.7 miles S. 36° E. of San Saba courthouse (see Pl. 11).

J. A. Udden, collector. Type locality for *Pseudozaphrentoides spatiosus*, n.sp., accompanied by *Lophophyllidium extumidum*, n.sp.

USGS–1767. Smithwick? shale. San Saba? Locality unrecorded. Numerous specimens of *Cumminsia aplata* (Cummins) are probably reliable indicators of Smithwick age of this exposure.

USGS–2415. Marble Falls? limestone. "San Saba quadrangle, Lot 49a, same as Lot 49 but higher in section. G. H. Girty, collector, Sept. 30, 1910." Type material for *Lophophyllidium adapertum*, n.sp.

USGS–2419. Marble Falls limestone. "San Saba quadrangle, Lot 46a, same as Lot 46. *Nautilus* limestone below 46. G. H. Girty, collector, Sept. 26, 1910." (Probably same as 205–T–1.) *Empodesma imulum*, n.sp., occurs at this locality.

/ **USGS–2606.** Marble Falls limestone (upper). About 2¼ miles south of San Saba on road to Llano. Going south after crossing creek, road swings right and goes uphill. At the first small cut and bottom of larger fill. Lot Ry 43a. P. V. Roundy, April, 1919. (This is probably the exposures just south of Simpson Creek crossing.)

USGS–2612. Marble Falls formation (upper). South bank of Colorado River about 1 mile west of Bend, about 6 feet above river. Lot Ry 51a. P. V. Roundy, April, 1919. (Same as 205–T–1.)

USGS–2619. Marble Falls limestone (middle). North bank of Rough Creek, just east of San Saba-Bend road, 8 miles east and 5 miles south of San Saba courthouse (same as 205–T–16). Lot Ry 60. P. V. Roundy, April, 1919.

USGS–2689. Marble Falls limestone (middle). North side of Simpson Creek about 1.7 miles south and 0.3 mile east of San Saba courthouse (probably same as 205–T–165). Lot HD19. Gastropod-bearing shale. K. C. Heald and G. F. Gerlz, collectors.

USGS–7015. Marble Falls limestone (upper). About one-half mile southwest of Bend (same as 205–T–1). 7015g, "Base of lower limestone ledge below black shale—horizon III of Ulrich's section." 5017h, "Lower half of horizon IV of Ulrich's section." Type locality for *Paracaninia? sana*, n.sp.

KU–4809. Marble Falls limestone (upper). On Colorado River at Bend (same as 205–T–1). Type locality for *Chaetetes favosus*, n.sp.

/ **KU–6885.** Marble Falls limestone (basal). Same as 205–T–4.

KU–7079. Marble Falls limestone (lower). Sloan ranch on King Creek, about 1300 feet north of King Springs, 12.9 miles S. 74° W. of San Saba courthouse, 0.6 of a mile south of Maxwell Crossing on road to King Springs (same as 205–T–65).

KU–7085. Marble Falls limestone (lower). Sloan ranch one-quarter mile northeast of Jack Sloan's house, 13 miles S. 74° W. of San Saba courthouse (same as 205–T–92); R. C. Moore, collector.

KU–7132. Marble Falls limestone (lower). On Llano road, 3.7 miles S. 15° W. of San Saba courthouse (same as 205–T–4).

KU–7149. Marble Falls limestone (lower). Chappel-Cherokee road, 1½ miles south of Cherokee Crossing (same as 205–T–49); R. C. Moore, collector.

KU–7171. Marble Falls limestone (lower). Same as 205–T–43.

KU–7511. Marble Falls limestone (lower). On Turkey Roost Creek, Jym Sloan ranch, 13.6 miles S. 72° W. of San Saba courthouse, or 1.3 miles south of Maxwell Crossing (same as 205–T–84).

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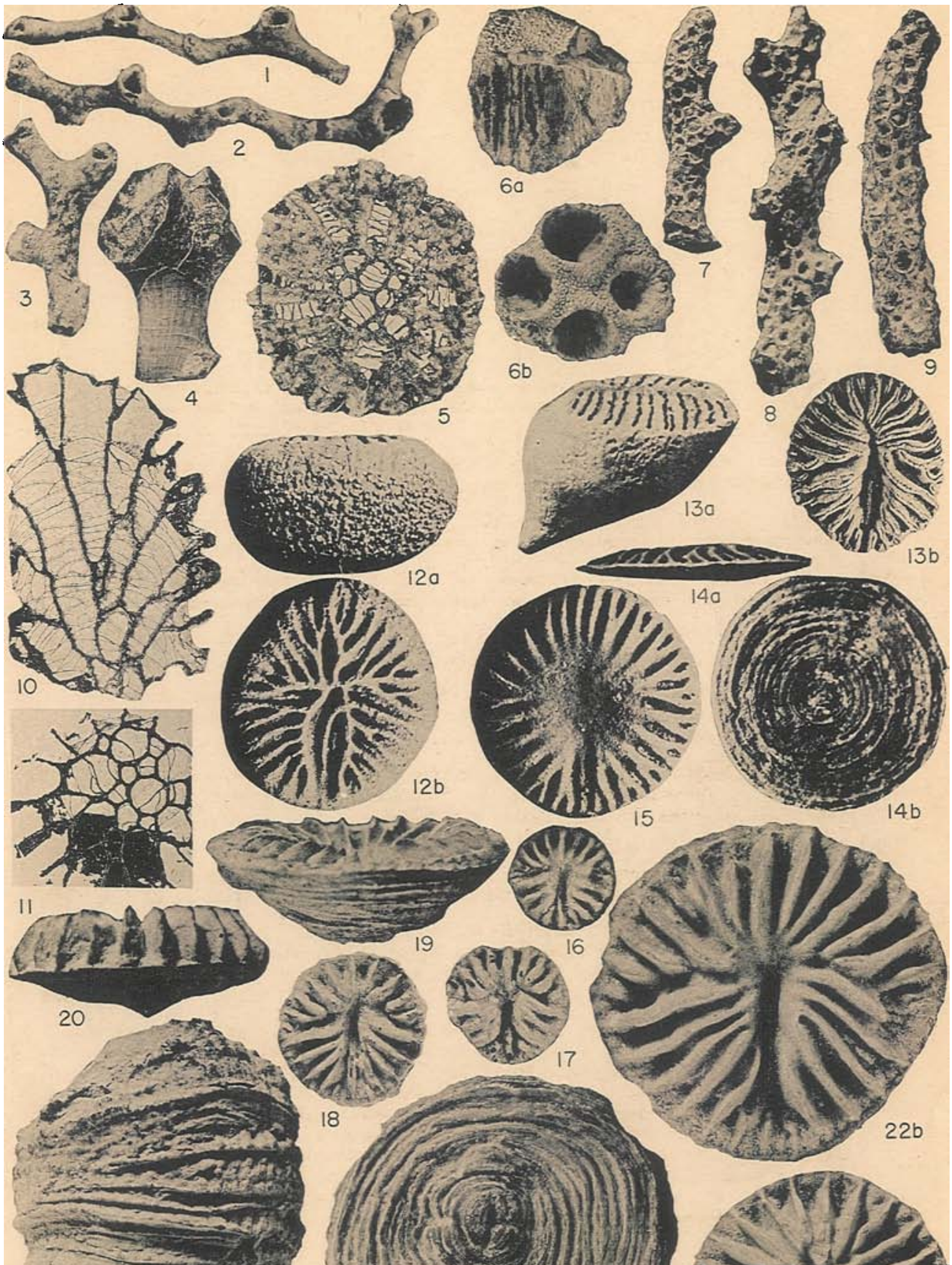
PLATE 14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SMALLER FORAMINIFERA IN THE MARBLE FALLS, SMITHWICK, AND LOWER STRAWN STRATA AROUND THE LLANO UPLIFT IN TEXAS

Helen Jeanne Plummer

INTRODUCTION

During the period of detailed mapping of the Mississippian and Lower Pennsylvanian formations around the Llano uplift in central Texas by F. B. Plummer and assistants for a forthcoming publication (Univ. Texas Pub. 4329, in press), it has been possible to make collections of representative material from these outcropping strata for study of their foraminiferal faunas (exclusive of fusulinids). Some material from the Barnett and Chappel formations (Mississippian) has been examined, but these strata have proved almost devoid of Foraminifera, though they carry some ostracodes, conodonts, and other microscopic marine organisms. The Marble Falls and Smithwick formations (Lower Pennsylvanian) were found so consistently foraminiferal, that attention has been focused on this sequence. Since the overlying lower Strawn beds (lower Middle Pennsylvanian) were so easily available and were found to be rich in foraminiferal tests, many excellent outcrops have been studied and included in this report largely to offer some clue as to upward ranges of the species found in the Lower Pennsylvanian formations.

Without the constant association with the areal mapping done by F. B. Plummer and without his aid and encouragement in procuring an abundance of representative material, this study could hardly have been undertaken. Dr. E. H. Sellards, Director of the Bureau of Economic Geology, has aided invaluably in making satisfactory arrangements to carry on the work and in forwarding its progress. Dr. J. A. Cushman of the Cushman Laboratory for Foraminiferal Research, Dr. H. N. Coryell of Columbia University, and Dr. R. S. Bassler and Mr. Lloyd Henbest of the U. S. National Museum have coöperated in every way to make available for study all type specimens of Carboniferous species described from outcrops in the Midcontinent states. Dr. Carl O. Dunbar, Director of Peabody Museum at Yale University and Mr. Erik Waering of Shell Production Company have rendered aid in identifications of fusulinids in some strata to help in age determinations and correlation problems. Dr. J. J. Galloway of University of Indiana, Dr. A. S. Warthin of Vassar College, and Mr. R. V. Hollingsworth of Shell Petroleum Company have contributed some type material from a few localities in Oklahoma. Mr. Frederick Chapman and Mr. W. J. Parr of Melbourne, Australia, have been helpful in supplying some literature and a few samples for comparative studies. Without the generous and numerous contributions from Mr. J. A. Waters from his original collections of material carrying species described by Cushman and Waters, and without his personal help in a few problems concerning their early studies, much of the investigation would have progressed less satisfactorily. Finally, a small portion of a grant from the Research Fund of the Geological Society of America, made available through the bequest of R. A. F. Penrose, Jr., was used to collect some of this outcrop material, though most of the grant was devoted to field work in formations higher in the geologic section for a forthcoming publication.

All specimens figured[1] in this paper have been deposited in the Plummer Collection in Austin, and a duplicate set will be available at the Bureau of Economic

[1]It is unfortunate that authors of paleontologic papers generally feel that deposition of their figured or unfigured hypotypes in reference collections is quite superfluous. Especially for students of stratigraphic problems is it important to study all specimens in a fauna formally recorded. As species are studied and described more comprehensively—taxonomically, geologically, geographically, and paleoecologically—such reference specimens will become more and more essential to the best interests of stratigraphy. Certainly when broad studies of faunal groups throughout a definite succession of formations in a geological province is undertaken, availability of representative specimens of all species recorded is imperative to aid in problems of correlation.

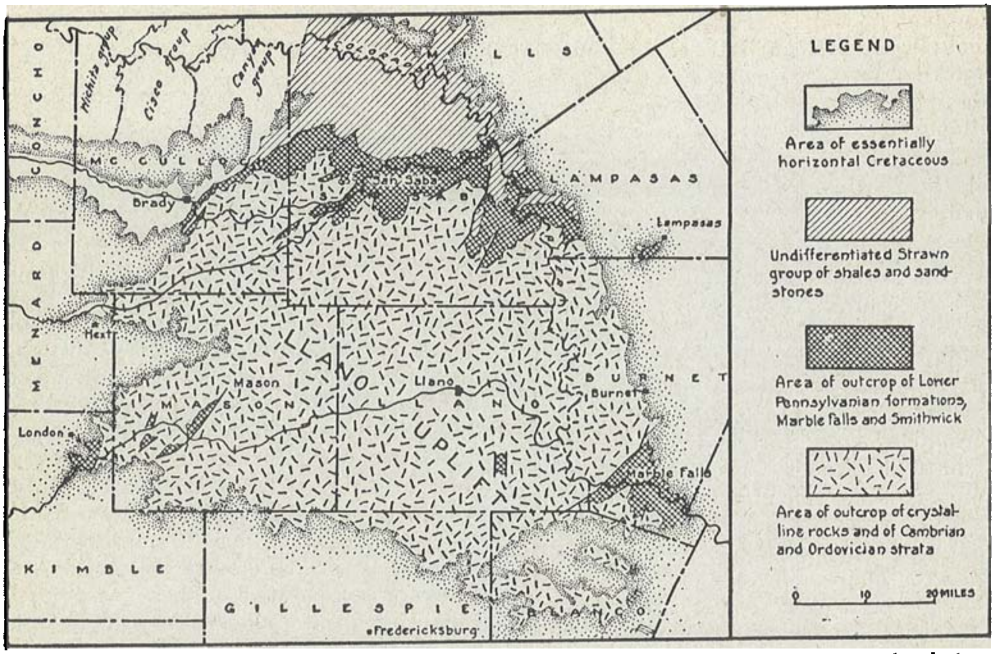

Fig. 1. Map of the area around the Llano uplift showing the regional distribution and relationships of the older Paleozoics, the Lower Pennsylvanian, the Strawn group, Canyon group, and Cisco group of the Middle and Upper Pennsylvanian, and the essentially horizontal Lower Cretaceous blanket that once covered the entire area but has been partially removed by Colorado River and its tributaries. (Details of the Lower Pennsylvanian geology by F. B. Plummer; border of Lower Cretaceous in Gillespie County by V. E. Barnes; rest of map compiled from several published sources.)

Geology. Sets will be sent to the British Museum (Nat. Hist.) and to the U. S. National Museum.

REGIONAL STRATIGRAPHY

The most complete and continuous outcropping section of the formations from the base of the Mississippian (Lower Carboniferous) upward through the Lower Pennsylvanian (lower Upper Carboniferous) and into the undifferentiated Strawn group of the Middle Pennsylvanian (middle Upper Carboniferous) lies in Colorado River valley on the north side of the Llano uplift. This area of continuous outcrop of the strongly folded and faulted Mississippian and Lower Pennsylvanian formations extends from western Lampasas County westward across San Saba County and southern McCulloch County (fig. 1; also Pl. 11 in paper by F. B. Plummer, this publication). Isolated small areas of Carboniferous strata are scattered on the west side of the uplift southwest of Mason in Mason and Kimble counties. On the east side an inlier in the Cretaceous area lies southwest of Lampasas in Lampasas County; another lies on both sides of Colorado River between Marble Falls and Spicewood in southern Burnet County (fig. 1 in paper by F. B. Plummer, this publication); and two very small outcrops are known in Blanco County. Almost on top of the uplift, about 10 miles southeast of Llano in Llano County, in the general vicinity of Slaughter ranch, is a down-faulted block of Lower Pennsylvanian formations.

Areally the Mississippian formations (Chappel and Barnett), on so small-scale a map as figure 1, would be represented by only a line on the south side of the area of outcrop of the Lower Pennsylvanian sediments and consequently are not indicated. Because of the paucity of Foraminifera in these two formations, they have not been included in the present investigation. For a brief resumé of the stratigraphy of the Lower Pennsylvanian formations, Marble Falls and Smithwick, and for a bibliography of stratigraphic contributions, the reader should refer to the paper in this publication by F. B. Plummer.

North of the irregular band of outcrop of the Marble Falls and Smithwick formations on the north side of the uplift, the relatively little disturbed Strawn (lower Middle Pennsylvanian) noncalcareous shales, sandy shales, and sandstones (fig. 1) strike in a general southwest-northeast direction in the immediate valley of Colorado River across western Lampasas County, southern Mills County, and northern San Saba County, and they dip northwestward at a low angle, so that the upward stratigraphic succession extends from southwestern Lampasas County, east of Bend, northwestward up Colorado River valley. In eastern McCulloch County, the Strawn sequence is terminated by the Rochelle conglomerate, above which and west of which are successively higher and higher Pennsylvanian and Permian formations. The lower Strawn beds in Colorado River valley have never been carefully mapped. In 1883, Drake[2] subdivided this Strawn sequence into twenty named units, which probably correlate broadly with the Millsap Lake and Garner formations of the Brazos River valley section north of the Cretaceous blanket that covers much of the divide between the two river systems. The Strawn beds in Colorado River valley area are exceedingly lean in large fossils, but microscopic organisms are abundant in many of the shales, sparse in the sandy shales, and practically absent in the sandstones.

The sequence of the major stratigraphic units in the Carboniferous section of Colorado River valley around the Llano uplift is as follows:

Middle Pennsylvanian series—
  Strawn group (undifferentiated)
Lower Pennsylvanian series—
  Bend group
    Smithwick formation
    Marble Falls formation
Mississippian series—
    Barnett formation
    Chappel formation

[2]Drake, N. F., Report on the Colorado coal field of Texas: Texas Geol. Survey, 4th Ann. Rept., pt. 1, pp. 371-387, 1893.

COLLECTION AND PREPARATION OF MATERIAL

For the present study, only unconsolidated material that could be disintegrated and concentrated by the usual washing processes has been sampled in the field, in order to make available isolated specimens for study. Most Smithwick and Strawn strata are soft, and samples of these formations used in this report should offer a fairly complete record of their faunas. Since the Marble Falls formation comprises largely hard limestone beds, its fauna may not be completely represented in the samples of soft layers studied, but the record of species found in the unconsolidated calcareous shales and chalky limestone beds should constitute a fair basis for further investigation of the fauna present in the hard beds. Since many of the shale partings sampled were thin, it seems more than likely that differences in results reached by a more intensive study of all types of layers will lie largely in frequency records of those Marble Falls species here described. For example, a polished surface of one very hard limestone bed recommended for building stone has revealed myriads of tests of *Cribrostomum marblense*, n.sp., which must have thrived more abundantly in a highly calcareous environment uncontaminated by argillaceous matter than in the soft shaly layers sampled, where specimens are generally not nearly so abundant and where compressional forces during compaction of the shaly sediments have effected greater distortion of tests. Intensive work on thin sections of the pure limestone will certainly contribute to paleoecologic problems involving the several species of the Marble Falls fauna and may enhance the faunal assemblage.

In collecting material from outcropping soft strata samples have been taken at definite positions, each representing not more than 5 inches of vertical section. A composite sample across many feet of section is usually not a satisfactory initial approach to its faunal study, since possible richly fossiliferous zones can be so diluted by considerable less fossiliferous material, that concentrates do not yield as satisfactory suites of tests in whatever period of time can be allotted to this important operation. From an exposure of several feet of vertical section, generous samples were usually taken at several different positions vertically and laterally.

To test each sample, approximately a cupful of material was washed and studied carefully for its microfaunal content. Many samples proved to be barren and were discarded. Others were lean, and the initial concentrate prepared was often sufficient, depending on what it yielded of interest. All samples found to carry microfossils of unusual worth, either in contributing particularly well-preserved specimens or especially fine faunal assemblages, were washed in larger amounts and examined intensively for tests of Foraminifera in all stages of development.

In preparing unconsolidated material for study small portions were washed at a time, even though a large amount of any particular sample was ultimately concentrated. All attempts to handle bulky portions in this process usually result in loss of some of the concentrate. The material was first thoroughly dried in a warm oven, an operation that increases its porosity and permeability, so that when dried material is put asoak, rapid and complete penetration of the water into permeable fragments mechanically disingrates whatever portion is not actually bound by some form of cement, mineral or organic. Periods of soaking vary with the sample; some shales, like the Strawn, form a fine mud quickly; tough fissile shales, like some in the Smithwick formation, break up slowly into some mud and smaller angular fragments.

About a cupful of dried material is placed in a deep three-quart pan and well covered with water. When maximum disintegration seems to have been reached by soaking, more water is added and the thin muddy mixture brought to a vigorous boil, when about two tablespoonfuls of sodium carbonate (sal soda, or washing soda, found at any grocery) is added. Some shales are so colloidal, that in order to prevent lumping of the mud at this stage the soda must be sprinkled into the rapidly boiling mixture with accompanying stirring. Within a few minutes the material is broken up about as much as it is likely to be at this stage, though some tough shales can well be allowed to simmer for a longer period. It has been found helpful to allow some tough material to stand for half a day or longer in an especially strong soda solution. The pan containing the mud is then filled with cold water and allowed to stand about half a minute, before the upper 1 or 2 inches of muddy water are poured off. The pan is then filled again, allowed to stand a brief period, and decanted only a short depth, and this process of adding water and decanting is continued until the water covering the bulk of material in the bottom is clear enough to offer some visual control of the position of the bottom sediment during a closer and very careful decantation. Undertow in the process of decantation may carry away some of the heavy mud that carries unreleased concentrate, unless precautions are taken. After most of the muddy water has been carefully poured off close to the bottom sediment, vigorous whirling of the pan will further break up the mixture and release more completely the fossils and mineral matter desired in the final concentrate to be studied. Continued whirling of the mud in the pan after each decantation and subsequent washing with water will quickly separate all the argillaceous particles of many shales without further treatment, and the resulting clean concentrate of mineral grains and fossils can be dried and labeled. If the first boiling and washing process still leaves resistant lumps of shale, the sample can be dried again at a temperature that does not burn the shale.[3] When cold water is poured over the rather hot lumps, further disintegration takes place and can be followed by boiling with soda and decantation. Some shales, especially the carbonaceous Smithwick, must be dried and washed several times before a small

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[3]Standard gas-range burners are much more satisfactory for use than is the Bunsen burner. Not only do they bring the muddy mixture more quickly to the boiling point, but tough samples that need to be dried between periods of decantation can be left in the wash pan and set back on such a burner turned very low with no danger of burning the material.

clean concentrate of fossils and mineral grains is produced.

The use of metal screens and a forceful spray for washing samples is deemed unwise for scientific work, for such treatment is obviously deleterious to the more delicate fossils. Fine silk gauze used by flour mills can be employed with safety, and a square of this material set firmly in an embroidery hoop makes an excellent washing screen that can be easily and quickly cleaned, but this device is usually employed in washing Recent dredging or Tertiary material, where tests are fragile and where many are exceedingly minute. The more consolidated shales of Carboniferous age require a process that includes some gentle abrasive force, and whirling the mud in the wash pan, after each close decantation of the muddy water, has proved very effective without being too heroic for the best condition of the fossils.

Concentrates to be studied at the microscope for microfossils can well be graded to facilitate progress. For this purpose, a series of cloth screens has been found satisfactory, and only material made of smooth wiry threads should be selected. For the coarser grades, marquisette has served well. A coarse imported Swiss muslin (not available at present) has been found excellent for a medium grade. Two different grades of organdie make finer screens, and finally a very fine rayon sheer has been found helpful in eliminating an abundance of very fine silt from some concentrates.

By grading concentrates into four or five portions and then examining these portions from the coarsest to the finest, each species is first observed in its maximum development, an introduction that has advantages in approaching the fauna of a new sample. Observing ontogeny in reverse places the student in the favorable position of making earlier generic identifications. Further, in studying the concentrate of a restricted grade, everything in the field of vision has essentially the same size value, and the eye is not distracted from smaller specimens by the presence of those of larger size. The finished faunal assemblage mounted for study and for future reference is more likely to be representative of the faunule in the sample, and many more specimens can be picked out of the material in a given period of time.

On the kind and amount of material picked from each concentrate and mounted on a faunal slide for intensive study depend important conclusions, taxonomic, geologic, and ecologic. Taxonomy is best served by a large number of specimens of each species in all stages of growth, to reveal morphologic variations due to factors in life history, to deformational forces in the sedimentary history, or to response to changing environmental stimuli inherent in physical and chemical factors. Even a small sample of outcrop material probably cuts across enough geologic section to represent several seasons to several years, or even decades, and the more sensitive species are likely to exhibit morphologic variation of minor characters due to seasonal and annual fluctuations in physical conditions of climate and sedimentation. Observing a species in large suites of specimens in each of many different outcrops leads to a more reliable choice of the criteria of identity of the species, based on those characters found to be consistent and critical. As many as fifty or more hours have been devoted to segregating large numbers of Foraminifera and other microscopic fossils from concentrates of especially fine samples. Those species found in abundance in a sample may be represented on the faunal slide by hundreds of specimens in all stages of growth and in all forms of distortion. Reliable geologic ranges of species must rest on complete records of faunules in each of many representative outcrops of each formation in a continuous sequence of formations. Until the present study of shale faunas has been greatly extended to include all groups of fossils in these same beds and in all other facies of these same formations, broad interpretations are out of place. These records of relationships of species to lithology of different types of unconsolidated strata may be of some service to future developments in the paleoecology of the seas during the period of time represented by this succession of sediments. Penetrating and comprehensive

TABLE 1. *Distribution of foraminiferal species in collections from the Marble Falls, Smithwick,*[a] *and Strawn strata around the Llano uplift in Texas.* VA = very abundant; A = abundant; VC = very common; C = common; VF = very frequent; F = frequent; R = rare; VR = very rare. The asterisk indicates type locality for the species.

MARBLE FALLS

SPECIES	27-T-5	134-T-6	134-T-27	205-T-2	205-T-25	205-T-57	205-T-92	205-T-113	205-T-130
1 *Proteonina cervicifera* Cushman and Waters									
2 *Thurammina texana* Cushman and Waters									
3 *Thuramminoides sphaeroidalis*, n sp									
4 *Hyperammina bulbosa* Cushman and Waters				F					
5 " *clavacoidea*, n sp									
6 " *elegantissima*, n sp									
7 " *spinescens* Cushman and Waters									
8 *Hyperamminoides expansus*, n sp									
9 *Earlandia minuta* (Cushman and Waters)									
10 *Reophax arenatus* (Cushman and Waters)									
11 " *asper* Cushman and Waters									
12 " *bendensis*, n sp				F*	F	F			
13 " *emaciatus*, n sp						R			
14 " *expatiatus*, n sp									
15 " *fittsi* (Warthin)									
16 " *glennensis* (Harlton)									
17 " *minutissimus*, n sp									
18 " *tumidulus*, n sp									
19 *Ammodiscus semiconstrictus* Waters			VR						
20 *Glomospira compressa* Waters									
21 " *articulosa*, n sp									
22 *Glomospirella umbilicata* (Cushman and Waters)			R						
23 *Haplophragmoides confragosus*, n sp									
24 *Ammobaculites minutus* Waters									
25 " *stenomerus* Cushman and Waters									
26 *Endothyra distensa*, n sp	F*	VF		R	F		R		R
27 " *rotaliformis* Warthin		F							
28 " *whitesidei* Galloway and Ryniker				VR					
29 *Endothyranella armstrongi* subsp *sobrina*, n subsp		R		F	VF*		F	F	R
30 *Bradyina holdenvillensis* Harlton		VR							
31 " sp				VR	F				
32 *Bigenerina perexigua*, n sp									
33 *Cribrostomum marblense* n sp	C	VC*		VF	F	R			
34 *Cornuspira* sp									
35 *Calcitornella* sp									
36 *Trepeilopsis* sp									
37 *Globivalvulina* sp		VR							
38 *Mooreinella biserialis* Cushman and Waters									
39 *Polytaxis scutella* (Cushman and Waters)	R	F		R		F			

SMITHWICK

SPECIES	134-T-5	134-T-31	134-T-32	134-T-33	149-T-7	153-T-6	205-T-76	205-T-79A	205-T-79B	205-T-120	205-T-127	205-T-135	205-T-136	205-T-146	205-T-147
1 *Proteonina cervicifera* Cushman and Waters		R			R					R				R	
2 *Thurammina texana* Cushman and Waters										R					
3 *Thuramminoides sphaeroidalis*, n sp					C	R	F	R		VF	A	VF	A	A	F
4 *Hyperammina bulbosa* Cushman and Waters										F	R				
5 " *clavacoidea*, n sp											C		C		
6 " *elegantissima*, n sp		R		VF											
7 " *spinescens* Cushman and Waters		R			VF	VF		R	F	VF	R	C	F	C	
8 *Hyperamminoides expansus*, n sp											VR				
9 *Earlandia minuta* (Cushman and Waters)				R											
10 *Reophax arenatus* (Cushman and Waters)															
11 " *asper* Cushman and Waters		F													
12 " *bendensis*, n sp															
13 " *emaciatus*, n sp	R		VF	A											
14 " *expatiatus*, n sp															
15 " *fittsi* (Warthin)	C	VR	VF		VR									VR	
16 " *glennensis* (Harlton)	R					F	VR		C						
17 " *minutissimus*, n sp											F	R		R	F
18 " *tumidulus*, n sp															
19 *Ammodiscus semiconstrictus* Waters		R			C	C	C	F	C	C	VC	A	VA	VC	C
20 *Glomospira compressa* Waters											VF				
21 " *articulosa*, n sp											F				
22 *Glomospirella umbilicata* (Cushman and Waters)	VA	C	VA	A							A*		VR	R	
23 *Haplophragmoides confragosus*, n sp	VR				C					R		R		R	VR
24 *Ammobaculites minutus* Waters						VF						R			
25 " *stenomerus* Cushman and Waters	F	VC	F	VF											
26 *Endothyra distensa*, n sp															
27 " *rotaliformis* Warthin															
28 " *whitesidei* Galloway and Ryniker	R								VR						
29 *Endothyranella armstrongi* subsp *sobrina*, n subsp															
30 *Bradyina holdenvillensis* Harlton															
31 " sp															
32 *Bigenerina perexigua*, n sp	F			A*											
33 *Cribrostomum marblense* n sp															
34 *Cornuspira* sp	VR														
35 *Calcitornella* sp	VR														
36 *Trepeilopsis* sp	VR														
37 *Globivalvulina* sp															
38 *Mooreinella biserialis* Cushman and Waters		R								VF		C	VF	C	
39 *Polytaxis scutella* (Cushman and Waters)															

STRAWN

SPECIES	141-T-14	205-T-29	205-T-128	205-T-139	205-T-140	205-T-141	205-T-143	205-T-145	205-T-148	205-T-149	205-T-150	205-T-151	205-T-154	205-T-157	205-T-158	205-T-159	205-T-164
1 *Proteonina cervicifera* Cushman and Waters		A*	F					R		R	R	VR	F		VR		
2 *Thurammina texana* Cushman and Waters		VC*			VR	C			C	F							
3 *Thuramminoides sphaeroidalis*, n sp			C	VF	VC		C	C	F*		C						F
4 *Hyperammina bulbosa* Cushman and Waters			C			F	C	C	VF	F							
5 " *clavacoidea*, n sp		F	R*				F										
6 " *elegantissima*, n sp									R		VC*						
7 " *spinescens* Cushman and Waters		F	C					VF		F	VC*	F	F			F	C
8 *Hyperamminoides expansus*, n sp		VR	VF*				F									VR	
9 *Earlandia minuta* (Cushman and Waters)											VF*						VR
10 *Reophax arenatus* (Cushman and Waters)		C	VR		F					F	F	VF					R
11 " *asper* Cushman and Waters													C				
12 " *bendensis*, n sp																	
13 " *emaciatus*, n sp											VF	F				R	VF*
14 " *expatiatus*, n sp				VR				R			F*	VF	F				
15 " *fittsi* (Warthin)		R		VR							F		F				R
16 " *glennensis* (Harlton)																	
17 " *minutissimus*, n sp		F	R*					F			R						
18 " *tumidulus*, n sp			F*					R									
19 *Ammodiscus semiconstrictus* Waters	F	VA	C	VC	VF	F	C	VC	VC	VF							
20 *Glomospira compressa* Waters																	
21 " *articulosa*, n sp			F*														
22 *Glomospirella umbilicata* (Cushman and Waters)			A				C	C	R	VF	VA	C	VF	F		R	C
23 *Haplophragmoides confragosus*, n sp		F	C*	VR			F	F	R	F			R				
24 *Ammobaculites minutus* Waters			R								R						R
25 " *stenomerus* Cushman and Waters							VR		F				VF		R	F	
26 *Endothyra distensa*, n sp																	
27 " *rotaliformis* Warthin																	
28 " *whitesidei* Galloway and Ryniker																	
29 *Endothyranella armstrongi* subsp *sobrina*, n subsp																	
30 *Bradyina holdenvillensis* Harlton																	
31 " sp																	
32 *Bigenerina perexigua*, n sp																	
33 *Cribrostomum marblense* n sp																	
34 *Cornuspira* sp																	
35 *Calcitornella* sp																	
36 *Trepeilopsis* sp																	
37 *Globivalvulina* sp																	
38 *Mooreinella biserialis* Cushman and Waters		A*	VF				C	C	R	F	R		F				VR
39 *Polytaxis scutella* (Cushman and Waters)																	

[a]At a date too late to permit any change in this chart, the fossiliferous shale at Sta. 134–T–5 (Kimble County) has been identified as probably Strawn rather than Smithwick, as it was originally mapped. Such a change undoubtedly affects also Stations 134–T–31, –32, and –33, but a new study of the outcrops in the field will be necessary to correct the present records. Also, a newly discovered exposure of Marble Falls shale (Sta. 153–T–136) points to the probable identity of the above *Globivalvulina* sp. as *G. biserialis* Cushman and Waters, as the revised text indicates.

taxonomic work is dependent in no small measure on the paleoecologic significance of lithologic factors and of faunal assemblages including fossils other than this group here under particular observation.

FAUNAL CHARACTERISTICS

The foraminiferal possibilities of the noncalcareous Pennsylvanian shales in the San Saba area have been indicated by the work of J. A. Cushman and J. A. Waters, who named six[4] species from two exposures of Strawn shales and one species from an exposure of Smithwick, as follows:

Strawn—
  Sta. 205–T–29—
    Proteonina cervicifera C. & W.
    Thurammina texana C. & W.
    Hyperamminella protea C. & W.
    Mooreinella biserialis C. & W.
  Sta. 205–T–150—
    Hyperamminella minuta C. & W.
    Hyperammina spinescens C. & W.
Smithwick (Sta. 205–T–127)—
    Glomospira umbilicata C. & W.

This restricted early investigation pointed to the interesting comparison of faunas in these same shales with the closely associated highly calcareous underlying Marble Falls formation in the same area.

The two distinctly different types of lithology represented by the geologic sequence of formations here treated are accompanied by two different types of Foraminifera (Table 1). The Marble Falls strata, almost without exception, are highly calcareous and yield fibrous and granular calcareous tests probably secreted entirely by the protoplasm, as no inclusions of foreign material in them have been detected. In a few places the calcareous tests carry extraneous particles on their surfaces, but since in the same material ostracodes and other fossils are similarly coated, these particles, spines, and other fragments are regarded as secondarily acquired. The noncalcareous and more or less silty to sandy Smithwick and Strawn shales yield almost consistently only insoluble agglutinate tests, most of which are composed wholly of mineral grains.

The calcareous Marble Falls faunal assemblage is accompanied by one diagnostic agglutinate species, *Reophax bendensis*, n.sp., which is very frequent in a few outcrops; the long-ranging *Hyperammina bulbosa* Cushman and Waters and *Reophax emaciatus*, n.sp., have each been found to occur rarely in two different outcrops. Such exceptions to the characteristic fauna of calcareous species appear to be restricted almost wholly to the unusually shaly facies of this formational sequence, although an *Ammodiscus* occurs in a white chalky parting in the limestone at Sta. 205–T–62. One very unusual, sandy, glauconitic, noncalcareous (except for reworked rounded limestone granules from the underlying limestones) layer at the base of the Lemons Bluff member of the Marble Falls just above the disconformity at Sta. 134–T–27 (Pl. 12, first columnar section, in paper by F. B. Plummer, this publication) yields only the agglutinate tests of *Ammodiscus semiconstrictus* Waters and *Glomospirella umbilicata* (Cushman and Waters), both highly characteristic of this general type of lithology in the Smithwick and Strawn strata of this area. It is therefore interesting to observe that, in this thick and almost consistently calcareous Marble Falls formation, a thin incidental noncalcareous and sandy layer is characterized wholly by the same forms that are so highly characteristic of superjacent noncalcareous and silty to sandy formations, and it emphasizes forcibly the need to study faunal groups in close association with obvious field relationships and with the lithology of the enclosing strata, in order not to be misled by species.

It is interesting to observe that the calcareous species *Earlandia minuta* (Cushman and Waters) has been found in the vicinity of the Llano uplift only in the noncalcareous strata of the Strawn succession, where it is rare. The occurrence of a single large test of *Endothyra whitesidei* Galloway and Ryniker in the glauconitic, dark, noncalcareous basal layers of the Smithwick formation at Sta. 205–T–79B is remarkable in a faunule that is otherwise typical for such

[4]A seventh species, *Hemigordius calcareus* Cushman and Waters, was recorded from Sta. 205–T–150, but in a large amount of material collected from this type locality and in the immediate vicinity no trace of such a test has been found. Mr. Waters, in a personal interview, has expressed the opinion that this record must be erroneous.

lithology, and it is believed that this calcareous test may have been reworked from the immediately underlying Marble Falls strata. The record of calcareous species in the "Smithwick" at Sta. 134–T–5 is explained by the footnote below the distribution chart, Table 1.

The only unequivocally diagnostic species in the Marble Falls formation is *Reophax bendensis*, n.sp., which can be confused with no other congener in the Texas geologic section, but unfortunately it is not widespread, and it appears to be confined to the more shaly layers. The endothyroid species, *Endothyra distensa*, n.sp., and *Endothyranella armstrongi* subsp. *sobrina*, n.subsp., should be good markers where tests are sufficiently abundant to permit correct identification, but unusual variants, where too few tests are available, can easily introduce confusion. *Bradyina* sp. is very different from any other congener in the Texas section, and if it were more frequent in the formation, it might be a very useful age determinant. *Cribrostomum marblense*, n.sp., is not sufficiently different from a form in the Adams Branch limestone (Canyon group) in McCulloch County to grant it index status at present, as further collections and study may finally establish identity.

All the arenaceous species found in the Smithwick range upward into the Strawn in the vicinity of the uplift, and some range even higher in the Pennsylvanian section farther west and north. Consequently no forminiferal species can be designated as a marker for the formation. The following species have been found in the Smithwick shales:

Proteonina cervicifera Cushman and Waters
Thurammina texana Cushman and Waters
Thuramminoides sphaeroidalis, n.sp.
Hyperammina bulbosa Cushman and Waters
Hyperammina clavacoidea, n.sp.
Hyperammina spinescens Cushman and Waters
Hyperamminoides expansus, n.sp.
Reophax fittsi (Warthin)
Reophax glennensis (Harlton)
Reophax minutissimus, n.sp.
Ammodiscus semiconstrictus Waters
Glomospira compressa Waters
Glomospira articulosa, n.sp.
Glomospirella umbilicata (Cushman and Waters)
Haplophragmoides confragosus, n.sp.
Ammobaculites minutus Waters
Endothyra whitesidei Galloway and Ryniker (reworked?)
Mooreinella biserialis Cushman and Waters

The Strawn shales, which are lithologically so similar to those of the Smithwick formation that field distinction is in many places difficult, carry all the Smithwick foraminferal species and several more not found in older strata. Consequently in the area adjacent to the uplift these several species serve as markers to distinguish the Strawn, though in counties farther west and north some of these markers useful around the uplift are found to extend upward into the Canyon and Cisco groups of formations. The following species have been found in Strawn strata around the uplift, and those useful around this structural province to mark the Strawn from the Smithwick are indicated by an asterisk. It must be kept in mind, however, that these so-called "markers" are likely to be of local significance only.

Proteonina cervicifera Cushman and Waters
Thurammina texana Cushman and Waters
Thuramminoides sphaeroidalis, n.sp.
Hyperammina bulbosa Cushman and Waters
Hyperammina clavacoidea, n.sp.
*Hyperammina elegantissima, n.sp.
Hyperammina spinescens Cushman and Waters
Hyperamminoides expansus, n.sp.
*Earlandia minuta (Cushman and Waters)
*Reophax arenatus (Cushman and Waters)
*Reophax asper Cushman and Waters
*Reophax emaciatus, n.sp. (questionably in the Marble Falls)
*Reophax expatiatus, n.sp.
Reophax fittsi (Warthin)
Reophax glennensis (Harlton)
Reophax minitissimus, n.sp.
*Reophax tumidulus, n.sp.
Ammodiscus semiconstrictus Waters
Glomospira articulosa, n.sp.
Glomospirella umbilicata (Cushman and Waters)
Haplophragmoides confragosus, n.sp.
Ammobaculites minutus Waters
*Ammobaculites stenomecus Cushman and Waters
Mooreinella biserialis Cushman and Waters

SYSTEMATIC DESCRIPTIONS

For comprehensive descriptions of Pennsylvanian species as they exist in the strata, the usual clipped and brief presentation of specific characters has been found entirely too inflexible. Tests are highly variable in their appearance, due in large measure to differences in the state of preservation and in the degree of deformations of tests at different localities and even in the same sample. Also fundamental and original morphologic variations are numerous, and an adequate description must take into account such differences that are obvious in large suites of specimens of any species. In strata where a species is rare, the very few specimens can then be more accurately identified.

Type localities for the new species offered have been restricted to as few outcrops as has been found feasible. Thus future collectors will be able to procure type material with the minimum of mileage, and most of these localities can be readily reached.

Though most original types of described Texas and Oklahoma species of Foraminifera have been examined, it has not always been possible to judge broadly the character of the species represented from the one or two selected tests of each. Almost every Texas type locality has been visited, and the study of many topotypes from material collected by the present author and from generous portions of Mr. Waters' original material has furnished ample opportunity to know most of the species at their source; and Mr. Waters has personally assisted in answering several puzzling questions that have arisen regarding the early records. Attempts to obtain, by exchange, material from most of the Oklahoma type localities have been fruitless. Material from the Atoka outcrop near Red Oak from Dr. J. J. Galloway, some from the Dornick Hills formation from Mr. J. A. Waters, and a few small samples from Dr. W. S. Warthin from the Wetumka, Holdenville, and Wewoka formations have been of considerable aid, though most of these same localities will need to be further investigated when larger amounts of material from these same outcrops can be made available. After many other Oklahoma type localities have been studied more intensively and large suites of topotype specimens have been examined, it is quite possible that some of the new specific designations here introduced may have to be discarded into synonymies. An intensive modern study of species at the British type localities will also introduce nomenclatural changes that cannot be safely made from the existing descriptions and illustrations alone.

Family SACCAMMINIDAE

Genus PROTEONINA Williamson, 1858

PROTEONINA CERVICIFERA Cushman and Waters

Pl. 15, fig. 1

Proteonina cervicifera Cushman and Waters, 1928, Cushman Lab. Foram. Res., Contrib., vol. 4, p. 33, pl. 4, fig. 11. (Strawn group, San Saba County, Texas.)

This stout, flask-shaped, roughly textured, unilocular test composed of coarse quartz grains bound by a subordinate amount of insoluble cement is generally collapsed in its fossil state, but rare specimens indicate that originally the main body of the test was essentially globular. The very well developed specimens found at the type locality carry the strongly protruding cylindrical apertural neck, that becomes slightly constricted around a small terminal opening. Smaller specimens carry the characteristic neck, but it is likely to be less sharply defined than on the larger tests.

The maximum development of this species has been found in Strawn strata in the area north and east of San Saba, and the type locality is especially rich in tests in all its ontogentic stages up to the maximum size of 1.1 mm. long and 0.75 mm. broad. In Strawn shales where the species is rare, the average size is likely not to exceed 0.6 or 0.7 mm. in length. The form is rare in Smithwick shales, where its length is rarely more than about 0.5 mm.

Proteonina cervicifera has been found only in noncalcareous shales, which are so characteristic of the Smithwick formation and of the lower Strawn sequence in northern San Saba County. Its type locality (Sta. 205–T–29) lies in eastern San Saba County about 7.5 miles east of San Saba and south of the new San Saba-Lampasas highway (fig. 16), where it is asscociated with many other arenaceous species.

Genus THURAMMINA H. B. Brady, 1879

THURAMMINA TEXANA Cushman and Waters

Pl. 15, figs. 2, 3

Thurammina texana CUSHMAN and WATERS, 1928, Cushman Lab. Foram. Res., Contrib., vol. 4, p. 33, pl. 4, fig. 2. (Lower Strawn group, San Saba County, Texas.)

The laterally compressed, circular to irregularly circular, unilocular, white to pale-gray, rather large tests of this species were originally subspheroidal, but as fossil specimens they generally occur partially or wholly compressed. The arenaceous texture comprises rather small and poorly sorted quartz grains well imbedded in an insoluble cement, so that the external surface is rather evenly granular and ranges from slightly rough to distinctly rough. On the inner wall the sand grains lie in sharper relief, and the inner surface is rougher than the outer surface. Apertural protuberances, which vary from low rounded elevations to abrupt extensions, number from none at all to five or six distributed irregularly over the test. The normal circular orifice at the end of the protuberances has generally been obliterated by processes of fossilization and they must have been very small.

The maximum diameter of the test at the type locality where the species is exceptionally well developed, is 1.6 mm., and the common size of mature tests is about 1 mm. The diameter of the apertural protuberances averages about 0.1 mm., and the length ranges from a very low mound to a short thick tube as long as 0.15 mm.

The pale-gray surface of this test is characteristically finely mottled by small darker spots due to absorption of light by the larger quartz grains in the compact masonry of different-sized small grains. Such an appearance is naturally a function of the preservation and can not be stressed as necessarily a constant character of the species everywhere. At the type locality the surface is rather smooth, but in some outcrops in the general area where it occurs the tests are rougher.

Thurammina texana Cushman and Waters is superficially very similar to *Thuramminoides sphaeroidalis*, n.sp., with which it commonly occurs. The test of *Thurammina texana* is composed of less well sorted and slightly larger quartz grains and is usually distinctly rougher. The outstanding difference lies in the internal structure, that of *T. texana* being a simple chamber, whereas that of *Thuramminoides sphaeroidalis* is labyrinthic. Identification of many of the tests of these two species must often depend on the texture of the external wall, since geologic processes have in some places destroyed the significant features that indicate the original labyrinthic structure of *T. sphaeroidalis*.

Thurammina texana is especially characteristic of the noncalcareous Strawn shales in northern San Saba County, and it is well developed at its type locality (Sta. 205–T–29) about 7.5 miles east of San Saba south of the new highway (fig. 16), as well as in other exposures in the immediate vicinity. It is recorded as rare in one outcrop northwest of San Saba (Sta. 205–T–120), which has been mapped by field parties as Smithwick, but this age is doubtful, and the present author believes that the species belongs only to strata younger than Smithwick.

Genus THURAMMINOIDES, n.gen.

The external characters of this globose, unilocular test are like those of *Thurammina*, but internally it is labyrinthic. Only the genotype species is known.

Genotype, *Thuramminoides sphaeroidalis*, n.sp.; lower Strawn shale, east of San Saba, San Saba County, Texas (Sta. 205–T–148, fig. 16).

THURAMMINOIDES SPHAEROIDALIS, n.sp.

Pl. 15, figs. 4–10

The finely arenaceous, white or very pale-gray, spheroidal test of this species exhibits in its original rotundity a moderate lateral compression. Specimens exhibiting this shape are very rare in the strata in which the species has been observed; by far the large majority of the tests are wholly or partially compressed. The shell wall, composed of uniformly very fine quartz grains, is bound by an insoluble cement, and, where the species is common and well developed, it is heavy and tough, but the test is likely to be small and more fragile where it is rare. The inside wall of many broken specimens displays a reticulate pattern, which is the last vestige of the labyrinthic interior structure that originally filled the tests. Specimens carrying this spongy interior filling are very rare, since its original fragility has contributed to its subsequent disintegration. The presence of apertural protuberances is exceedingly variable; many tests are devoid of this feature, whereas others bear from one to many, and especially well-preserved protuberances show the round terminal orifice.

The maximum diameter observed is 1.6 mm. A common diameter of fully developed tests where the species is frequent is about 0.7 mm. The rare tests exhibiting their original full-bodied form show a lateral compression of about 0.7 their greatest diameter. Size is a variable feature, and in some strata it averages much smaller than at its type locality and in other outcrops where it is common.

The only similar species in the Pennsylvanian strata in Texas is *Thurammina texana* Cushman and Waters, which is frequent and well developed in several of the same concentrates that have yielded *Thuramminoides sphaeroidalis*, n.sp. This new form is differentiated by its more uniformly very fine-grained outer shell wall and by the reticulate pattern on the inner wall of tests that are not too worn or leached. The internal wall of *Thurammina texana* is distinctly rougher than its external wall, and the individual sand grains in the masonry stand out in bold relief. Many unbroken and flattened specimens of the two species must be distinguished by the differences in the texture of the external wall, but breaking open a few tests will usually reveal the critical internal evidence. In some deposits the pockets of the reticulation of the inner wall of specimens of *Thuramminoides sphaeroidalis* are stained internally by a thin black mineral coating, and wetting such unbroken tests commonly creates a temporary translucency that reveals the presence of the characteristic regular internal reticulation, which is the clue to its original labyrinthic interior.

The type locality (Sta. 205–T–148) for the species is an exposure of lower Strawn shale on the old highway about 8 miles east of San Saba, San Saba County (fig. 16). The species has been found to be widely distributed in the noncalcareous Smithwick and lower Strawn shales around the Llano uplift.

Family HYPERAMMINIDAE

Genus HYPERAMMINA H. B. Brady, 1878

Hyperammina H. B. BRADY, 1878, Ann. Mag. Nat. Hist., ser. 5, vol. 1, p. 433.

Hyperammina, CUSHMAN and WATERS, 1930, Univ. Texas Bull. 3019, p. 33.

Hyperammina, GALLOWAY, 1933, A Manual of Foraminifera, p. 74.

Hyperammina, CUSHMAN, 1940, Foraminifera, Their Classification and Economic Use, ed. 3, p. 83.

The free, very elongate, arenaceous tests of *Hyperammina* comprise a proloculum[5] followed by a long, undivided, subcylindrical second chamber that terminates in a faint constriction and a circular aperture. The shell wall of the Texas Pennsylvanian species in this generic group consists of siliceous grains bound by an insoluble siliceous cement, which is generally subordinate enough to leave the surface distinctly dull and rough but commonly of fine texture, and the cement base of the original wall was so elastic that most tests have been unable to withstand the compressional forces in the sediments and are flattened. Transverse growth constrictions, where present, are generally broad and very shallow. The oral extremity of the tubular chamber

[5]The original form "proloculum," not "proloculus" (H. G. Schenck, Jour. Paleont., vol. 18, pp. 275–282, 1944), is here accepted as established in our scientific terminology. Century Dictionary, revised and enlarged, 1914, lists "proloculum, n. (pl. prolocula)," with derivation "*pro*, before, for, +*loculum* for *loculus*" and cites J. A. Cushman's article in Nature, Sept. 21, p. 516, 1905, as the place of introduction of the new word to designate the initial chamber of a foraminifer. If the editors of such a dictionary, though cognizant of the etymological barbarism, have found it desirable to perpetuate the original form of the word, it seems inadvisable at this late date to change a form that has been employed so extensively in many languages. A crusade to correct the many errors in forms of words of supposedly classical origin would necessitate stratographic for stratigraphic, megalodyne for megadyne, etc. To be sure, the original "megasphere" of Munier-Chalmas and Schlumberger (1885) has given way to "megalosphere," a correction introduced by J. J. Lister (1895), for sound etymological reasons, but at this time the original form had not been employed in the literature, and Lister's correction was accepted generally and has been used by most authors ever since, so that this is the form found in Century Dictionary. Unnecessary confusion can be averted by a pragmatic attitude toward terminology.

is slightly constricted around the aperture.

Genotype, *Hyperammina elongata* H. B. Brady; Recent, Arctic Sea.

The fundamental difference between *Hyperammina* and *Hyperamminoides* lies in the form of the second chamber. In *Hyperammina* it increases in diameter very slowly or almost imperceptibly, and Pennsylvanian species in the Texas strata must have attained considerable length, but the fragility of such long and slender tubes has contributed to its fragmentary state in washed material. In *Hyperamminoides* the diameter of the second chamber, especially during its earliest stage, increases rapidly, tests are generally proportionately shorter and stouter than those of *Hyperammina,* and complete mature specimens are abundant. Another common difference between tests of these two genera lies in the outer texture of the wall, though this difference is not consistent enough to constitute a reliable diagnostic feature. In most Pennsylvanian species of *Hyperammina* the siliceous cement is not so abundant as to obliterate the individual grains of the masonry; consequently the surface is somewhat rough, though of fine texture. Weakly developed tests of *H. elegantissima,* n.sp., and frequent normal tests of *H. clavacoidea,* n.sp., are smooth and glistening, a superficial character that may in part be due to mineralization, since they vary from place to place. In most forms of *Hyperamminoides* the shell surface is very smooth and glossy, since the proportion of siliceous cement is higher and envelops the uniformly very siliceous particles in the wall masonry. Though transverse growth lines alone can not be regarded as generically significant, those of *Hyperammina* are much more likely to be less distinct than the sharp and well-defined ones in *Hyperamminoides.*

Since the tests in *Hyperammina* are characteristically much more slender and less flaring than those in *Hyperamminoides,* the constriction of the oral extremity around the apertural opening is naturally less obvious, but it is characteristic of all Pennsylvanian species of this genus in Texas. Tests of species of *Hyperammina* in these strata attained considerable length but are found in the washed material mainly as short fragments, very few of which carry the true apertural extremity. Generic descriptions that state the opening to be formed by the unconstricted open end of the tube have undoubtedly been based on fragments of the tubular chamber below the aperture, since large suites of fragments studied in the present investigation demonstrate the true apertural extremity of these tests to be consistently constricted. Brady's figures of recent forms of *Hyperammina* (*H. friabilis,* Challenger, pl. 23, fig. 3, and *H. subnodosa,* pl. 23, figs. 11, 12) show clearly this constriction around the aperture. He described the aperture as "but little, if at all, constricted," and perhaps those forms figured as unconstricted represented broken tubes and not true apertural extremities.

Since in Carboniferous species of *Hyperammina* the form of the proloculum is one of the most critical of the specific characters, the numerous broken tubes in some concentrates are difficult or impossible to identify, until enough specimens of associated prolocula have been found, often a tedious search. The identification of several species of *Hyperammina* in many individual samples has meant long periods of search in concentrates and has illustrated how worthless are the fragments of the tubes in themselves alone.

HYPERAMMINA BULBOSA Cushman and Waters

Pl. 15, fig. 36

Hyperammina bulbosa CUSHMAN and WATERS, 1927, Cushman Lab. Foram. Res., Contrib., vol. 3, p. 109, pl. 22, fig. 7. (*Lingulina* bed, near Grand Ledge, Clinton County, Michigan.)

Hyperammina gracilis WATERS, 1927, Jour. Paleont., vol. 1, p. 130, pl. 22, figs. 4, 5. (Dornick Hills formation, Oklahoma.)

Hyperammina gracilis var. *rugosa* WATERS, 1927, Jour. Paleont., vol. 1, p. 130, pl. 22, fig. 6. (Dornick Hills formation, Oklahoma.)

Hyperammina bulbosa, CUSHMAN and WATERS, 1930, Univ. Texas Bull. 3019, p. 34, pl. 2, figs. 4, 5. (Graham formation, north Texas.)

This very elongate, subcyclindrical, agglutinate test carries a characteristic prominent globular proloculum separated from the very slowly expanding tubular second chamber by a shallow to fairly prominent constriction, which on many tests is somewhat emphasized by compressional forces that have acted against the lower end of the proloculum, thus exaggerating the breadth of this initial chamber. The tubular chamber normally increases slowly in diameter, though many fragments show that a fairly constant diameter may be maintained after it has reached maturity. Occasional broad and shallow transverse constrictions mark the tube of some tests, but they are not common. In some places compressional forces acting in the direction of the axis or at a slight angle to the axis have created transverse folds in the originally somewhat elastic test, but these are clearly secondary. The shell wall is composed generally of uniformly fine quartz grains and particles in a siliceous cement, which does not wholly envelop the grains, yet most tests in the Lower Pennsylvanian are not highly rugose. Some variation in rugosity of the surface has been observed. Where the species is well developed, the shell is generally thick and the original full-bodied form of the test may have been fairly well maintained during the period of fossilization. In most places, however, the shell wall has not been sufficiently stout to resist the stresses and strains of compaction of the enclosing sediments, and tests are nearly everywhere completely flattened or otherwise deformed. Fragments bearing the true apertural extremity exhibit a gentle constriction of the tube around the terminal opening, which on rare uncollapsed specimens is round.

The average size of *Hyperammina bulbosa* varies so greatly with the locality, and even in the same sample, that size must not be disregarded as a specific character. In some samples, tests are fairly uniform in size of proloculum and tube, being either small or very large. The clue to the worthlessness of size as a character is found in any material that yields tests of a wide assortment of sizes, which, in a sample cutting very few inches of vertical section, must constitute a response in development to fluctuations in minor seasonal or annual changes in environmental conditions. In such a sample the diameter of the proloculum may vary from 0.18 mm. to 0.43 mm. with tubes of corresponding diameter at the initial extremity, about 0.1 mm. to 0.3 mm. The largest proloculum measured is 0.6 mm., and the diameter of the tubular chamber at its initial end is 0.38 mm.

The distinguishing feature of *H. bulbosa* is its globular proloculum, which is generally separated from the second chamber by a definite constriction amounting generally to an average of three-quarters the diameter of the proloculum, but which may be much weaker or somewhat stronger. Deformation of the proloculum frequently produces forms designated as *H. gracilis* var. *rugosa* Waters and otherwise twisted or folded tests. *H. clavacoidea*, n.sp., bears a more elongate rotund proloculum separated from the second chamber by a less abrupt constriction, and its wall is generally smoother.

H. bulbosa was named from an outcrop in Michigan. Type Oklahoma material for *H. gracilis* Waters from the Dornick Hills formation has been made available by Mr. Waters, and the species has been found identical with *H. bulbosa*, for the excess of cement in its wall masonry is here regarded as specifically insignificant, considering the range of variation in this feature. In Texas, the species ranges vertically from the Marble Falls formation, where it is rare, upward into the upper Cisco strata. Its best development is in noncalcareous strata, but it has been found also in somewhat calcareous shales.

HYPERAMMINA CLAVACOIDEA, n.sp.

Pl. 15, figs. 11–14

The large, elongate, gently bulbous initial extremity of this elongate species, which is invariably completely compressed in the Texas Pennslyvanian section, characteristically merges very gradually into the somewhat narrower tubular second chamber, which enlarges almost imperceptibly. The thin shell wall is very finely rugose with considerable cement, but in some places is almost smooth. Only a single oral extremity is known, and this is somewhat constricted and bluntly attenuate toward the terminal aperture, which was originally round but in the flattened fossil tests is an elongate slit.

Length of holotype (short fragment of an initial extremity), 1.0 mm.; breadth of proloculum, 0.23 mm.; breadth of tubular chamber at end of fragments, 0.15 mm. The paratypes figured show a much larger size of test. Fragments of this rather rare species are so small, that it is impossible to estimate the possible length attained, but it was probably considerable.

Like all Hyperamminas, wide variation in size and proportions of the test can be observed even in single samples.

H. clavacoidea, n.sp., differs from *H. bulbosa* Cushman and Waters mainly in the more elongate proloculum, which merges gently into the narrower tubular chamber with less abrupt constriction. This early development has allowed the uniform compression of the entire test, whereas the more globose form of the proloculum of *H. bulbosa* and the sharper constriction at its junction with the tubular chamber lends rigidity at this point that commonly prevents the complete flattening of the initial chamber. *H. clavacoidea* is somewhat thinner walled and is slightly less rough than *H. bulbosa.* The smoothness of the Smithwick test may be the result of some mineralization. Future study of the English Carboniferous faunas may prove the identity of this species with *H. elongata* var. *clavatula* Howchin.

H. clavacoidea has been found in only a few outcrops of noncalcareous shales in the Smithwick and lower Strawn units in northern San Saba County. Elsewhere in the Pennsylvanian geologic section it is very rare. Its type locality (Sta. 205–T–128) is the base of the prominent slope of Strawn shales and sands about half a mile northeast of Algerita (fig. 16).

HYPERAMMINA ELEGANTISSIMA, n.sp.

Pl. 15, figs. 17–25

This slender, usually rather glossy, smooth test has a very narrowly rounded initial extremity and a straight to arcuate, gradually expanding tubular chamber, which is only rarely separated from the small megalosphere by a faint constriction. The microspheric form is finely tapering. The shell wall, composed of minute siliceous granules, is thin, so that most tests are strongly compressed or otherwise deformed, but the considerable proportion of siliceous cement makes them unusually rigid for their size. The oral extremity is somewhat constricted around a circular terminal aperture.

Length of holotype, 1.6 mm.; greatest breadth, 0.17 mm.; diameter of megalosphere, 0.05 mm., which is average. The diameter of the tubular chambers expands from the proloculum to a breadth of about 0.2 mm. or less at a length of about 0.6 mm., from which point expansion is generally almost negligible. Frequent tests in large suites of specimens are much more slender and may not exceed diameters much more than 0.1 mm. at mature lengths. Tests probably range up to a maximum of about 2 mm. in length.

The unusually glossy surface of many tests of *Hyperammina elegantissima,* n.sp., simulates that of species of *Hyperamminoides* and may be the result of mineralization which has rendered tests translucent. The more characteristic frosty surface of *Hyperammina* in Pennsylvanian strata is frequent on the more strongly developed specimens. Transverse constrictions are not normal but have been produced secondarily by compressional forces that have acted more or less axially. Whether the curvature of some tests is original or is due largely to deformation is uncertain. The moderate length and comparative rigidity of the tests make it possible to observe many almost complete tests.

Compared with other slender species of *Hyperammina* in the Texas Pennsylvanian section, this form is more delicate, carries more cement in its shell wall, and is characteristically very narrowly rounded at its initial extremity and most commonly without a constriction between the proloculum and the tubular chamber.

H. elegantissima, n.sp., has been found in only a few outcrops of noncalcareous Strawn shales in the area under consideration. Its type locality (Sta. 205–T–150) is a roadside slope southeast of Neal, northern San Saba County (fig. 16). In the Brazos River valley this species has been found as a rare member of the Mineral Wells fauna, upper Strawn group.

HYPERAMMINA SPINESCENS Cushman and Waters

Pl. 15, figs. 26–30

Hyperammina spinescens CUSHMAN and WATERS, 1928, Cushman Lab. Foram. Res., Contrib., vol. 4, p. 35, pl. 4, fig. 1. (Lower Strawn group, San Saba County, Texas.)

The outstanding and distinctive feature of the test of this species is the stout, short arenaceous spine at the base of the prominent, globular proloculum; otherwise it is very similar in shell texture and in proportions to large tests of *Hyperammina bulbosa* Cushman and Waters, with which it occurs in the area around San Saba, Texas.

The average diameter of the proloculum is about 0.35 mm., though it ranges from 0.25 to 0.45 mm. Fragments of the second chamber range in breadth up to 0.6 mm., and total lengths of mature tests must have been several millimeters.

The type locality (Sta. 205–T–150) of this species is the roadside exposure of gray shale and interbedded thin sandstones about 1½ miles by road southeast of Neal in San Saba County (fig. 16). It has been observed commonly in outcrops of noncalcareous Smithwick and lower Strawn shales around the Llano uplift, to which area it is apparently restricted.

Genus HYPERAMMINOIDES Cushman and Waters, 1928

Hyperamminella, CUSHMAN and WATERS, 1928 (not DeFolin, 1881), Cushman Lab. Foram. Res., Contrib., vol. 4, p. 36.

Hyperamminoides CUSHMAN and WATERS, 1928, Cushman Lab. Foram. Res., Contrib., vol. 4, p. 112.

Hyperamminoides, CUSHMAN and WATERS, 1930, Univ. Texas Bull. 3019, p. 35.

Hyperamminoides, GALLOWAY, 1933, A Manuel of Foraminifera, p. 75.

Hyperamminoides, CUSHMAN, 1940, Foraminifera, Their Classification and Economic Use, ed. 3, p. 84.

The free, generally elongate, flaring, siliceous, finely arenaceous tests of *Hyperamminoides* comprise a globular to ellipsoid proloculum followed by a rapidly expanding tubular second chamber, which is generally marked by sharp transverse constrictions and is strongly constricted around the terminal aperture. The strong shell wall is composed of fine, siliceous grains bound by considerable siliceous cement, so that the surface is commonly smooth and glossy.

Genotype, *Hyperamminella elegans* Cushman and Waters, Graham formation, Stephens County, Texas.

The conical or flaring second chamber and the resultant proportionally less elongate test are the fundamental characters of species of this genus as distinguished from the subcylindrical and the much more slender tests of *Hyperammina*. These more robust proportions make it possible to find large numbers of complete tests in washed material. Most of the species exhibit such an abundance of siliceous cement in the shell wall, that the surface is very smooth and even glossy, but sufficient variation exists in both genera to render this feature too unstable to serve as a generic character. Sharp, transverse growth constrictions are common, though on some species they are rare, and they vary widely in abundance on tests of any single species at any given locality. Both *Hyperamminoides* and *Hyperammina* in Carboniferous strata differ essentially from *Earlandia* in the siliceous and agglutinate constitution of the shell wall.

HYPERAMMINOIDES EXPANSUS, n.sp.

Pl. 16, figs. 1–6

In this species the diagnostic feature of the genus is expressed to an exaggerated degree in the short and very widely expanding second chamber, which is transversely marked by sharp growth constrictions. The proloculum is generally not distinctly set off by any constriction but, rather, forms the broadly rounded initial extremity of the megalospheric test and the more sharply pointed extremity of the microspheric test. The very finely arenaceous shell wall, composed of minute siliceous granules, carries an abundance of siliceous cement and externally is smoothly finished but internally is rough and even irregularly pustulate. The character of the oral extremity as it originally existed is still questionable, since an exhaustive search has failed to produce any specimen other than those wide open at the end, and such a condition is unacceptable as representing the true aperture. It seems reasonable to believe that the aperture was a small round opening in the constricted end of the second chamber, which in this species was too thin and fragile for preservation.

Length of the holotype, 0.64 mm.; breadth, 0.47 mm.; general angle of expansion, 50 degrees. Lengths up to 1.1 mm. have been observed in tests that expand gradually at angles varying from about 30 to 40 degrees, and these are tentatively regarded as microspheric forms from which the convincing earliest portion is missing. The broader and shorter tests as a rule are complete with their broadly rounded initial ends, and these flare at angles varying from 45 to 75 degrees with a common angle of about 50 degrees.

Most specimens of *Hyperamminoides expansus*, n.sp., are somewhat compressed and deformed. Rare tests exhibit cross sections so nearly circular that it is concluded that they were all characteristically conical. The thin outer edge of the broad opening of many tests points strongly to a very thin-shelled apertural extremity, which has disintegrated during fossilization and perhaps in the washing process.

The species has been found in one exposure of Smithwick (Sta. 205–T–127) and in a few outcrops of lower Strawn noncalcareous strata in northern San Saba County. Its type locality (Sta. 205–T–128) is a succession of thick Strawn shales and thin sandstones at the base of a prominent slope about half a mile northeast of Algerita (fig. 16). The abundance of material collected from the extensive geologic section in Brazos River valley has yielded no trace of this species, which is believed to be restricted to the lower Strawn in the immediate vicinity of the Llano uplift.

HYPERAMMINOIDES PROTEUS (Cushman and Waters)

Hyperamminella protea CUSHMAN and WATERS, 1928, Cushman Lab. Foram. Res., Contrib., vol. 4, p. 36, pl. 4, figs. 5, 6. (Strawn strata east of San Saba, San Saba County, Texas.)

Hyperamminoides protea, CUSHMAN and WATERS, 1928, Cushman Lab. Foram. Res., Contrib., vol. 4, p. 112. (New generic name substituted.)

In all the many samples collected from Strawn outcrops east of San Saba, no trace of anything like the tests originally figured and named have been found. The holotype suggests a rather unusual form of the species *H. elegans* (Cushman and Waters). This specimen in itself does not conform very well to the definition of *Hyperamminoides*, but until supporting topotypes can be found and studied, the established record is tentatively accepted.

Genus EARLANDIA Plummer, 1930

EARLANDIA MINUTA (Cushman and Waters)

Pl. 15, figs. 37, 38

Hyperamminella minuta CUSHMAN and WATERS, 1928, Cushman Lab. Foram. Res., Contrib., vol. 4, p. 37, pl. 4, figs. 8, 9. (Lower Strawn group, northern San Saba County, Texas.)

Hyperamminoides minuta (Cushman and Waters), CUSHMAN and WATERS, 1928, Cushman Lab. Foram. Res., Contrib., vol. 4, p. 112. (Correction of generic designation.)

The small, slender, tapering test of this species consists of a small spherical proloculum followed by a long, usually straight or rarely very faintly arcuate, steadily enlarging, tubular second chamber without transverse constrictions or marked so faintly by very few that they are hardly distinguishable. The dull, opaque, calcareous shell wall appears to be composed of minute calcareous granules probably secreted by the protoplasm, since no extraneous material has ever been found incorporated in the wall. The glassy proloculum is constricted where it joins the tubular chamber. The round apertural opening lies at the slightly constricted end of the tubular chamber.

At the type locality the tubular chamber increases in diameter from about 0.03 mm. at its junction with the proloculum to about 0.12 mm. at a length of about 0.6 mm. Tests as long as 0.8 mm. are rare. The diameter of the proloculum is usually about 0.04 mm.

The similar species, *Earlandia perparva* Plummer, which occurs commonly in higher Pennsylvanian strata farther north in Texas, is much more elongate and more slender, is conspicuously and almost consistently arcuate, bears numerous transverse constrictions, and carries a somewhat smaller proloculum.

In the area here under consideration, this species is rare, even at its type locality (Sta. 205-T-150) in Strawn shales about 12 miles north-northwest of San Saba (fig. 16) and in one other near-by exposure of the same age. It has been found rare in one shale outcrop (Sta. 134-T-33) on the Pfluger ranch in Kimble County, where the strata above the Marble Falls limestone have been mapped by field geologists as Smithwick (fig. 15), but recent careful study of the larger fossils in these layers indicates that they should probably be regarded as Strawn. The species has been found to be rare in Strawn strata in the Brazos River valley farther north in the state. It is curious that it has been observed only in noncalcareous shales, since calcareous tests in the Pennsylvanian section are more commonly associated with calcareous strata. Biologically this rare and rather robust form may be the response to its noncalcareous environment and the much more elongate *E. perparva* may be the form of the same species in a calcareous environment.

Family REOPHACIDAE

Genus REOPHAX Montfort, 1808

REOPHAX ARENATUS (Cushman and Waters)

Pl. 17, figs. 1–3

Nodosinella arenata CUSHMAN and WATERS, 1927, Cushman Lab. Foram. Res., Contrib., vol. 3, p. 147, pl. 26, figs. 2, 3. (Upper Strawn group, Mineral Wells formation, Palo Pinto County, Texas.)

Nodosinella? arenata, WARTHIN, 1930, Oklahoma Geol. Survey, Bull. 53, p. 28, pl. 2, fig. 8. (Holdenville formation, Oklahoma.)

This usually straight, short, stout, very roughly arenaceous test is composed usually of not more than three, rarely four, rather rapidly enlarging inflated chambers, generally separated by sharply indented sutures, which may be obscured by compression, and terminating in a protruding oral extremity. The proloculum is globular and often prominent. The lateral outline of many of the mature chambers is roughly subpyriform, though shape is highly variable. The heavy shell wall is composed of angular quartz grains of varying sizes bound by an insoluble cement that does not envelop the grains, so that they stand out in bold relief. The aperture is a simple opening at the end of the final chamber and is situated most commonly in a protuberance forming a short, usually narrow, tubular neck.

The average length of well-developed tests is about 0.8 mm. with a breadth of the final chamber of about 0.35 mm. Sizes and proportions are highly variable. One Strawn test from northern San Saba County is 1.4 mm. long and 0.5 mm. across the final chamber, but this is rare. The breadth of the initial chamber ranges from 0.15 to 0.3 mm., and some weakly developed tests are finely tapering. The rate of increase in breadth of the chambers varies so greatly that detailed measurements have little meaning.

Numerous samples of Mineral Wells shale from the extensive outcrop at the type locality for this species 4 miles west of Mineral Wells, Palo Pinto County, have yielded no trace of its tests, nor has the sample contributed by Mr. Waters from his original collection. The type specimens are typical of the species as it occurs in the same zone on the west slope of East Mountain in the town of Mineral Wells, and a study of the species has been based on this material. In Strawn shales in northern San Saba County, the tests are somewhat thinner shelled, but the fundamental features of the test and the range of variability are like those of tests in the type area. The size of test, depth of sutural constrictions, diameter of proloculum, and shape of chambers are all variable, but amongst the few-chambered species of this generic group *R. arenatus* is especially characterized by the coarseness and irregularity of the surface texture, the inflation of its chambers, and the elongation of the final chamber into a protruding neck. The subpyriform outline of the final chamber is likely to be a prominent feature in suites of specimens, but this character is not consistent, and where the species is weakly developed it may not be expressed. *R. expatiatus*, n.sp., which is also coarse, has very obscure sutures, and the outline of the short test is more or less evenly flaring without any oral protrusion. *R. asper* Cushman and Waters exhibits no sutural constrictions and essentially no enlargement of chambers with growth.

R. arenatus around the Llano uplift has been found only in lower Strawn strata in northern San Saba County. It is frequent in higher Strawn formations in the Brazos River valley section.

REOPHAX ASPER Cushman and Waters

Pl. 17, fig. 23

Reophax asperus CUSHMAN and WATERS, 1928, Cushman Lab. Foram. Res., Contrib., vol. 4, p. 37, pl. 4, fig. 7. (Cisco group, Graham formation, Young County, Texas.)

Reophax asper, CUSHMAN and WATERS, 1930, Univ. Texas Bull. 3019, p. 37, pl. 2, fig. 10. (Cisco group, Graham formation, Young and Stephens counties, Texas.)

This neat, compact succession of six or seven, roughly arenaceous chambers along a straight to faintly curved axis broadens slightly from a rather small proloculum to about the third chamber, and from this point it maintains an almost constant breadth, terminating in a gently rounded oral extremity. The heavy shell wall is composed of very coarse and angular quartz grains of varying sizes, and the insoluble cement is so inconspicuous, that the larger grains stand out in bold relief at different heights, so that the outline of the test is very irregularly rough. Sutural constrictions are indistinct to faintly expressed but never sharp. The aperture is a small and simple opening at the constricted end of the rounded final chamber.

The test in the area here considered rarely attains more than 0.6 mm. length and a breadth of about 0.18 mm.

R. expatiatus, n.sp., which is about the same size and texture, broadens rapidly with growth, thus producing an outline that differentiates the test from that of *R. asper*, with which it occurs in noncalcarous Strawn shales in the San Saba area, and in one shale outcrop (Sta. 134-T-31) of probably Strawn age in Kimble County.

At present this species in the San Saba area has been found only in Strawn shales, but in north Texas it is found also in the Graham formation, stratigraphically several hundred feet higher, and it will most likely be found in intervening strata.

REOPHAX BENDENSIS, n.sp.

Pl. 17, figs. 7–9

This very long, slender, very moderately rough, siliceous test consists of a linear series of many slowly enlarging ellipsoidal to slightly pyriform chambers separated by strong shallow sutural constrictions. The chambers average in width from one-half to two-thirds their height and are joined end to end by partial overlapping of the posterior extremity of each chamber over the protruding apertural extremity of the previous chamber, so that the sutural constrictions are extended and necklike. The shell wall comprises small to moderate-sized rounded siliceous granules, and in places other extraneous material, bound by considerable insoluble cement, that envelops the smaller particles but leaves some in partial relief, so that the surface is only moderately and bluntly irregular. The aperture is a simple round opening at the end of the bluntly tapering to protruding final chamber.

The length of a fully developed test must reach several millimeters, but deep sutural constrictions contribute to the fragmentary condition of specimens, and rarely can more than four or five chambers be found in a single fragment. The observed maximum length of a final chamber is 0.8 mm., and its breadth is 0.35 mm. No specimen bearing a proloculum has been found, but the youngest set of chambers (Pl. 17, fig. 8) shows the smallest chamber to be 0.085 mm. in diameter, and this must have been very close to the proloculum, if not the next following.

Most specimens of *Reophax bendensis*, n.sp., are strongly compressed, and youthful chambers are completely flattened. In the few outcrops where this form has been observed, some tests carry scattered mineral particles and chonetid spines in high relief on some parts of the tests. Some of these obviously do not belong inherently to the shell masonry, but are extraneous fragments and grains that have been added by cementation processes in the sediments, since ostracodes and other shells in the same material are similarly characterized. Some very youthful chambers are composed so largely of cement, that they are translucent and smooth.

No other members of this genus in the Lower Pennsylvanian strata can be confused with this sequence of loosely connected elongate chambers. It has been found only in the Marble Falls formation in the San Saba area and is undoubtedly a marker of this formation.

The type locality for *R. bendensis*, n.sp., is the calcareous shale exposure 2.7 miles south of San Saba (Sta. 205–T–2), San Saba County, Texas, and it has been found in three other calcareous shale beds in this county. This is the only agglutinate species restricted to the Marble Falls formation.

REOPHAX EMACIATUS, n.sp.

Pl. 17, figs. 18–22

The flattened spatulate test of this straight series of chambers is bluntly pointed at the initial extremity and truncate at the constricted oral extremity. The separate elongate chambers that overlap by about one-half are very obscure, if visible at all, for only rarely are sutures faintly constricted, though an occasional test exhibits the succession. The first two or three chambers broaden rapidly, but from this stage forward lateral increase is slower, but generally persistent, throughout growth. The shell wall is rather thin and all specimens have been completely flattened by sedimentary compaction, so that the combination of clear quartz grains in clear siliceous cement makes many of the tests semi-translucent. The poorly sorted angular mineral grains of the shell wall are well imbedded in the cement but are not wholly enveloped, so that the surface is moderately rough and in some strata very rough. In a few places dark siliceous mineral grains are included in the masonry. The anterior half of the final chamber is constricted gradually to the very slightly produced broad terminus marked by a large opening, which on these flattened tests is generally a narrow slit.

The length of the holotype is 1.33 mm., its greatest breadth is 0.46 mm., a typical form and average size. The size of some fragmentary specimens that include the final chamber indicates that the species must have attained lengths of almost 2 mm., but specimens anywhere near complete are generally about one millimeter or less.

The species is most commonly represented in Texas strata by fragments composed of the last one or two chambers. The wall is thin for the size of the test, though the coarseness of its texture in some strata creates the illusion of strength. Only rarely can specimens bearing the proloculum be found.

This species of *Reophax* is unusually stable in form, and only rarely is the mineral grain composition broken by the inclusion of scattered minute shell fragments. Steady increase in breadth of chambers throughout growth is the rule, but a few tests exhibit a constant breadth beyond the first few chambers.

From *R. fittsi* (Warthin) this species is differentiated by its much more elongate and less tapering test, by its constantly straight axis of growth, by its elliptical chambers, and by its broader and less protruding apertural extremity. It is sharply distinguished from *R. glennensis* (Harlton) by its more bluntly tapering initial extremity, its greater uniformity in shell masonry, its thinner shell, its almost total lack of sutural constrictions, and its more broadly truncate apertural extremity.

The type locality for *R. emaciatus*, n.sp., is a roadside exposure (Sta. 205–T–164) of noncalcareous Strawn shale west of the San Saba-Regency highway south of Neal (fig. 16), San Saba County. It is rather frequent in Strawn strata. A small suite of fragmentary and underdeveloped tests in a roadside bank of Marble Falls marl 2.6 miles south of San Saba (Sta. 205–T–57) may belong to this species. It has been found in the Brazos River geologic section in the Garner, Millsap Lake, Mineral Wells, Graford, Graham, and Pueblo formations, but is not common above strata of the Strawn group. The distribution chart, Table 1, records several Smithwick occurrences, which are now in question, since the shale outcrop of Kimble County has recently been reported as Strawn, on the basis of the coral *Striatopora moorei* Wells and others fossils.

REOPHAX EXPATIATUS, n.sp.

Pl. 17, figs. 4–6

This small, compact, flaring, coarsely arenaceous linear succession of short originally uncompressed chambers, lying along a straight to curved axis and separated by very indistinct sutures, is especially characterized by its few chambers that increase rapidly in breadth from a finely tapering initial extremity to a broad final chamber and a truncate septal face. The shell wall is composed of angular quartz grains varying in size up to relatively large grains for the size of the test, and the insoluble cement is sufficient only to hold them firmly without enveloping the coarse grains, so that the surface is irregularly rough. The proloculum is very small and is seldom well defined, and its external outline is generally irregular because of the coarseness of the shell masonry. The aperture is a simple small opening in the septal face at the terminus of the constricted and truncate final chamber.

Length of the holotype is 0.58 mm.; its greatest breadth (about fifth chamber) is 0.3 mm., which is average for the fully developed form of the species. It has been observed as long as 0.75 mm., with a width of 0.34 mm., where the species is exceptionally well developed, but for seemingly the same number of chambers the size varies widely.

The original roughly circular outline of the cross sections of the chambers has been somewhat altered by deformational forces, but the rigidity of the wall and coarseness of its component grains have contributed to less deformation than is characteristic of some of its congeners in the Pennsylvanian geologic section.

From other coarsely arenaceous and few-chambered species of this genus in the Texas Pennsylvanian beds, *Reophax expatiatus*, n.sp., is defined by the very rapid increase in breadth of its successive chambers, by its truncate septal face, and by its ill-defined sutures. *R. arenatus* (Cushman and Waters) has well-defined sutural depressions and a produced septal face. *R. asper* Cushman and Waters exhibits essentially no lateral expansion with growth.

The type locality for this species is the roadside exposure of Strawn shales and sandstones about 1½ miles by road southeast of Neal, San Saba County (Sta. 205–T–150, fig. 16). It has been found only in Strawn shales in northern San Saba County.

REOPHAX FITTSI (Warthin)

Pl. 17, figs. 10–17

Nodosinella? fittsi WARTHIN, 1930, Oklahoma Geol. Survey, Bull. 53, p. 27, pl. 2, fig. 7. (Wetumka, Wewoka, and Holdenville formations, Oklahoma.)

This elongate-ovate, short test tapering at both ends consists of a few rather rapidly broadening, strongly embracing, and roughly pyriform chambers separated by sutural constrictions that are very obscure, if they are visible at all. The chambers are broadest posteriorly and are overlapped by about one-half. The axis of growth is typically gently curved, especially at its initial extremity, but straight tests are frequent. The usually heavy shell wall is generally irregularly rough, in places very coarse, composed of quartz grains set in sufficient siliceous cement to produce a strong test but not to envelop the grains, which stand out in relief. Almost all specimens have been considerably or completely flattened by forces of compaction in the sediments, but originally they were probably uncompressed. The apertural extremity is constricted and produced into a very short neck toward the round terminal opening.

The length of tests of this species in the Texas section ranges up to almost a millimeter with a breadth of somewhat less than half the length.

The only other species with which *R. fittsi* can be. confused, and with which it frequently occurs, is *R. emaciatus*, n.sp., which is a thinner shell wall and is consequently always flattened to wafer thinness, is always straight, is generally more finely tapering toward its initial end, attains greater length, has a blunter more broadly truncate oral extremity, and is likely to be fragmentary in most material. *R. glennensis* (Harlton) generally has so thick a wall that it is commonly not greatly flattened, or where it does show considerable lateral compression the axis is straight, and the whole test is more elongate and tapering with sutures well defined.

Noncalcareous Strawn shales commonly carry *R. fittsi*, and it is found in formations of the Canyon and Cisco groups higher in the Brazos River valley section. The highest record is Pueblo shale (Permian), which carries it very rarely. Two exposures of Smithwick shale have yielded rare specimens of *R. fittsi;* one of these (Sta. 205–T–146) northwest of San Saba may eventually be found to belong to the Strawn sequence, but the other (Sta. 149–T–7) in the small downfaulted block of Pennsylvanian formations 10 miles southeast of Llano is without doubt true Smithwick, since the coral *Cumminsia aplata* (Cummins) has been recorded from shales in this vicinity.

REOPHAX GLENNENSIS (Harlton)

Pl. 17, fig. 24

Nodosinella glennensis HARLTON, 1927, Jour. Paleont., vol. 1, p. 17, pl. 1, fig. 4. (Upper Glenn formation, Oklahoma.)

Nodosinella ardmorensis HARLTON, 1927, Jour. Paleont., vol. 1, p. 18, pl. 1, fig. 5. (Upper Glenn formation, Oklahoma.)

Nodosinella laheei WATERS, 1927, Jour. Paleont., vol. 1, p. 131, pl. 22, fig. 8. (Dornick Hills formation, Oklahoma.)

Nodosinella brevis WATERS, 1927, Jour. Paleont., vol. 1, p. 131, pl. 22, fig. 9. (Dornick Hills formation, Oklahoma.)

Nodosinella crassa WATERS, 1927, Jour. Paleont., vol. 1, p. 131, pl. 22, fig. 10. (Dornick Hills formation, Oklahoma.)

Nodosinella? ardmorensis, WARTHIN, 1930, Oklahoma Geol. Survey, Bull. 53, p. 27, pl. 2, fig. 5. (Wewoka and Wetumka formations, Oklahoma.)

Nodosinella glennensis, CUSHMAN and WATERS, 1930, Univ. Texas Bull. 3019, p. 38, pl. 2, figs. 11, 12; pl. 12, fig. 4. (Cisco group, Graham formation, Young County, Texas.)

Nodosinella glennensis, HARLTON, 1933, Jour. Paleont., vol. 7, p. 11, pl. 2, fig. 1. (Johns Valley shale, Oklahoma.)

The sides of these usually straight tests converge aborally at an average angle of about 25 degrees from the broadest diameter through the posterior portion of the final chamber, and the lateral slopes of the oral extremity converge at an angle of about 40 degrees toward the apertural opening. The several gently inflated, regularly enlarging, embracing, elongate chambers are separated by sharp, but not deeply incised, sutures, which may be obscured by compression or deformation of the shell walls. The shell wall is characteristically composed of many kinds of adventitious material including fine to large mineral grains, shell fragments, conodonts, acicular particles, holothurian plates, and minute foraminiferal tests, but in some places the masonry comprises almost wholly mineral grains and may be of fine and uniform texture. Only rarely do the components of the wall project obtrusively, since the included flat shell fragments are so placed that their broad surfaces blend well into the external contours of the chambers, and all adventitious matter is well bound into a stout wall masonry by considerable cement, which commonly is rich in in reddish ferruginous matter. The anterior two-thirds of the final chamber is regularly constricted and produced toward the rather small rounded aperture at the terminus, which may be slightly extended into a short tube.

The size attained by *Reophax glennensis* (Harlton) varies widely. A length somewhat under a millimeter may be regarded as average in the Texas strata, but at a few localities tests of two or three millimeters are frequent and resemble in this respect more nearly the Oklahoma types and also identical forms from the Dornick Hills formation designated as *Nodosinella laheei* Waters, *N. brevis* Waters, and *N. crassa* Waters. In one outcrop in the lowest part of the Smithwick formation (Sta. 205–T–79B), very large fragmentary specimens indicate that the species must have attained lengths of several millimeters, for one series of three chambers is 2.8 mm. long, and the breadth of the final chamber is 1.6 mm.

The wide geographic and stratigraphic range of *R. glennensis* offers excellent opportunity to follow its variations and to determine its consistent and fundamental specific characters. Disregarding the confusing effects of deformation in identifying some tests, the regular enlargement of successive chambers throughout growth, thus producing evenly tapering forms, the distinct sutures, the elongate chambers, and the somewhat produced septal face comprise a reliable ensemble of characters that mark this species.

The precise composition of the shell wall is superficially exceedingly variable, but a common character is a heterogeneity of material, and in a few places the wide variety of its components is remarkable; on the other hand, the surface may be uniform. One characteristic feature of the masonry where the test is well developed is the persistence of minute acicular particles, and in some strata tests seem to be composed almost wholly of such material. In other places comminuted shell material is dominant in the composition of the wall with perhaps an occasional conodont, small ostracode, holothurian, or mineral grains for variety. In a few strata the wall is composed almost entirely of quartz grains, but in a suite of such specimens the specific tendency to build the test of different kinds of material is likely to exhibit itself in the inclusion of a few scattered bits of material other than sand. That this shell composition is truly a variable character of the species becomes evident in a suite of tests from an outcrop at the base of the Smithwick formation (Sta. 205–T–79B), where some tests are composed wholly of acicular particles or largely of such particles with a few scattered glauconite grains; others in the same sample carry an assortment of glauconite, quartz grains, acicular particles, conodonts, and shell fragments all carelessly arranged and in somewhat greater relief than is typical; still others are composed almost wholly of different kinds of coarse mineral grains with some scattered acicular particles. In general, however, the character of the shell wall is fairly constant in each stratum where the species occurs.

Most of the tests of *R. glennensis* in the Texas strata are straight, but faintly arcuate large forms are frequent at a few localities, and in this respect they are more like the specimen recorded from the Glenn and Dornick Hills formations in Oklahoma where deformational forces have been more intense. In some places the test never attained even the average size for the species and is composed of only about four small chambers. More favorable environment in other places produced large long tests of seven or eight larger chambers. The thickness and rigidity of the wall is reflected in the ability of the different tests to resist compressional and deformational forces, which have flattened the weaker ones, whereas the more common, large and strong tests have attained their original rotundity. Sutural constrictions in this species are so sharp, that even the extreme degree of collapse rarely obliterates the distinctive character.

R. glennensis differs from *R. fittsi* (Warthin) in its more elongate and generally straighter form, in its more distinct sutures, and commonly in the heterogeneity of material in its shell wall. In *R. emaciatus*, n.sp., sutures are very obscure if they are visible at all, its apertural extremity is broader and more truncate, and its shell wall is regularly composed of siliceous grains in so fragile a wall, that all tests are completely compressed to wafer thinness.

Reophax glennensis has been found to be common or frequent in two exposures (Sta. 153–T–6 and Sta. 205–T–79B) of undoubted Smithwick shale, where *Cumminsia aplata* (Cummins) dates the formation. The fossiliferous shale in Kimble County (Sta. 134–T–5), originally mapped as Smithwick (fig. 15), has very recently been designated as more probably Strawn, where the species is very rare. Higher in the Strawn succession, in the Millsap Lake, Garner, and Mineral Wells formations in Brazos River valley it occurs with some frequency and has been seen as high as the Graham formation, Cisco group.

REOPHAX MINUTISSIMUS, n.sp.

Pl. 17, figs. 25–30

The small and only moderately rough, slender test, which in its fossil state is almost consistently wholly compressed, comprises a straight succession of 6 to 8 gradually enlarging, short, inflated, and moderately embracing chambers separated by sharply incised transverse sutures. In general the chambers measure in length about two-thirds their breadth, though somewhat more elongate chambers are frequent. Considerable siliceous cement lends a gloss to the wall but does not envelop all the larger grains in the wall composition. The aperture of the collapsed tests is an elongate opening at the end of the constricted septal face of the final chamber, but in its original form it was undoubtedly round in a circular septal face.

Length of holotype, 0.46 mm.; breadth of proloculum, 0.065 mm.; breadth of final (fifth) chamber, 0.20 mm. The holotype is smaller than average size but has been chosen because it is one of the very rare tests to bear the proloculum, which is so thin-shelled and delicate, that the most careful preparation of the raw sample fails to preserve many of the earliest chambers of these tests. Megalospheric tests of an average of five or six chambers measure about 0.7 mm. in length from an average proloculum of about 0.06 mm. or less to the final chamber about 0.2 mm. in breadth. The only microspheric test found (Pl. 17, fig. 29) bears an initial chamber 0.045 mm. in diameter and is followed by seven steadily enlarging chambers comprising a total length of 0.64 mm., and the final chamber is 0.17 mm. in breadth.

The only other species comprising a succession of globose chambers is *Reophax tumidulus*, n.sp., which is a much larger and thicker walled test of coarser texture and is composed of very few chambers that maintain almost a constant size throughout growth.

The type locality for *R. minutissimus*, n.sp., is the basal 15 feet of the steep and prominent sandstone-capped elevation about half a mile northeast of Algerita (Sta. 205–T–128; fig. 16), San Saba County. It is nowhere abundant but is frequent in noncalcareous Smithwick and Strawn shales in San Saba County. It has not been found in Pennsylvanian strata elsewhere.

REOPHAX TUMIDULUS, n.sp.

Pl. 17, fig. 31

This linear series of a maximum of four, roughly arenaceous, globose, and only slightly embracing chambers, separated by sharp sutural constrictions, exhibits only very slight increase in its breadth from the large globular proloculum to its final chamber, which is broadly rounded distally. The shell wall is composed of moderate-sized, angular quartz grains bound by an insoluble cement that does not envelop the grains, which therefore stand in relief and at differing heights to produce an irregularly rough surface. The aperture is a simple small opening in the broadly rounded septal face of the final chamber.

Length of holotype, 1.05 mm.; breadth of globular proloculum, 0.3 mm.; breadth of final (fourth) chamber, 0.4 mm.

Moderate collapse of the tests of *Reophax tumidulus*, n.sp., tends to accentuate the irregular surface texture, which, however, was originally very rough. The species is distinctive amongst its congeners in the Texas Pennsylvanian fauna in its few globose chambers of almost uniform size. *R. minutissimus*, n.sp., is a much smaller form, with a more delicate shell wall, has on the average more chambers in the mature test, and shows a steady increase in breadth of its successive chambers.

This rare species has been found in only two samples of Strawn shales in northern San Saba County, and its type locality is the base of the prominent escarpment about half a mile northeast of Algerita (Sta. 205–T–128; fig. 16). It has not been observed in any Carboniferous strata elsewhere in north-central Texas.

Family AMMODISCIDAE

Genus AMMODISCUS Reuss, 1861

AMMODISCUS SEMICONSTRICTUS Waters

Pl. 16, figs. 7, 8

Ammodiscus semiconstrictus Waters, 1927, Jour. Paleont., vol. 1, p. 132, pl. 22, fig. 1. (Lower Pennsylvanian, Dornick Hills formation, Carter County, Oklahoma.)

Ammodiscus semiconstrictus var. *regularis* Waters, 1927, Jour. Paleont., vol. 1, p. 132, pl. 22, fig. 2. (Lower Pennsylvanian, Dornick Hills formation, Carter County, Oklahoma.)

Cornuspira semiconstrictus, Harlton, 1933, Jour. Paleont., vol. 7, p. 9, pl. 2, fig. 2. (Johns Valley shale, Pushmataha County, Oklahoma.)

The circular to elliptical, discoid, broadly biconcave, finely arenaceous, rugulose test comprises a minute globular to ovoid proloculum surrounded by as many as twelve planispiral convolutions of the very slowly enlarging, inflated tubular chamber, which is faintly to strongly marked by irregularly distributed transverse constrictions. The delicate fine structure of the central area can best be observed in limonite-filled tests viewed in transmitted light, though commonly the depressed whorl suture almost throughout the disc is sharply discernible. The whorl suture between the last several coils is very conspicuous. The peripheral area of uncompressed tests is broadly rounded. The shell wall is composed of fine and uniform quartz grains bound by considerable enveloping insoluble cement, so that the tests in some strata glisten; therefore the test owes its rugosity largely to the characteristic undulating surface of the tube. The aperture is the open end of the tube.

A common diameter of the test is about 0.8 mm. where it is moderately well developed and common, though an average of only 0.6 mm. characterizes tests in some strata. In many beds of Smithwick and lower Strawn age, numerous tests of a millimeter or more in diameter are abundant. The largest test measured is 1.45 mm. The last convolution of an undistorted test about 0.8 mm. in diameter and composed of 9 or 10 convolutions is about 0.1 mm. thick. The proloculum, as seen in transmitted light in many limonite-filled tests, measures from 0.03 to 0.05 mm.

The tests of *A. semiconstrictus* in type material furnished by Mr. Waters are large and very well preserved with almost no deformation or compression, and its characteristics are strikingly exhibited. A suite of topotypes in all stages of growth shows the same gradual increase in strength of the transverse constrictions from youth to maturity as do the Texas tests, and consequently the holotype of *A. semiconstrictus* var. *regularis* Waters, which is about one-seventh the diameter of the holotype of the species, is regarded as a youthful test. In some strata the irregularity in the diameter of the tube is not so marked as in other strata, especially where the test is unusually thin-shelled and has been exceedingly compressed by forces of compaction in the sediments, but this apparent difference may be due to the obscuring effects of the deformations.

In the Pennsylvanian section in Texas, *A. semiconstrictus* is especially differentiated by the irregularity in the diameter of the tube and by the large number of convolutions of the tubular chamber that increases very slowly in size from a minute proloculum. Similar forms of *Ammodiscus* have been recorded in the present oceans, but until broad comparative studies can be made of all the species of this genus the name given by Waters to a Lower Pennsylvanian form should serve as a distinctive designation for the fossil.

This species is the commonest foraminiferal species in the Smithwick and lower Strawn noncalcareous shales around the Llano uplift. A somewhat glauconitic, conglomeratic, and noncalcareous layer near the top of the Marble Falls (Sta. 134-T-26 and -27) has also yielded frequent moderately well-developed tests. The form described[6] as *A. semiconstrictus* var. *regularis* from the Graham formation is probably not identical with the Dornick Hills species, as it has been drawn, for it possesses a large proloculum, and the tube from its initial extremity is large. A difference in generation cannot be sought as the basis for the difference, for the thousands of tests of *A. semiconstrictus* taken from the Smithwick and Strawn samples show a consistently minute proloculum followed immediately by an extremely fine and delicate tube through several convolutions before it attains an appreciable diameter. The species ranges upward into recognized Millsap Lake strata and perhaps higher, but it is probably restricted to the lower part of the Pennsylvanian succession of strata.

Genus GLOMOSPIRA Rzehak, 1888

GLOMOSPIRA COMPRESSA Waters

Glomospira compressa WATERS, 1928, Jour. Paleont., vol. 1, p. 273, pl. 42, fig. 5. (Canyon

[6]Cushman, J. A., and Waters, J. A., Foraminifera of the Cisco group of Texas: Univ. Texas Bull. 3019, p. 40, pl. 2, figs. 13–15, 1930.

group, Brad formation, Brown County, Texas.)

The test of this finely arenaceous species consists of a globular proloculum followed by a tubular second chamber of considerable length and of almost constant diameter, which winds very loosely back and forth around about upon itself without any apparent sense of direction. The aperture is the open end of the tube.

The diameter of the tube at the only locality where this species has been observed in the Lower Pennsylvanian formations is about 0.09 mm., which is considerably less than that of topotypes in a shale outcrop about 35 feet above the Adams Branch limestone, Graford formation (redefined).[7] The whole tangle made by the tube in the Smithwick also averages considerably smaller.

The species is fairly common in the very black, laminated Smithwick shales at Sta. 205–T–127, and the character, or lack of character, of the test is the same as it is in the larger form at the type locality, 5 miles southwest of Brownwood, Brown County. There seems to be no reason for making any specific differentiation on the basis of size alone, since size has been found commonly to be, to a considerable degree, a result of environment, which governs development.

GLOMOSPIRA ARTICULOSA, n.sp.

Pl. 16, figs. 21–25

This tight tangle of disorderly convolutions of a very slowly enlarging tubular chamber is the Gordian Knot of the foraminiferal structures in Pennsylvanian faunas in this area. It apparently follows no formal plan of coiling, but twists and turns about itself haphazardly, winding itself into a compact body of no definite shape. The shell wall is composed of very minute quartz particles bound by considerable clear and insoluble cement. Transverse constrictions are frequent but not consistently present. The whorl suture is sharply depressed. The aperture is the open end of the tube but can rarely be found.

The diameter of the holotype, which happens to be one of the more nearly globular tests, is about 0.5 mm. Transverse measurements of these irregular tests can reach 0.7 mm., and they average about 0.6 mm. The diameter of the mature tube averages about 0.1 mm.

For variability, the illustrations speak for themselves. It is unlikely that this species can be confused with any other in the Pennsylvanian strata in Texas and differs from *G. compressa* Waters in being a compact tangle. It has so far been observed only in the vicinity of San Saba, in one outcrop of Smithwick (Sta. 205–T–127; fig. 16) and one outcrop of Strawn (Sta. 205–T–128; fig. 16), which is the type locality.

Genus GLOMOSPIRELLA, n.gen.

The earliest part of the undivided, finely arenaceous tube in this structure winds compactly in different directions like a ball of twine, as in *Glomospira*, beyond which it becomes more and more nearly planispiral, until in maturity it is perfectly planispiral. The aperture is the open end of the tube.

Genotype, *Glomospira umbilicata* Cushman and Waters; Smithwick shale on highway 1.5 miles east of Algerita, San Saba County Texas (Sta. 205–T–127, fig. 16).

The structure of *Trochamminoides* Cushman is somewhat similar to that of *Glomospirella*, but its planispiral coils are regularly constricted into definite chambers.

GLOMOSPIRELLA UMBILICATA (Cushman and Waters)

Pl. 16, figs. 26–31

Glomospira umbilicata CUSHMAN and WATERS, 1927, Cushman Lab. Foram. Res., Contrib., vol. 3, p. 148, pl. 26, figs. 7, 8. (Smithwick formation, San Saba County, Texas, erroneously recorded as Southwick shale.)

This large, discoidal, finely arenaceous, and generally very broadly umbilicate test with considerable insoluble cement and of uniform texture comprises a proloculum followed by a gradually enlarging, distinctly and irregularly constricted, tubular second chamber. In its small initial stage, the tube winds compactly in widely different directions upon itself

[7]Nickell, C. O., Stratigraphy of the Canyon and Cisco groups on Colorado River in Brown and Coleman counties, Texas: Univ. Texas Bull. 3801, pp. 96–107, 1938.

throughout two to five convolutions; then throughout several convolutions it winds in different planes that lie at low angles to the general plane of the growing discoid test by lapping over the peripheral area on one lateral face and then on the other as it becomes more and more nearly planispiral; finally in fullest maturity the tube describes from one to three planispiral coils. The whorl suture is distinctly, and often deeply, depressed. The aperture is the open end of the tube.

The diameter of this flat thin test reaches 1.1 mm.; the width of the final planispiral whorl, which is usually flattened, is 0.15 mm. measured on the lateral face; the thickness of mature whorls is about 0.1 mm., which because of the compression of the fossil tests is somewhat less than the original thickness.

The three so-called "stages" of coiling comprise in reality a gradual progressive advance toward the final planispiral disposition of the convolutions of the tube in full maturity from an initial stage composed of coils that twist about the proloculum in planes lying at widely divergent angles suggestive of a ball of twine. Each of the three "stages" varies considerably in the number of coils involved, and consequently the fully developed discoid test presents wide variation in general lateral appearance. A test in which the earliest stage comprises a tangle of several coils with one or two lying almost at right angles to the discoidal plane and across the central area, is not umbilicate (Pl. 16, fig. 28). The first stage in many tests is less well developed by being composed of so few convolutions, that the tube has not reached such a diameter as to form a bulky central area before the second stage, which defines the general plane of the disc, is entered, and such tests are broadly umbilicate (Pl. 16, figs. 26, 30, 31). The second series of convolutions, which comprise the greater portion of the test, also presents some variation in manner of coiling that gives rise to tests differing considerably in lateral pattern. Each convolution very commonly overlaps the peripheral area of the growing discoid test by about one-third the perimeter on one side and then on the other, through many complete turns of the enlarging tubular chamber. Each convolution, therefore, makes one lap on one side of the disc and two on the other, and on one lateral face a succession of three laps defining 360° represents two convolutions of the tube. A fairly regular succession of many such convolutions may contribute to a subtriangular outline of the test during this state of development, if the overlaps change sharply from one side of the test to the other. Tests on which these changes take place in broader curves maintain fairly circular outlines, though the triangular pattern of the whorl suture on each face may be distinct. Many other tests, however, have been developed by second-stage coils that have shifted so irregularly around the central area, that the whorl suture of the test makes no particular pattern on the lateral face of the disc. The third stage of true planispiral coils is commonly not strongly developed, but in a large suite of specimens, many are mature enough to exhibit from one to three convolutions.

At the type locality of *Glomospirella umbilicata*, in the upper Smithwick shales, the species is very common to abundant, and a suite of several hundred tests shows the wide variations in the development of each of the three stages of coiling, as described above. The holotype and paratype figured by the authors of the species illustrate both the broadly umbilicate test with a weakly developed early stage and one showing a more strongly developed and a more bulky early stage of several coils, two of which lie in planes almost at right angles to the discoidal plane of the mature test, which therefore is not distinctly umbilicate. The disposition of the successive planes of coiling is erratic enough in the species at its type locality to give rise to many different patterns on the lateral faces of the tests, but fundamentally the structure of this species is constant. Umbilicate tests characterized by a subtriangular outline throughout the second stage of coiling, well illustrated by the holotype, are much less frequent at the type locality than are the nonumbilicate tests with well-developed early stages followed by low-angle coils shifting irregularly about the periphery and having subelliptical and subcircular outlines.

This same species in somewhat larger size is common in shales in the base of the overlying Strawn strata not far from the type locality for the species in the Smithwick, and here a similar range of variation in general pattern of the lateral faces has been observed. The typical umbilicate test with its small initial stage followed by a subtriangular second stage is the dominant form in these strata. The Strawn tests are likely to exhibit a larger number of planispiral coils than do those in the underlying Smithwick strata, and the ontogeny presents some evolutionary advancement. Since each formation carries tests showing the same wide variations in the positions of the convolutions in this species, it has proved impracticable to separate the Smithwick and Strawn forms on the basis of dominance of any particular type.

The only roadside outcrop of Smithwick shale (not Southwick shale, as recorded by Cushman and Waters) east of Algerita, San Saba County, lies 1.5 miles by road from the cross-roads in the north edge of the town (Sta. 205–T–127; fig. 16) instead of 3 miles, as originally recorded. Material from several different places in the outcrop has yielded concentrates precisely like that which Mr. Waters has supplied from his collection, and therefore this conspicuous roadside ditch is regarded as the type locality for *Glomospirella umbilicata* (Cushman and Waters).

The species is frequent in the noncalcareous Smithwick and Strawn shales around the Llano uplift and has been observed in a very unusual noncalcareous facies of the Marble Falls formation (Sta. 134–T–27; fig. 15).

Family LITUOLIDAE

Genus HAPLOPHRAGMOIDES Cushman, 1910

HAPLOPHRAGMOIDES CONFRAGOSUS, n.sp.

Pl. 15, figs. 39–41

The only planispiral and involute, agglutinate, chambered coil in the Texas Carboniferous strata is *Haplophragmoides confragosus*, n.sp., in the area under consideration. It is consistently so completely compressed and otherwise deformed, as to render its fundamental and original structure at least very obscure and generally impossible to identify generically. Had the test been compactly built, deformational stresses would not have been so obliterating, but chambers were as globose as those of *Globigerina aequilateralis* H. B. Brady. External forces acting in different directions upon such a test, built probably on a chitinoid base, have pushed the chambers in diverse directions out of their original positions, and the resultant fossil generally appears formless. It is significant, however, that no test of the many hundreds studied has shown any evidence of a spire that would indicate the trochiform test of a *Trochammina*. Several tests, on the contrary, have produced evidence that the coil was originally involute and planispiral.

The medium large, coarsely arenaceous, rough test of this species shows five or six enlarging chambers in its final convolution in fullest maturity. Where the species is not well developed, only four may be visible. Sutures are very deeply incised between what were originally highly globose chambers, so that the periphery was very broadly rounded. The shell wall is composed of quartz grains of diverse sizes set in an insoluble cement, and the surface is irregularly rough. Since no aperture is clearly discernible on any of the many specimens, it must be assumed that it was a low arch at the base of the septal face, a type that would be quickly obliterated by deformation.

Diameters of the deformed tests reach 1 mm. Any estimate of the original thickness of the test is a mere guess, but it is likely that thickness was approximately half the diameter. In some shales the tests are undeveloped and average only about 0.6 mm. in diameter, and at such places the species is likely to be rare.

H. confragosus has been found only in the noncalcareous Smithwick and Strawn shales around the Llano uplift. It is much more common in the Strawn, and its type locality (Sta. 205-T-128; fig. 16) is the base of a conspicuous sandstone-capped slope about half a mile northeast of Algerita, San Saba County.

Genus AMMOBACULITES Cushman, 1910

AMMOBACULITES MINUTUS Waters

Pl. 15, figs. 15, 16

Ammobaculites minuta WATERS, 1927, Jour. Paleont., vol. 1, p. 133, pl. 22, fig. 3. (Dornick Hills formation, Carter County, Oklahoma.)

The small, slender, moderately rough test of this species is of a rather fine texture and is composed of quartz grains of very uniform size. The early somewhat evolute coil of about two convolutions exhibits from eight to nine inflated chambers in the final convolution, and these are followed by several short, somewhat inflated rectilinear chambers of constant breadth along a normally straight axis. Sutures throughout the test are distinct, though not deep. The aperture is terminal on the somewhat constricted septal face of the final rectilinear chamber and was undoubtedly originally round, but all specimens are found compressed, and the orifice is a very obscure elongate slit.

The average length of a test bearing six rectilinear chambers is 0.55 mm.; the average diameter of the early coil is 0.2 mm.; the average breadth of the rectilinear chambers is 0.13 mm.

The critical characters of *Ammobaculites minutus* Waters are the partially evolute convolutions in its initial coil and especially the many chambers in the final convolution of the coil. Many tests are too deformed to show clearly the earliest convolution, but generally the numerous small chambers in the final convolution are obvious and separate this form sharply from all the other small species of *Ammobaculites* in the Texas Pennsylvanian section. Its rectilinear chambers average somewhat shorter than those of the other associated small species, but deformation of most specimens of all these species makes the slight difference in this proportion rather unreliable in itself alone as a basis for identification.

Partly because of the misleading illustration of the holotype from the Dornick Hills formation in Oklahoma, Galloway and Ryniker[8] have identified a calcareous test of similar proportions and structure as *Endothyranella minuta* (Waters). Topotypes from the original sample collected by Mr. Waters have been studied, and insoluble tests are found to be truly agglutinate and composed of quartz grains. It cannot be further argued that these tests have been silicified and recrystallized, since they are accompanied by an abundance of soluble calcareous tests of other speceis.

A. minutus has been found rarely in the Smithwick and lower Strawn noncalcareous shales in the area here under observation. In the Brazos River valley area, it has been found in the Graford formation and may be recorded elsewhere in the Pennsylvanian section when compilations have been completed.

AMMOBACULITES STENOMECUS Cushman and Waters

Pl. 15, figs. 31-35

Ammobaculites stenomeca CUSHMAN and WATERS, 1928, Cushman Lab. Foram. Res., Contrib., vol. 4, p. 39, pl. 5, fig. 1. (Graham formation on Salt Creek, Young County, Texas.)

Ammobaculites stenomeca, CUSHMAN and WATERS, 1930, Univ. Texas Bull. 3019, p. 48, pl. 3, fig. 15. (Graham formation, Salt Creek, Young County, Texas.)

Ammobaculites stenomeca, WARTHIN, 1930, Oklahoma Geol. Survey, Bull. 53, p. 30, pl. 2, fig. 9. (Holdenville formation, Oklahoma.)

This small test is very coarsely arenaceous and is composed of an assortment of angular quartz grains of widely varying sizes set in a subordinate amount of insoluble cement, so that the grains stand out in high relief. The initial coil, which is prominent on some tests and insignificant on others, comprises probably little more than a single convolution of about five gradually enlarging chambers and is followed by several short rectilinear chambers, which enlarge little, if at all. Throughout development sutures are generally indistinct or even indistinguishable on some tests, though tests of unusually uniform surface texture may exhibit the

[8]Galloway, J. J., and Ryniker, C., Foraminifera from the Atoka formation of Oklahoma: Oklahoma Geol. Survey, Circ. 21, p. 14, pl. 2, figs. 5, 6, 1930.

sutures clearly. The oral extremity is somewhat constricted around a small obscure opening.

Size varies widely in different samples. Commonly, in the area under consideration, tests are weakly developed and range to only about 0.35 mm. in length with an initial coil approximately 0.12 mm. in diameter or less. Where the test is stronger and larger, lengths as great as 0.6 mm. may be attained with initial coils varying from an almost indistinguishable feature up to diameter of 0.18 mm.

Examination of the holotype and suites of topotype specimens indicates that the angular peripheral outline of the early coil of the holotype is by no means a specific character. This peculiar shape is due to the inclusion in the coil of some angular quartz grains so set in the peripheral area as to lend angularity to the outline. The lack of uniformity of grains in the masonry produces coils of highly irregular and diverse outlines.

Ammobaculites stenomecus is more coarsely arenaceous than the uniformly fine-textured *A. nitidus* Waters, the chambers are less distinct, and the test is much more likely to be compressed, especially where tests are small and weakly developed. From the more coarsely arenaceous *A. spirans* Cushman and Waters, it is distinguished largely by its more obscure sutural constrictions and by its straighter rectilinear succession of chambers. *A. minutus* Waters has a more uniform surface texture, a larger number of chambers in the initial coil, and sharper delineation of chambers and sutures.

The type locality for *A. stenomecus* is in north-central Texas, the dark shale in the upper part of the Graham formation (Cisco group), a mile west of Graham, on Salt Creek, Young County, where it attains a moderate development. Around the Llano uplift it is frequent in the noncalcareous Strawn shales.

Genus ENDOTHYRA Phillips, 1846

Endothyra Phillips, 1846, Geol. Polytech. Soc. West Riding, Yorkshire, Rpt. Proc. (1844–45), vol. 2, p. 277.

Endothyra, Brady, 1876, Palaeontogr. Soc., vol. 30, p. 90.

Endothyra, Möller, 1878, Acad. Imp. Sci. St. Pétersbourg, Mém., ser. 7, vol. 25, no. 9, p. 89.

Endothyra, Galloway and Harlton, 1928, Jour. Paleont., vol. 2, p. 347.

Endothyra, Warthin, 1930, Oklahoma Geol. Survey, Bull. 53, p. 18.

Endothyra, Cushman and Waters, 1930, Univ. Texas Bull. 3019, p. 46.

Endothyra, Galloway, 1933, A Manual of Foraminifera, p. 157, pl. 14, figs. 9, 10.

Endothyra, Cushman, 1940, Foraminifera, Their Classification and Economic Use, ed. 3, p. 102, pl. 10, fig. 17; key, pl. 5, figs. 1, 2.

This free and tightly coiled, laterally compressed test with rounded periphery varies in bilateral symmetry from perfectly planispiral and symmetrical through all degrees of asymmetry to strongly rotaliform. The coil may be wholly involute throughout growth, or it may become gradually more and more evolute in its advancing ontogenetic development, depending on the species. The characteristically smooth surface of the test in some species exhibits regularly distributed minute, shallow pits, or surficial punctations, which can be seen only in carefully adjusted light. The wholly calcareous shell wall has been found to be both fibrous or granular or both. Finely granular calcareous matter commonly thickens the sutures and the inner extremities of the chamber walls around the umbilical areas on tests of some species; other species are totally devoid of limbations. The aperture throughout growth remains at the base of the septal face, but it varies in shape from a broad crescentic arch extending well over the peripheral area to a narrow high arch in the septal face on the periphery.

Genotype, *Endothyra bowmani* Phillips; Carboniferous strata in Yorkshire, England.

The character of the shell wall of *Endothyra* has been the subject of considerable controversy. Only a broad study of the shell walls of numerous species in different areas, in many successive stratigraphic positions, and in different lithologic environments is likely to harmonize the many seemingly conflicting observations into a satisfactory interpretation. Brady (1876, p. 90) described the test as subarenaceous, that is, "built up of minute particles of sand (necessarily in these limestone seas, of calcareous sand) embedded in calcareous cement," and he commented that the shell "is never conspicuously sandy" (p. 14) in surficial texture. Möller (1878, p. 90 et seq.) described the shell as hyaline-like and contended that any apparent granulation must be the result of recrystallization of the originally fibrous calcareous wall. Brady's concept of the agglutinate character of the calcareous wall has been endorsed by Cushman, who in several publications has recorded the shell as arenaceous usually with a large amount of calcareous cement. Henbest's study[9] of thin sections of *Endothyra baileyi* (Hall) in the Spergen limestone (Mississippian) led to the same conclusion, with the disarming comment that the unindurated character of the rock "shows unusually small evidence of secondary mineralization and change of composition." Warthin, who found crystallized walls in most thin sections of specimens from Wetumka, Wewoka, and Holdenville formations (Pennsylvanian) in Oklahoma concluded from a study of his "best sections" that most of the thin calcareous endothyrine wall was secreted but carried "a small proportion of included round grains of non-secreted matter." Galloway (and collaborators), on the other hand, follows Möller and has described the wholly calcareous shell masonry as transversely fibrous in its original state, or granular only through agencies of fossilization and consequently deceptively arenaceous. The wall is therefore regarded by this school of though as a product of secretion without included grains. It is certain, from the present observations of endothyrine tests throughout a thick section of Texas Carboniferous sediments, that any surficial rugosity due to unimbedded grains is a result of cementation of foreign matter in the matrix by secondary processes, since accompanying ostracodes and other fossil fragments are similarly characterized, and in some strata rugosity may result from secondary deposition of crystalline calcium carbonate on the originally smooth shell surfaces. It is very important that the internal character of the wall of *Endothyra*, and those of other Carboniferous genera characterized by calcareous walls, be carefully and comprehensively studied throughout the geologic ranges of these forms, for it is possible that such an investigation may reveal some regular and progressive features of evolution in wall structure that may prove useful as age determinants, much as fusulinids now serve the stratigrapher.

The question of porosity of the shell wall of *Endothyra* needs thoughtful investigation. Brady believed it to be imperforate, yet he expressed himself guardedly, since the condition of his specimens prohibited dogmatic statement. He recognized a "dotted appearance" of the surface but concluded this to be the result of the granular condition of the wall, an opinion confirmed by Henbest in his study of *E. baileyi.* Möller's penetrating study demonstrated a definite porosity with capillary pores regularly distributed, as shown by many fine illustrations. Galloway (and collaborators) has recorded definite surficial punctation in some species but consistently reports the walls as imperforate. Warthin suggested that certain lines in his thin sections perpendicular to the surface may represent original perforations.

The smoothly finished surface of many well-preserved endothyrine tests in the Texas geologic section carries regularly and rather widely distributed, minute, shallow pits, which must be seen in carefully adjusted light. The character of these can not be related to the crystalline structure of the wall, which gives the more crowded "dotted appearance" noted by Brady and commonly observed in the material here treated. These shallow depressions are probably the same as the punctuations found and illustrated by Galloway in Oklahoma material, but whether they have always been a surficial feature or whether they penetrated the shell wall as tubular perforations remains problematical. They certainly are not of the character of surface ornamentation and probably served a physiological purpose. An open void in a thin section is relatively easy to recognize, but

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[9]Henbest, Lloyd, The species *Endothyra baileyi* (Hall): Cushman Lab. Foram. Res., Contrib., vol. 7, pp. 90–93, pl. 12, 1931.

an exceedingly delicate tubular opening now filled with secondary calcite in a fibrous or mineralized calcareous wall may challenge the technique of the most refined technician. Only painstaking work with adequate equipment on large numbers of unusually thin sections, by application of stains, and by mineralogic investigations can reveal the true significance of the several characters of the present shell wall of species of *Endothyra* and *Endothyranella*, and it seems more than likely that, as in the fusulinids, porosity will eventually be conclusively demonstrated.

After Phillips published the horizontal section of a coiled foraminifer, *Endothyra bowmanni* (corrected by Brady to *bowmani*) from a lower Carboniferous (Mississippian) limestone in Yorkshire, nothing further was done on this old microfauna until about 30 years later, when Brady undertook his study of an immense amount of Carboniferous material, including samples from Yorkshire. A mere thin section in itself is of little value unless it can be compared with associated free specimens, and Brady's careful study of the free forms present in the softer or weathered layers of the same geologic section demonstrated that no type of coiled form in his fauna, other than those he called *Endothyra*, could produce Phillips' section. Even though the common species designated and fully described by him as *Endothyra bowmani* is seemingly the logical choice as a counterpart for the thin section recorded by Phillips, some doubt as to the absolute specific identity may always remain to cast its shadow of invalidity upon the genotype. Rather than permit legal technicalities to become active toward eliminating a well-understood name used consistently for over 60 years, validity of the genotype as interpreted by Brady in 1876 should be established by the International Commission on Zoological Nomenclature.

ENDOTHYRA DISTENSA, n.sp.

Pl. 16, figs. 9–11

This small to moderate, strongly compressed, calcareous test comprises an almost symmetrical umbilicate coil of two or three convolutions, of which the first one and one-half to two are essentially involute followed by a succession of chambers that are somewhat less embracing. The strongly inflated and gradually enlarging chambers that average eight in the mature whorl and may number as many as nine are almost as broad as high and produce a lobate and an almost circular general peripheral outline and a broadly rounded peripheral area. Most of the surface of the chambers is rather finely and evenly granular, but the inner extremities of the chambers bounding the whorl suture are thickened by a more coarsely granular limbation that extends along the posterior margin of each chamber and partially fills the sutural depressions. The sutures are radiate throughout most of the ontogeny of the coil but tend to become somewhat oblique toward the final chamber. They are distinctly depressed, especially over the peripheral area and are generally marked by granular calcareous shell matter. Throughout its entire ontogeny, the aperture is a high arch rising from the base of the septal face.

The two diameters of the holotype are 0.46 mm. and 0.52 mm.; its thickness is 0.25 mm. For the Marble Falls formation as a whole this is an average size, but at some localities the species averages somewhat smaller and at other localities a slightly larger size is common. The diameters of the full-bodied paratype here figured are 0.56 mm. and 0.6 mm., a rather unusual size.

Since *Endothyra distensa*, n.sp., has been found only in the calcareous and highly compact strata of the Marble Falls formation, all the tests are crystallized to translucent calcite, which absorbs much of the light and fails to throw into sharp relief the limbation that would be more conspicuous if the tests were opaque. However, careful observation shows its presence, and the collapse of the chambers of some tests commonly throws these thicker areas into prominent relief, or on some tests absorption of the light by the limbation is so much greater that this feature appears somewhat darker even without the ferruginous stain that accentuates limbation on other species that occur in strata carrying this element. Conditions of preservation also tend to obscure the evolute character of the later whorls, but in any suite of numerous specimens, this relationship of whorls is evident in some of the specimens, and curiously compression of the chambers is likely to emphasize this feature of the structure.

In its morphologic characters, *E. distensa* is a counterpart of *Endothyranella armstrongi* Plummer in its coiled stage, except that the aperture remains consistently at the base of the septal face throughout its ontogeny even to the final chamber of the largest tests so far found. Its coil averages somewhat larger and the evolute relation of its lateral whorl is generally less evident, but considering variation in both species, the final distinguishing feature is the position of the aperture. *Endothyra whitesidei* Galloway and Ryniker is distinctive in having no limbation and fewer chambers.

The type locality is a soft layer in the extensive exposure of Marble Falls limestone (near base of Big Saline member) on the left bank of Colorado River near Marble Falls, Burnet County, Texas (Sta. 27–T–5B). It has been found well distributed in the highly calcareous Marble Falls shales and shaly limestones, though it is nowhere abundant. Possibly its optimum environment was in the pure limestones of this formation, which as yet have not been studied.

ENDOTHYRA ROTALIFORMIS Warthin

Pl. 16, fig. 18

Endothyra rotaliformis WARTHIN, 1930, Oklahoma Geol. Survey, Bull. 53, p. 20, pl. 1, fig. 11. (Wetumka formation, Oklahoma.)

In the Lower Pennsylvanian section in Texas, *Endothyra rotaliformis* Warthin has been found at only two localities (Sta. 134–T–6 and Sta. 153–T–136) where very highly mineralized specimens show clearly the critical features of this most distinctive endothyroid form in the Carboniferous fauna of the state. Formations higher in the geologic section have yielded larger suites of tests, which illustrate better the range of possible variations in minor details within specific limits.

The smooth, thick, calcareous test is especially characterized by its strongly unsymmetrical plan of coiling shown in any peripheral view, by its elliptical peripheral outline, and by its very broadly rounded peripheral area. The dorsal face of the Marble Falls tests is completely involute, but in higher formations, where the species in some places is better developed, some tests may exhibit one or two partially evolute chambers. The radiate sutures are nonlimbate and somewhat depressed on most tests between the six or seven enlarging and inflated chambers of the final convolution of Marble Falls tests and between as many as eight or nine chambers on larger tests found in a few outcrops higher in the geologic section. The umbilical depression on the ventral face is small and shallow, and on occasional tests in the Marble Falls, as well as in higher formations, the ventral face of the final chamber carries an umbilical lobe that quite covers the central depression. The low, crescentic aperture at the base of the septal face extends from the dorsal side of the peripheral area well over onto the ventral side, and on some tests it almost reaches the umbilicus. In fact, it is likely that the aperture regularly reaches this maximum span, but the actual aperture of most specimens is so obscured by secondary calcareous deposit, that precise observations are impossible.

The figured specimen, a representative Marble Falls test, is 0.57 mm. in longest diameter, 0.45 mm. in its shortest diameter, and 0.31 mm. through the final chamber. This size and proportion are average for the species wherever it has been found in Texas Carboniferous and Permian strata.

Endothyra rotaliformis was named from an outcrop of Wetumka shale in Oklahoma, a stratigraphic position younger than Marble Falls. Everywhere the species occurs in at least somewhat calcareous strata, and the two Marble Falls beds that have produced this oldest record are very highly calcareous shales. Farther northwest in the Colorado River valley and north in the Brazos River valley the species has been found from the Millsap

Lake formation upward as high as the Pueblo formation (Permian).

ENDOTHYRA WHITESIDEI Galloway and Ryniker

Text fig. 2

Endothyra whitesidei GALLOWAY and RYNIKER, 1930 (Jan.), Oklahoma Geol. Survey, Circ. 21, p. 12, pl. 2, fig. 4. (Atoka formation, Latimer County, Oklahoma.)

This closely coiled, umbilicate, very smooth, calcareous test is almost circular in its lobate peripheral outline, is perfectly planispiral, and bilaterally is perfectly symmetrical. It changes from completely involute in youth and earliest maturity to somewhat evolute in full maturity and very old tests may be strongly evolute. Its distinct, large, tumid chambers increase gradually in size, have a broadly rounded peripheral area, number six or seven in fully mature whorls and as many as eight in the final whorl of large tests, and tests of exceptional size carry as many as nine. The sharply incised sutures show no trace of thickening, and they change from essentially radial in extreme youth to strongly oblique in fullest maturity. The aperture is a rather high and narrow arch at the base of the septal face.

The figured test is 0.58 mm. along a diameter across the final chamber, and the thickness of the final chamber is 0.25 mm. This is the only perfect specimen showing clearly all the fundamental specific features. Another undeformed specimen, from which the final chamber is missing, is 0.65 mm. in diameter and has eight chambers in the final convolution. Other tests in the formation under consideration are either more or less collapsed, broken, or immature, but indications are that a size of 0.8 mm. diameter was a rare maximum.

E. whitesidei is especially characterized by its perfect nautiloid plan of coiling, by its comparatively few chambers at any given diameter, by its clean sharp umbilicus in its youthful stages, and by a continued lack of any extraneous shell deposit as sutural limbations or thickening of the chambers around the umbilical area with advanced growth, so that the chambers of the earlier whorls in the partially evolute late stage are usually observable, depending largely on the state of preservation of the tests. *E. distensa*, n.sp., which is much more common in Marble Falls strata and accompanies *E. whitesidei* at the only locality where the latter has been observed in this formation, displays a larger number of smaller chambers that increase more slowly in size, are separated by more nearly radiate sutures, and bear considerable thickening of the shell wall around the umbilicus and along the sutures, so that the slightly evolute character of the fully mature test is generally very obscure. *E. pauciloculata* Cushman and Waters, so common and widely distributed in formations of the Canyon and Cisco groups in Texas, is distinguished solely by the shape of its aperture, which is typically a broad arch extending well over the peripheral area, as shown on the holotype (youthful test) and the more mature test designated as "*E. whitesidei*" by Plummer.[10]

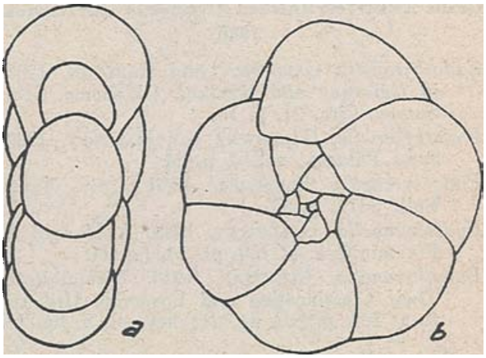


Fig. 2. *Endothyra whitesidei* Galloway and Ryniker, Strawn shale (Sta. 134–T–5), x80. *a*, Peripheral view; *b*, lateral view.

The species was named from an outcrop of calcareous Atoka shale in Oklahoma, a formation probably equivalent to at least a portion of the Texas Lower Pennsylvanian sequence. In the formations here under consideration around the Llano uplift, *E. whitesidei* has been found in the Marble Falls only in the lowest chalky bed at Sta. 205–T–2, where it is rather frequent, and rarely in the *Chonetes*

[10]Both specimens figured in Univ. Texas Bull. 3019, Pl. 1, figs. 7, 8, are hypotypes (not "holotype" and "paratype," designations originally assigned to a new species that was invalidated by the publication of *E. whitesidei*, without proper correction of type designations by Plummer).

shale somewhat higher in the same exposure. An outcrop (Sta. 205–T–79B) of basal Smithwick dark shales lying on typical Marble Falls limestone and a few feet below the *Cumminsia aplata* (Cummins) zone near by (Sta. 205–T–79A) along the same creek has yielded a broken large test, which may be reworked from Marble Falls strata, as the noncalcareous character of the shales does not favor such a form and as no other calcareous test is present. The unusual calcareous Strawn strata in Kimble County (Sta. 134–T–5; fig. 15) have provided several typical specimens, most of which are partially or completely compressed.

Genus ENDOTHYRANELLA Galloway and Harlton, 1930

Endothyranella GALLOWAY and HARLTON, 1930, in Galloway and Ryniker, Oklahoma Geol. Survey, Circ. 21, p. 13.
Endothyranella, GALLOWAY and HARLTON, 1930, Jour. Paleont., vol. 4, p. 24.
Endothyranella, PLUMMER, 1930, Univ. Texas Bull. 3019, p. 17.
Endothyranella, GALLOWAY, 1933, A Manual of Foraminifera, p. 158, pl. 14, fig. 11.
Endothyranella, CUSHMAN, 1940, Foraminifera, Their Classification and Economic Use, ed. 3, p. 104, pl. 10, fig. 21; key, pl. 5, fig. 15.

This dimorphic test, comprising an endothyrine coil followed by uncompressed rectilinear chambers, shows a distinctive gradual change in position of the aperture throughout the coiled stage. The arched opening at the base of the septal faces of the earlier chambers gradually rises in successively later chambers to a higher and higher position within the septal face, until the coil is complete and the nearly circular opening is almost terminal on the last chamber. On the succeeding rectilinear chambers the aperture is round and terminal. This ontogenetic feature in the coil becomes a valuable aid in making generic identification of specimens in the coiled stage, where the endothyranellid species present is not sufficiently abundant to yield fully mature tests, except by long search in considerable material. The symmetry, or asymmetry, of the coiled stage in this genus is almost as varied as in *Endothyra*, depending on the species, though no early coil has been found nearly so conspicuously rotaliform as is the test of *E. rotaliformis* Warthin. The wall is like that of *Endothyra*, and the problems concerning its original character are the same for both genera.

Genotype, *Ammobaculites powersi* Harlton; Glenn formation, Lower Pennsylvanian, Oklahoma.

ENDOTHYRANELLA ARMSTRONGI Plummer subsp. SOBRINA, n.subsp.

Pl. 16, figs. 12–17

This subspecies is distinguished from the typical species fundamentally by its proportionately longer rectilinear stage of several chambers, which follow a coil that averages fewer convolutions than are generally found in the typical species. The better developed coils in any suite of tests are partially evolute just prior to the final stage, and limbation is similar to that of *E. armstrongi*, but the chambers in the final whorl of the average coil are slightly larger than in the typical species. The range in proportions of the two stages of the structure is from a very small coil of little more than a single convolution and as many as seven or eight rectilinear chambers to a coil of about two convolutions and somewhat fewer rectilinear chambers.

The average diameter of the somewhat deformed and collapsed coil of the holotype is about 0.35 mm., and the length of the test is 0.87 mm. The average diameter of the very small coil of the paratype (Pl. 16, fig. 13) is about 0.15 mm., and the length of the test is 0.85 mm.

In the Marble Falls strata, to which this subspecies is restricted, most of the specimens of this form are totally or partially compressed and deformed, secondary calcite partially fills some of the umbilici, and the shell matter is almost everywhere altered to clear gray calcite, the translucency of which obscures some surface details. Rare tests are full bodied and illustrate the partially evolute character of the coil and the strong inflation of the chambers. Only a few somewhat opaque tests reflect some of the light so as to reveal faintly the limbation characteristic of the species, but in some outcrops limbation is accentuated by a ferruginous stain.

Those specimens comprising a coil of minimum size and a long rectilinear stage are similar to *E. stormi* (Cushman and Waters), and some isolated tests might introduce some confusion in identification. However, this new subspecies, even in this extreme proportion, generally carries one more chamber in the coil, and the umbilicus is broader. Limbation also serves as a diagnostic feature, which in the highly mineralized tests can be obscure.

The type locality is a roadside bank of calcareous Marble Falls shale and limestone on the old Brady highway just west of the city of San Saba, San Saba County, Texas (Sta. 205–T–25; fig. 16), and it has been found at several other exposures of the same formation.

Genus BRADYINA Möller, 1878

BRADYINA HOLDENVILLENSIS Harlton

Bradyina holdenvillensis Harlton, 1927, Jour. Paleont., vol. 1, p. 18, pl. 2, fig. 1. (Upper Glenn formation, Carter County, Oklahoma.)

Very few typical tests in a highly mineralized condition have been found in the very calcareous shale bed between Marble Falls limestone beds on Big Saline Creek in Kimble County (Sta. 205–T–6; fig. 15). The largest test is 1 mm. long and 0.72 mm. wide and shows three and one-half chambers in the final convolution with prominent vertical slits along the sutures as well as irregular openings on the central portion of the septal face.

The species is much better represented higher in the section and will be discussed and illustrated amply in a forthcoming paper.

BRADYINA sp.

In the very calcareous layers of the Marble Falls formation a very large species of *Bradyina* has been found, but specimens in all stages are completely compressed and distorted, and details are further obscured by mineralization to gray calcite. The indications are that in its original form the test was very broadly rounded with practically no sutural depressions. The zones of short, straight, closely spaced slits along the suture lines between from five to seven gradually enlarging chambers are exceedingly obscure and not visible at all on most tests, since secondary calcite has been deposited in most of them. Distribution of apertural openings in the septal face above the zone of slits can not be discerned.

The longest diameter of the largest test is nearly 2.5 mm., but allowing for an increase in this measurement through collapse, the original rotund test was perhaps approximately 2 mm.

The size suggests a possible identity with *Bradyina magna* Roth and Skinner, but too little is known about the Marble Falls form to allow comparisons of details in the morphology of the two forms.

This species of *Bradyina* has been found in some frequency in material from one calcareous shale bed just west of San Saba (Sta. 205–T–25; fig. 16); but its distribution in the bed is spotty, and many samples must be examined in order to find material for study. It is very rare in an unconsolidated bed below the *Chonetes* shale south of San Saba (Sta. 205–T–2). Further collecting may provide specimens in fit condition for satisfactory analysis.

Family TEXTULARIIDAE

Genus BIGENERINA d'Orbigny, 1826

BIGENERINA PEREXIGUA, n.sp.

Pl. 16, figs. 19, 20

This very minute, slender test is rather coarse considering its size. The globular proloculum is followed by eight to ten gradually enlarging biserial chambers. On some tests two succeeding chambers are loosely biserial before the regular sequence of as many as seven uniform uniserial chambers is added. Sutures are sharply, but not deeply, incised. The shell wall is thin and insoluble in acid and is composed of quartz grains so neatly fitted, that the surface is not sharply rugose, though granules are rather large for the delicate build of the test. The aperture is a terminal round opening on the somewhat constricted final chamber.

A common length of test bearing five uniserial chambers is about 0.4 mm., and the breadth of the uniserial portion is almost uniformly 0.09 mm. The length of the biserial stage averages about 0.15 mm.

Tests of this species are consistently flattened. Rarely chambers are filled with limonite, like the holotype, and this mineral sharpens the shape and relationship of the chambers. In spite of the translucency of most of these minute tests, the structure is remarkably clear.

Bigenerina perexigua, n.sp., is abundant at the type locality (Sta. 134–T–33; fig. 15) in noncalcareous, buff shales, probably of Strawn age on the Pfluger ranch, Kimble County. This exposure is in the lower part of the same 30 to 40-foot shale bed that outcrops at Sta. 134–T–5 (fig. 15), where the lower layers of shale tend to be more calcareous. The only other place of occurrence of this form is in the noncalcareous East Mountain shale, Mineral Wells formation, in the east edge of Mineral Wells, Palo Pinto County.

Genus CRIBROSTOMUM Möller, 1879

Cribrostomum MÖLLER, 1879, Acad. Imp. Sci. St. Pétersbourg, Mèm., ser. 7, vol. 27, no. 5, p. 39.

The stout elongate test comprises an initial biserial stage of many enlarging chambers followed by uncompressed, short, uniserial chambers. The calcareous shell wall is almost wholly fibrous with an external coating of irregular calcareous particles or granules, so that the surface is pebbled, though composed of no adventitious matter. The aperture of the earliest biserial chambers is a low slit at the base of the septal face; on a few succeeding chambers the low slit is supplemented by one or more irregularly shaped openings in the septal face above the basal slit; with advancing biserial development the multiple openings in the septal face increase in number and are scattered without any particular arrangement over an area that becomes more and more nearly terminal. The terminal face of each uniserial chamber is occupied by numerous openings of irregular outline, size, and distribution, and with each additional chamber in the series, the openings become gradually more numerous. The cribrate surface of chambers in the late biserial stage and throughout the uniserial stage is supported and strengthened by irregularly developed walls and pillars that tie the terminal wall to the last septum, thus making the chamber labyrinthic. Whether such internal structures are permanent or are resorbed as new chambers are added can not be demonstrated with certainty by the material in hand.

Genotype, *Cribrostomum textulariforme* Möller, from Lower Carboniferous limestone at Tschernyschino, Dugno, and Sloboda, Russia. The illustrations are of specimens from Dugno, which should be accepted as the type locality.

The designated genotype is without doubt the immature form of one of the five biformed species in the group of eight "species" recorded in the same paper with the description of *Cribrostomum*. *C. commune* Möller is recorded from the same localities as *C. textulariforme* and can well be the mature form of the species. The ontogeny illustrated by the development of the multiple small apertures on the septal face of the last seven chambers of the biserial stage (Möller's pl. 3, figs. 5a–c, the biserial stage in three periods of development) of *C. textulariforme* followed by further development in size and number of the apertures throughout the chambers of the uniserial stage in *C. commune* corresponds perfectly to the ontogeny of species found in the Texas geologic section and most abundantly represented by suites of specimens in highly calcareous shales or marls of the Marble Falls limestone formation.

The absence of critical apertural characters in the biserial stage of *Textularia antiqua* H. B. Brady, the genotype of *Climacammina*, as originally described and figured,[11] is a serious handicap in

[11]Brady, H. B., On *Saccammina carteri*, a new foraminifer from the Carboniferous limestone of Northumberland. Ann. Mag. Nat. Hist., ser. 4, vol. 7, p. 184; Nat. Hist. Trans. Northumberland and Durham, vol. 4, pt. 1, p. 277, 1871. In this short paper *Textularia antiqua* is mentioned and informally described: "The *Textularia* alluded to is a stout arenaceous variety, frequently Bigenerine in its mode of growth, and with an anomalous aperture, sometimes labyrinthic, but more frequently consisting of two or three distinct circular pores. . . . I find, in my notes . . . that I have the manuscript name *Textularia antiqua* appended to it." The more ample and formal description in 1878 (Palaeont. Soc. Mon., p. 68) introduces more details and variations, due largely to poor preservation of tests, and several illustrations appear for the first time.

any endeavor to employ this name with absolute assurance. Therefore deductions for the present must rest on experience with abundant local material in relationship to Brady's records. His specimens of *C. antiqua* were highly mineralized, deformed, or crushed; consequently, some details in the morphology of the test were rendered obscure, and many features mentioned are merely individual as a result of processes of fossilization. The significant feature in the illustrations is the rather symmetrical arrangement of four large openings on the third uniserial chamber of the test in figure 4 (Pl. 2, Paleontographical Soc. Mon., 1876). In Oklahoma, Colorado, and Texas, forms displaying such a pattern of apertures on the third uniserial chamber belong to a more slender test with an ontogeny that involves a biserial stage characterized by a single terminal opening on several late biserial chambers, or at most only two, or rarely three, symmetrically arranged, the number varying within specific limits. Beyond the biserial chambers in this ontogeny the first uniserial chamber commonly carries only two elongate openings of essentially equal size and symmetrically placed on the terminal wall; as the number of relatively large openings slowly increases with the addition of uniserial chambers, a symmetrical pattern is maintained. In an abundance of well-preserved tests of species referred to *Deckerella* in some of the Texas literature, the third uniserial chamber may show as many as four symmetrically arranged large openings. Acceleration may be so retarded that only two terminal openings persist throughout several uniserial chambers, or it may be more rapid to produce more than two on very early uniserial chambers. The rate of increase in the number of openings varies greatly, but symmetry in arrangement and in shape of the large and comparatively few openings throughout the uniserial stage is a consistent feature that distinguishes the group represented by Brady's genotype of *Climacammina* from Möller's genotype of *Cribrostomum*.

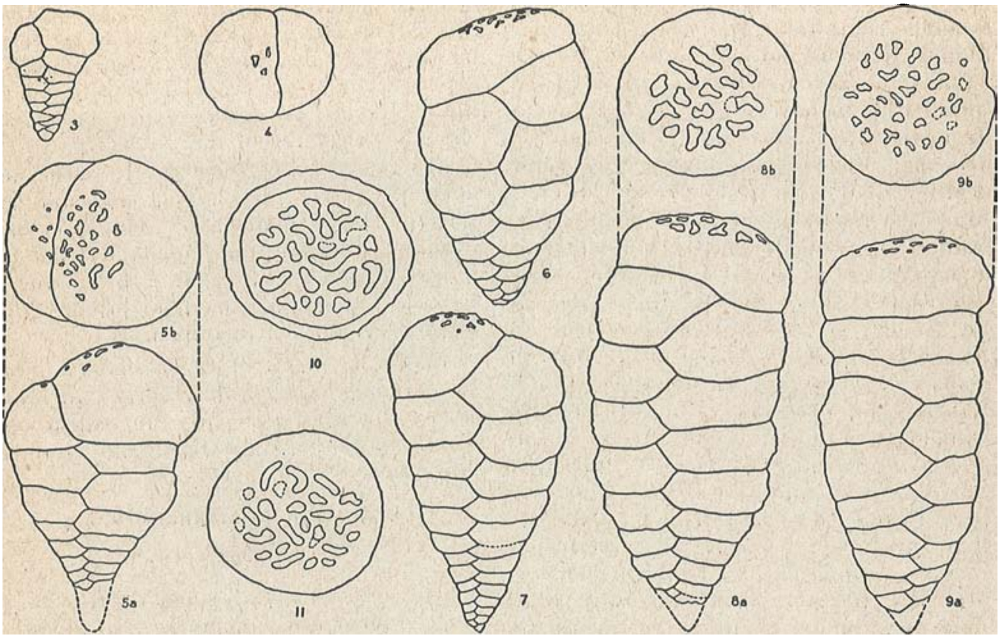
In strata where a species of *Cribrostomum* or *Climacammina* occurs rarely, the few specimens found in the amount of material usually examined and for the time allotted this phase of the work may be only in the biserial stage. Where preservation of the biserial tests is good, the character of the openings on these chambers may reveal the generic position of the species represented. In such an outcrop, it has been found advisable to select a large number of samples from different positions, for commonly one or more of these will catch a level where tests are abundant enough to produce the critical evidence in mature tests.

In Texas, forms of *Cribrostomum* have been found rather widely spread in Marble Falls strata, locally in calcareous strata in the Millsap Lake and Graford formations.

CRIBROSTOMUM MARBLENSE, n.sp.

Text figs. 3–11

The early biserial stage of this large and stout species comprises a globular proloculum followed by 14 to 20 chambers that generally increase rather slowly through several pairs beyond the proloculum and then enlarge rapidly and become highly inflated, producing a very broadly rounded peripheral area. Frequent tests exhibit a biserial succession of chambers that increase at a uniform rate throughout this stage and the unusually large number of chambers in such a test suggests that it is the microspheric form. The uncompressed uniserial sequence of usually up to a maximum of four, rarely as many as six, very short, broad, short and somewhat inflated chambers shows no appreciable change in size with growth. Sutures are sharply incised, except between the earliest biserial chambers. The aperture on the earliest biserial chambers is a slit at the base of the septal face; succeeding biserial chambers carry a gradually increasing number of scattered, small, irregularly shaped openings over the area of their septal faces, until the final chamber in this series shows numerous openings that occupy an area almost terminal. This cribrate pattern develops further on the rectilinear chambers, the openings becoming gradually more numerous and somewhat larger, but no pattern of arrangement can be discerned. The final cribrate



Figs. 3–11. *Cribrostomum marblense*, n.sp., x20, Marble Falls formation (Sta. 134–T–6). 3, Very youthful test showing proloculum and slowly enlarging early chambers followed by a sudden rapid increase in size of last pair, from which point the successive biserial chambers grow rapidly larger and are ventricose. 4, Terminal view of a test approaching the end of its biserial stage with probably two or three more pairs to be added; three small irregular openings lie in the septal face above the slit at the base of the face. 5, Average well-developed test in the biserial stage showing common proportions and cribrate septal faces; *a*, lateral view; *b*, terminal view. 6, Fully developed biserial test showing very well developed cribrate septal face with its many irregularly shaped and spaced openings. 7, Evenly tapering biserial test composed of chambers that increase in size more uniformly than is common; the larger number of chambers and size of test suggest the microspheric generation. 8, Mature test of typical proportions with one uniserial chamber; *a*, lateral view; *b*, terminal view. 9, Holotype; fully mature test with three rectilinear chambers; *a*, lateral view; *b*, terminal view. 10, Septum between two rectilinear chambers showing relative wall thickness. 11, Terminal area of a third rectilinear chamber.

surface of the test is strengthened by vertical interior walls and columns that tie the terminal area to the last septum, thus creating a labyrinthic chamber.

The biserial stage averages about 1.3 mm. long and about 1.1 mm. across the final pair of chambers; a few biserial tests are as large as 1.6 mm. long and 1.4 mm. broad. The more slender proportions are represented by a biserial test that is 1.7 mm. long and 1.1 mm. broad. Uniserial chambers measure between the sutures about 0.35 mm. in height and are about 1 mm. or slightly more in breadth or diameter. One test bearing six uniserial chambers is 3.8 mm. long, but a length of about 3 mm. is fairly frequent in strata that carry the species in moderate numbers.

Initial extremities are so delicate, that they are commonly broken off, so that it is difficult to relate the evenly tapering biserial tests to dimorphism. Mineralization also conceals features such as proloculum and succeeding small chambers to make such a problem more equivocal.

In the outcropping geologic section under consideration, *C. marblense*, n.sp., is restricted to the Marble Falls formation, perhaps largely because only the Marble Falls seas offered a sufficiently calcareous environment. What appears to be the same species has been found in generous numbers in calcareous strata not far above the Adams Branch limestone (Canyon group) southwest of Mercury in McCulloch County. After the Oklahoma forms of *Cribrostomum* have been more completely studied and described, it is possible that this new specific designation will be abandoned in favor of one of the species already named. The deposited "holotype" of *C. lucilleae* Harlton from the Glenn formation can not be any of the tests figured in 1927 (Jour. Paleont., vol. 1, p. 22, pl. 4, fig. 2), and since the museum specimen exhibits four rather prominent symmetrically arranged openings on its single uniserial chamber, it is probably a *Climacammina* belonging to the species designated as *C. antiqua* H. B. Brady in the same paper.

The type locality for this species is a fossiliferous shale bed on Big Saline Creek in Kimble County (Sta. 134–T–6).

Family OPHTHALMIDIIDAE

Genus CORNUSPIRA Schultze, 1854

CORNUSPIRA sp.

In the somewhat calcareous and fossiliferous shale of probable Strawn age at the base of the slope on Morgan ranch along Llano River (Sta. 134–T–5) are rare specimens of a very small, neat *Cornuspira,* which is more abundantly represented higher in the Pennsylvanian geologic section in counties farther north. The form will be treated more completely in a forthcoming paper.

Genus CALCITORNELLA Cushman and Waters, 1928

CALCITORNELLA sp.

Small specimens of a weakly developed *Calcitornella* have been observed in the slightly calcareous, probably Strawn shales at Sta. 134–T–5 in Kimble County, but material on hand is insufficient to permit adequate description and identification.

Genus TREPEILOPSIS Cushman and Waters, 1928

TREPEILOPSIS sp.

The somewhat calcareous, probably Strawn shale at the base of slope at Sta. 134–T–5, Kimble County, has yielded several specimens of a small *Trepeilopsis,* represented largely by calcite casts. Since the genotype, *T. grandis* Cushman and Waters, has been found to be porcellaneous and highly ornamented at its type locality in the Mineral Wells formation, Palo Pinto County, Texas, with a *Calcitornella* initial stage, this unnamed form is included in the family Ophthalmidiidae. A future paper will treat this problem more extensively with many illustrations.

Family TROCHAMMINIDAE

Genus MOOREINELLA Cushman and Waters, 1928

MOOREINELLA BISERIALIS Cushman and Waters

Pl. 17, figs. 32–36

Mooreinella biserialis Cushman and Waters, 1928, Cushman Lab. Foram. Res., Contrib., vol. 4, p. 50, pl. 6, figs. 9, 10. (Strawn group, east of San Saba, San Saba County, Texas.)

This elongate, moderately rough, arenaceous, and usually tapering test starts with a small coil, which rare specimens show to be trochiform, but the collapsed condition of most specimens combined with the relatively coarse texture for a series of such small chambers makes analysis of their relationship difficult. The few tests that show individual chambers in the coil point to about five in the final whorl, and the number in the apical portion of the spire has not been determined. The second stage, which comprises most of the test, is a sharply defined series of closely interlocking, gradually enlarging, tumid biserial chambers, which on the average mature test number about 9 or 10, but as many as 15 have been counted where the species is unusually well developed. On some tests increase in breadth is fairly rapid immediately following the coil through about three pairs of biserial chambers, and from this point enlargement may be less rapid. Other tests exhibit a very gradual and steady increase throughout growth. Still others are very slender and show almost no increase in breadth, but this proportion is rather rare. The axis of biseriality may be straight, but it is more commonly slightly to markedly arcuate, a character due in part, no doubt, to the effect of compressional forces in the colloidal shales. The peripheral area was originally very broadly rounded, and rare tests can be found in their true rotundity, but lateral compressions in almost any direction relative to the plane of biseriality is the rule. In some strata the texture is fairly uniform, and the surface exhibits rather fine quartz grains in relief. In other places, sizes of quartz grains vary widely, and flakes of mica and granules of dark siliceous minerals may be incorporated. The sutures between the biserial chambers are sharply, but not deeply, incised. It seems likely that originally the sutures in the early coil were also somewhat incised, since rare tests reveal traces of such a condition, especially where the shell surface is not exceptionally coarse, but compressional forces have obliterated structural details of most coils. The aperture is a high arch at the base of the septal face throughout growth.

Size is so variable, that it can not be regarded as a character of the species. At the type locality an average specimen is about 0.8 mm. long and about 0.5 mm. broad across the fifth pair of biserial chambers, and the diameter of the initial coil ranges from 0.15 to 0.3 mm. In the same material other tests of practically the same number of chambers are only about 0.45 mm. long and about 0.25 mm. broad, and all sizes between this small test and those of average size can be found in abundance. At a few other localities considerable size is attained, and tests a millimeter in length may be common. The maximum length measured is 1.6 mm. with a breadth of 0.9 mm. Wherever the species is abundant, wide range in size for any given number of chambers is conspicuous, and leads to the conclusion that *Mooreinella biserialis* was probably sensitive to changes in environmental conditions. Any sizeable sample must necessarily be cut across at least three or four inches of vertical section, which represents from several years to perhaps several decades of time, during which period seasonal and annual fluctuations in minor factors were reflected in the development of the tests of this species. In any material where the species is abundant the initial coil ranges widely in diameter, 0.12 mm. to 0.3 mm., but is generally small compared with the size of the mature test. At one locality, however, the coil averages unusually large, 0.25 mm. to 0.32 mm., and the proportions of the mature tests are somewhat stouter than is usual.

The choice of the holotype from Strawn shales along the abandoned San Saba-Lampasas highway (Sta. 205–T–29; fig. 16) is rather unfortunate, as it is badly deformed, is not so well developed, and does not display clearly the morphology of the test of this species. It is, however, typical of the condition of many of the tests in these shales, where deformational forces have twisted the plane of biseriality as well as its axis. Consequently in order to follow the succession of interlocking chambers through the second stage it is necessary to turn such tests around through about 90 degrees or more. Forces acting almost axially upon the apertural extremity of the holotype have practically ironed out the final suture, and merged the last two chambers, so that the aperture that really lies at the base of the septal face appears to be subterminal in relation to the penultimate suture, like many topotypes found in material from the type locality, as well as at other places. Usually adjustment of the direction of the light in examining such tests will reveal the critical final suture, or side views often show the biserial relations of the last two chambers. Critical features are especially difficult to observe accurately at the type locality, because the arenaceous texture is coarse and uneven.

Mooreinella biserialis is common in the noncalcareous shales of the lower Strawn sequence in northern San Saba County. Some Smithwick shales carry the species in some frequency and in the usual wide range of sizes up to a maximum of 1.5 mm. in length. No trace of any species of *Mooreinella* has been found in the Texas section above the Strawn around the Llano uplift or in any part of the Carboniferous section exposed in the Brazos River valley.

Genus GLOBIVALVULINA Schubert, 1920

GLOBIVALVULINA BISERIALIS Cushman and Waters

Globivalvulina biserialis, CUSHMAN and WATERS, 1928. Cushman Lab. Foram. Res., Contrib., vol. 4, p. 64, pl. 8, fig. 7. (Graham formation, Bunger limestone, near South Bend, Young County, Texas.)

Globivalvulina biserialis, CUSHMAN and WATERS, 1930, Univ. Texas Bull. 3019, p. 70, pl. 8, figs. 1–5. (Graham formation, Young County, Texas.)

While this paper was in proof, material from a newly discovered exposure of Marble Falls shale in McCulloch County (Sta. 153–T–136) has yielded excellently preserved and well-developed tests typical of *Globivalvulina biserialis* Cushman and Waters. The two very small and highly mineralized tests found in shales on Big Saline Creek, Kimble County (Sta. 134–T–6), have been recorded in Table 1 without specific identification, but it is now likely that they represent *G. biserialis*. It is unfortunate that the fauna of the McCulloch County shales has not been included in the table, but the species of the fauna can be found in the description of the locality, Sta. 153–T–136. The numerous specimens in this fossiliferous calcareous shale bed range up to average size, diameter about 0.5 mm., and show the typical interlocking narrow chambers on the highly convex dorsal side.

The type locality for *G. biserialis* is in the Graham formation, near South Bend, Young County, Texas. The Marble Falls record is now its earliest occurrence in this state, and it has been found in many formations upward in the Texas geologic section into the Pueblo formation (Permian).

Genus POLYTAXIS Cushman and Waters, 1928

Polytaxis CUSHMAN and WATERS, 1928, Cushman Lab. Foram. Res., Contrib., vol. 4, p. 51.
Polytaxis, CUSHMAN and WATERS, 1930, Univ. Texas Bull. 3019, p. 76.

This conical to almost flat calcareous test is in its early stage a *Tetrataxis*, with all its narrow, overlapping, and spirally arranged (either dextral or sinistral) chambers around a globular proloculum visible on the convex dorsal face, and only the few chambers of the final whorl visible on the flat or concave ventral face, where the inner lobate projection of each chamber extends almost to the center of the umbilical area. This early stage may be small, as in *Polytaxis laheei* Cushman and Waters, or comparatively large, as in *P. scutella* (Cushman and Waters). Beyond the *Tetrataxis* stage, successive chambers do not follow the regular spiral plan, but are added irregularly around the peripheral margin of the test or in opposite pairs, and the direction in which chambers are added may be the reverse of that of the initial spiral. On some tests, such as large specimens of *P. laheei*, very late peripheral chambers may subtend from 100 to as many as 150 degrees of the periphery, and a single chamber of this size may carry as many as three apertural lobes. The ventral aspect is especially distinctive in the larger species, in that the tumid, lobate, and linguiform projections overlying the apertural openings do not extend far enough inward to cover those of previous convolutions, and consequently the broad inner area of the ventral face of fully mature tests and of very advanced tests exhibits many overlapping swollen lobes. Smaller species do not exhibit so conspicuously these ventral features and relationships as do the larger forms, except in very advanced development. The aperture of each chamber is normally at the inner edge of the somewhat swollen umbilical extremity of its ventral face, but exceptionally large chambers may carry more than a single aperture.

Genotype, *Polytaxis laheei* Cushman and Waters, Kickapoo Falls limestone, lower part of Millsap Lake formation, Strawn group, Middle Pennsylvanian, Hood County (not Parker County, as recorded), Texas.

Commonly species of this genus are outspread or almost flat in the *Polytaxis* stage, but this is not an essential characteristic, for *P. maxima* (Schellwien), so well figured originally, is conical throughout, yet exhibits the swollen linguiform apertural lobes of chambers in several convolutions on the concave ventral face. Though its chambers are shown as loosely overlapping throughout development, later ones probably do not follow one another in regular spiral sequence. Most species of *Polytaxis* in the Texas Pennsylvanian section tend to be outspreading in their full development, though wide variation in dorsal contour exists within specific limits.

Possibly some of the forms described as *Tetrataxis* from strata in the Midcontent area will be found to belong to *Polytaxis* when sufficient material from the many localities recorded can be studied to reveal fully mature tests in sufficiently good condition to permit analysis of salient characters. That local conditions of deposition contributed to retarded development of the majority of tests in some strata has been evidenced especially in the study of *P. scutella* (Cushman and Waters). *Polytaxis,* like its relative *Tetrataxis,* is apparently best developed in the more calcareous strata, such as fossiliferous marls and limestones.

POLYTAXIS SCUTELLA (Cushman and Waters)

Text figs. 12–14

Tetrataxis scutella CUSHMAN and WATERS, 1928, Cushman Lab. Foram. Res., Contrib., vol. 4, p. 65, pl. 8, fig. 9. (Graham formation, just below Gunsight limestone, Salt Creek, Young County, Texas.)

Tetrataxis corona CUSHMAN and WATERS, 1928, Cushman Lab. Foram. Res., Contrib., vol. 4, p. 65, pl. 8, fig. 10. (Graham formation, 5 feet above Gunsight limestone, Salt Creek, Young County, Texas; also Pueblo formation, Coleman County, Texas.)

Tetrataxis corona, CUSHMAN and WATERS, 1930, Univ. Texas Bull. 3019, p. 75, pl. 7, figs. 3, 8, 9. (Graham and Pueblo formations, Young and Coleman counties, Texas.)

Tetrataxis scutella, CUSHMAN and WATERS, 1930, Univ. Texas Bull. 3019, p. 76, pl. 7, figs. 6, 7 (not fig. 9, which is the refigured holotype of *T. corona*). (Graham formation, Salt Creek, Young County, Texas.)

The calcareous shale at the type locality has provided a large number of topotype specimens of this species in all stages of development and has offered excellent opportunity to observe the wide diversity in its dorsal contour and the considerable variation in size of each of its two stages. All attempts to divide the group of tests from its type locality into two or more species, or at any other locality where the form is common, have proved futile. In a forthcoming paper on Middle and Upper Pennsylvanian faunas many illustrations of topotypes will present the wide variation possible within specific limits.

The dorsal contour of the mature test in Marble Falls strata, as at the type locality for the species, is typically conical in its earliest development and becomes more and more outspreading with growth. The average test shows about three convolutions in the steeply conical initial portion, but frequent specimens show only two, and still others as many as four. Thus the mature test varies from a fairly flat form to one that is dominantly conical. The ventral face is flat to gently concave, and the central umbilical area is small and shallow. The peripheral margin is narrowly rounded and essentially round in outline. The *Tetrataxis* stage is commonly composed of about five convolutions of regularly spiral, overlapping, crescentiform chambers around a globular proloculum at the apex of the cone, and the direction of the spiral may be either dextral or sinistral. The earliest chambers of Marble Falls specimens are generally difficult to differentiate, but rare tests show the proloculum surrounded by four chambers in the first convolution. At the type locality for the species the preservation of tests allows precise observation of the earliest chambers, and the number has been found to vary from four to five, and very rare tests, which may be microspheric, show six. Everywhere the number of chambers in successive convolutions slowly decreases to about three in the final convolution of the *Tetrataxis* stage, beyond which the chambers lie around the periphery with no definite geometric plan, and successive chambers overlap slightly or not at all. Commonly the earliest set of peripheral chambers comprises two opposite chambers, and the succeeding pair lies along an axis normal to the first pair. Present collections of Marble Falls strata show that more than four chambers in the *Polytaxis* stage is rare, a maximum development common also to many outcrops of geologically later strata in the Texas Pennsylvanian section. The broadly curving dorsal sutures in the early part of the test are flush, but become slightly depressed between late chambers. Ventrally a few visible chambers overlap with very little break in the smooth and gently concave face; their inner extremities around the central umbilical depression are faintly swollen and arch over apertures that open into the umbilicus, though some of these delicate features are difficult to see on most mineralized Marble

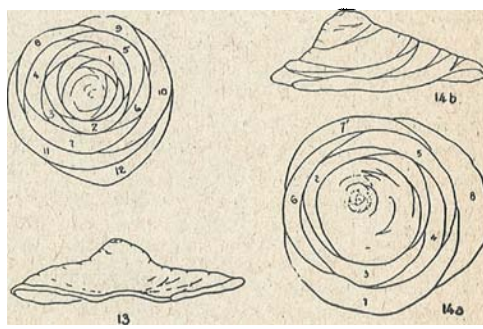
Falls tests. Ventrally the few late chambers comprising the second stage project somewhat less deeply into the umbilical area and bear narrow, linguiform, swollen inner extremities. The shell wall of this species is smooth and devoid of inclusions of extraneous material.

The average diameter of a fully mature Marble Falls test is about 0.65 mm., but one as large as 1.1 mm. in diameter has been found. A height about one-quarter to one-third the diameter is average, but rare tests can be nearly half as high as wide.

Local conditions of deposition must have had a bearing on the development of tests of *Polytaxis scutella,* for in some material very frequent tests in the *Tetrataxis* stage can be found accompanied by very rare fully mature tests. At other places tests in all stages are frequent. It is likely that some records of *Tetrataxis* in the Carboniferous strata in the Mid-continent will be changed to *Polytaxis* when further search can be made in type material.

P. scutella is restricted to calcareous strata, and consequently in the section here under consideration only the Marble Falls formation has yielded specimens, and it is apparently rather rare in the calcareous shales of the formation. In the lowest bed sampled at Sta. 205–T–2, level A (see description of locality), below the *Chonetes* shale it has been found the least mineralized and is fairly frequent, and farther down this same slope at Sta. 205–T–57, the test is unusually well developed. At Sta. 134–T–6, the species on the average is more conical, but it fits into the range of variations observed at the type locality, Salt Creek, Young County, in the upper part of the Graham formation. It has been observed in many calcareous beds in north-central Texas from the Mineral Wells formation upward into the Pueblo formation of Permian age.

The Atoka fauna in Oklahoma, described by Galloway and Ryniker, probably represents the period of deposition, when possibly a portion of the upper Marble Falls and Smithwick formations were laid down. Their *Tetrataxis corona* Cushman and Waters may be the same as the species here treated as *Polytaxis scutella,* which includes *P. corona* as a synonym. The final pair of opposite chambers shown in the figures of the Atoka form suggests the beginning of the *Polytaxis* stage, and the Atoka species, *Tetrataxis concava* Galloway and Ryniker, is obviously a *Polytaxis* and may be the fully mature test of the species labeled "*Tetrataxis corona*" in the same fauna. The samples generously submitted by Dr. Galloway have as yet not yielded sufficient specimens to lead to a definite conclusion. Their figures of *T. concava* do prove, however, that in the Lower Pennsylvanian strata *Polytaxis* was rather well developed, somewhat better developed than the present few Texas specimens indicate. More intensive search in Texas Lower Pennsylvanian strata will probably be rewarded.



Figs. 12–14. *Polytaxis scutella* (Cushman and Waters). 12, Holotype from Graham formation; reproduction of original figure in which some errors in recording overlap of the earlier chambers have resulted from obscurity of the sutures in the test. The last 12 chambers are clearly defined, and 11 of these follow the plan of the right-hand spiral. Chamber 12 occupies a position that reverses the direction of the spiral sequence and is the first chamber in the second stage, and it would undoubtedly have been followed by chamber 13 in a position on the opposite side of the test, had growth continued. 13, Peripheral view of a typical outspreading test in the Marble Falls formation (Sta. 205–T–2A), x40; sutures are not sharply enough defined to show, except in a generalized way. 14, Fully developed test in the *Polytaxis* stage; Marble Falls formation (Sta. 205–T–2A), x40. *a,* Dorsal view in which the earliest sutures are more or less obscure, but the succession of the last nine chambers is clear. Chambers 1 to 6 follow the plan of a left-handed spiral in the *Tetrataxis* stage; the pair 7 and 7′ constitute the common position of the first two chambers in the *Polytaxis* stage; chamber 8 has been added in such a position as to reverse the spiral direction, which is characteristic of tests in the genus *Polytaxis.* *b,* Peripheral view.

DESCRIPTIONS OF LOCALITIES

Most of the following outcrops of Marble Falls, Smithwick, and lower Strawn were visited and sampled by the author or under her supervision. Several have been brought to the laboratory by F. B. Plummer, who carefully spotted on his field sheets precise geographic positions in mapped outcrops during his period of detailed mapping of the Mississippian and Pennsylvanian formations around the Llano uplift.[12] More localities than are here recorded have been studied, but some have been discarded because of somewhat indefinite map locations or because they add nothing to the record. The following exposures described are representative of the formations under scrutiny for their foraminiferal content. Outcrops that are both rich and very lean in Foraminifera have been included to illustrate how variable the strata are in this respect. The chart (Table 1) includes enough localities to present a fair picture of frequencies of species and to include all the species found in each formation. Descriptions of those outcrops not listed in the chart carry lists of species found and the frequency[13] of each. Since no two samples in any outcrop are likely to carry the characteristic species in the same proportions, other collectors of material from these same outcrops can not expect to duplicate all the frequencies as here given. For brevity, many of the records in the chart represent average frequencies, where the set of samples carried approximately the same species and where obviously only a single formation is represented.

Burnet County

27–T–5. Marble Falls. Steep bank on north side of Colorado River, between old Alexander dam and bridge at Marble Falls (see fig. 1 in paper by F. B. Plummer, this publication, for general geologic and geographic relations; also fourth columnar section on Pl. 12 for the succession of strata in this exposure). Sample A was taken from a soft parting almost at the top of the sequence designated as Sloan member by F. B. Plummer; sample B from a soft granular layer about 15 feet above the base of the Big Saline member. Both concentrates carry many crinoid fragments, many bryozoa, rare ostracodes, few holothurians, and many tests of the smaller Foraminifera listed in Table 1, as well as *Millerella marblensis* Thompson. Since both beds carry the same species, differing only in frequency of two of the species, the records have been combined in the chart of occurrences. The granular stratum in the Big Saline member is the type locality for *Endothyra distensa*, n.sp.

Kimble County

Unfortunately a change has been made in the identification of the shale formation in the area north of Llano River and southeast of London at too late a date to permit correction of the distribution chart, Table 1, and of the map, fig. 15. The 30- to 40-foot shale above the Marble Falls limestone was originally mapped as Smithwick, but a careful study of the gastropods and other fossils recently by J. Brookes Knight and F. B. Plummer indicates that it should probably be regarded as Strawn. The change affects Stations 134–T–5, –31, –32, and –33 in the chart and accompanying map.

134–T–5. Strawn. Conspicuous, southwest-facing, 30-foot slope of brownish-gray to gray, laminated and nodular shale just north of the concrete foundations of old silos and of the abandoned irrigation project on the Morgan (old Bierschwale) ranch, on west side of bend of Llano River, 4½ miles southeast of London (fig. 15; also first columnar section on Pl. 13 in paper by F. B. Plummer, this publication). The compact shale is fairly uniform above the massive limestone (Marble Falls) that lies below the level of the road and along the river banks. The lower few feet of the shale slope are rich in the coral recently named *Striatopora moorei* Wells (Jour. Paleont., vol. 18, p. 260, pl. 40, figs. 3–10, 1944) from this exposure. Small ammonites and other large fossils are common in this same bed, which is somewhat more thinly laminated and more calcareous than that of the higher levels in the slope. Several samples were taken at different stratigraphic positions, and the species of smaller Foraminifera have been assembled in a composite list in Table 1 with average abundance records for each species. As explained above, this locality was placed on the chart in the group of Smithwick outcrops, according to the original mapping. Each sample washed to a moderate or small concentrate of some quartz sand, some limonitic matter, considerable calcite, frequent ostracodes, rare holothurian fragments, frequent conodonts, and many foraminiferal tests of very few species and rare tests of several species.

[12]In the near future a report on the stratigraphy, paleontology, and economic resources of this area will be published by the Bureau of Economic Geology (Univ. Texas Pub. 4329), and the accompanying map will contribute considerably to a better understanding of geologic relationships of the outcrops used here than is possible in this paper. In addition, county maps covering this same area are being prepared for later distribution, and these maps will show precisely all fossil localities used in this paper as well as other fossil localities represented by fossils in the Bureau collections.

[13]VA, very abundant; A, abundant; VC, very common; C, common; VF, very frequent; F, frequent; R, rare; VR, very rare.

134–T–6. Marble Falls. Steep exposure of limestone strata in west bank of Big Saline Creek, on Morgan (old Bierschwale) ranch, about 3500 feet north-northwest of goat shed, about 1¾ miles in direct line northwest of the old Pfluger ranch house (fig. 15) and 3 miles southeast of London. Some of the beds are fossiliferous, and *Chaetetes* is prominent at one level. Near the base of the slope is a 1-foot bed of gray, highly calcareous, laminated, and fossiliferous shale, which washed to a rather large concentrate rich in minute and largely indeterminate fossil fragments, broken bryozoa, rare ammonite protoconchs, frequent ostracodes and conodonts, many fusulinids, and numerous tests of smaller Foraminifera (Table 1) typical of calcareous deposits of this age. This is the type locality for *Cribrostomum marblense*, n.sp., which is common here and well preserved.

134–T–26. Marble Falls. Left bank of Big Saline Creek about 300 feet southeast of the stream crossing at old Pfluger ranch house (fig. 15), about 4¾ miles southeast of London. Black, cherty limestone at the water's edge is overlain by about 5 feet of thin-bedded flaggy and glauconitic limestone, on top of which is a 6-inch layer of loosely consolidated, greenish-gray, laminated sandy clay, which weathers back deeply beneath massive beds of conglomeratic limestone carrying *Chaetetes* and crinoids. The 6-inch layer was sampled and washed readily to a large concentrate composed of sand grains, glauconite, light-colored fragments of sandstone made up of glauconite, quartz, and fossil frag-

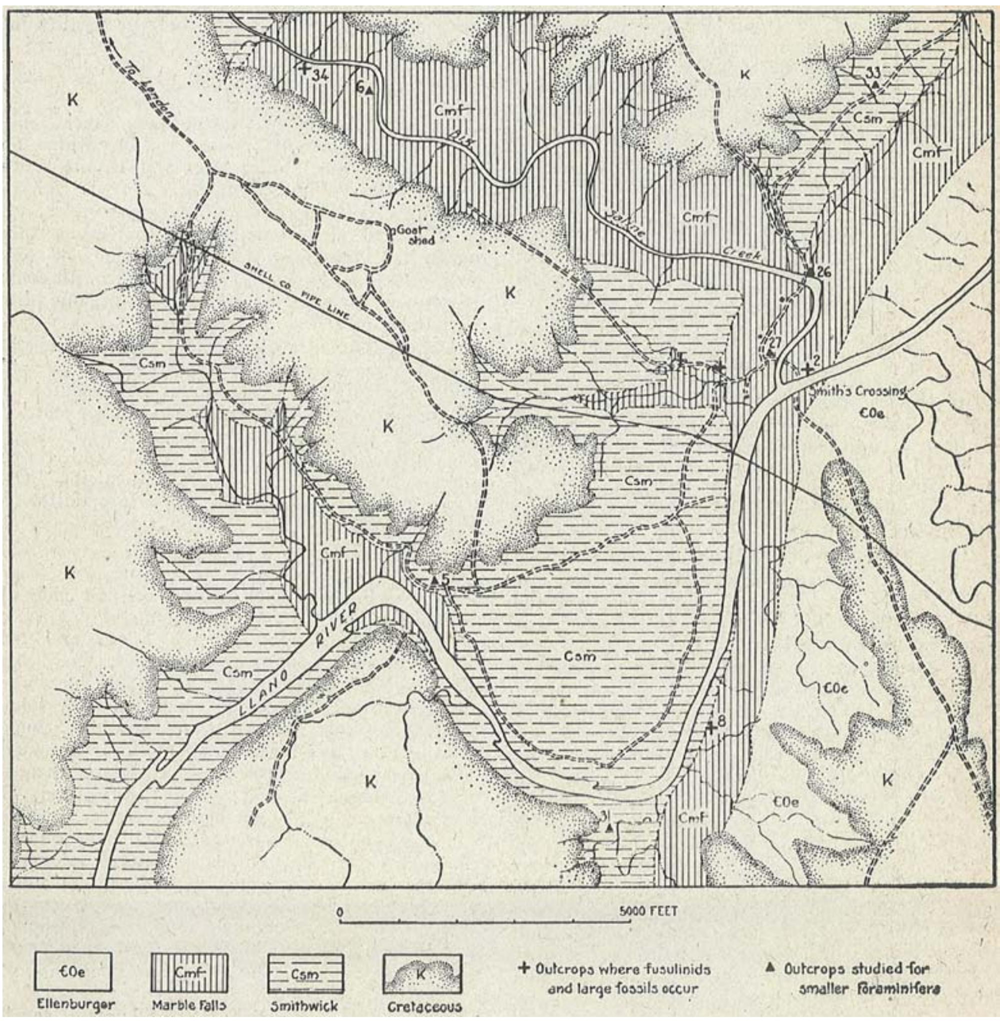


Fig. 15. Sketch map of the area along Llano River in eastern Kimble County showing locations of samples collected for the study of smaller Foraminifera, as well as some other fossiliferous localities. (The shale formation indicated as Smithwick on original field sheets, from which this map was taken, has recently been changed to Strawn and affects Stations 5, 31, 32, and 33.)

ments, carbonized plant remains showing cell structure, spines and crinoid fragments some of which are replaced by black quartz, abundance and variety of conodonts, and a few tests of an *Ammodiscus*, probably *A. semiconstrictus* Waters. One conspicuous feature of the concentrate is the abundance of minute, black geodes so completely filled with gray to deep black quartz crystals, that few are characterized by cavities. These strata exposed near the Pfluger ranch house lie just below the 30 to 40 feet of overlying Strawn shale.

134–T–27. Marble Falls. At mouth of Big Saline Creek on north bank of Llano River, near wire gate on road between the Pfluger Lodge and the old ranch house on Big Saline Creek, 5 miles southeast of London. In this exposure (fig. 15; see also first columnar section on Pl. 12 in paper by F. B. Plummer, this publication) typical massive beds of limestone, Big Saline member, rise from Llano River to the level of the ranch road, and the uppermost strata carry fusulinids and black chert. From the road level a slope of flaggy limestone and loosely consolidated glauconitic shaly sand (base of Lemons Bluff member) carrying comminuted fossils, few fusulinids, and seemingly reworked rounded fragments of limestone rises rather rapidly through about 6 feet to a capping of hard, sandy, conglomeratic calcareous sand with fusulinids and other fossil fragments. A sample was taken from the 6-foot zone of loosely consolidated material and washed to a large concentrate composed of a little quartz in rounded grains, little dark-green glauconite, much calcareous material in irregularly shaped fragments (as if reworked), and considerable tough, noncalcareous shale fragments that could not be further disintegrated. The fossil content consists of rare ostracodes, few spines and other echinoid fragments, very few conodonts, and very rare specimens of *Ammodiscus semiconstrictus* Waters and *Glomospirella umbilicata* (Cushman and Waters).

134–T–31. Strawn. High bank on west side of Rocky Creek and about one-quarter mile south of its junction with Llano River, at the southern extremity of the big bend of Llano River, 6 miles southeast of London (fig. 15). Two samples taken in this buff-gray, nodular, noncalcareous shale (one about 25 feet above the creek; another about 60 feet) have yielded almost identical concentrates of fine silt with few flakes of biotite, few fragments of carbonized plant remains still showing cellular structure, and a scattering of foraminiferal tests of several species (Table 1, in the group of Smithwick localities, as originally mapped).

134–T–32. Strawn. Shale slope at head of small branch about three-quarters of a mile northeast of the abandoned irrigation project on Llano River, Morgan ranch and close to the Shell Company pipe line, about 4½ miles southeast of London (fig. 15). This compact, gray, laminated shale washes to a small concentrate of some quartz sand, and abundance of secondary calcite in thin plates and small nodules, few poor shell fragments, rare holothurian remains, very rare conodonts, frequent ostracodes of few species, and a generous scattering of foraminiferal tests of five species (Table 1, in group of Smithwick localities, as originally mapped).

134–T–33. Strawn. Gully on north side of Pfluger ranch road that leads northeastward from the ranch house on Big Saline Creek, at a point about half a mile northeast of the cattle pens, 4½ miles southeast of London (fig. 15). In this neighborhood the Strawn shale forms a long sweeping slope upward through 40 to 50 feet to the Cretaceous capping, and laterally it extends from the cattle pens northeastward for about 2 miles. The road lies about on the stratigraphic level above the fossiliferous zone exposed at Sta. 134–T–5. The gray, compact, unctuous noncalcareous shale washes to a very small concentrate of some limonitic flakes, few tough shale fragments, frequent ostracodes, and numerous foraminiferal tests representing several species (Table 1, in group of Smithwick localities, as originally mapped). This is the type locality for *Bigenerina perexigua*, n.sp.

Lampasas County

141–T–14. Strawn. Donalson Creek, one-half mile downstream from the iron bridge on Espeyville road, 4 miles west and 1 mile south of Lampasas. The red, nodular clay is rich in tripoli. Material washes to a large concentrate of silt, secondary calcite, and numerous thin partings of hard red shale. Specimens of *Ammodiscus semiconstrictus* Waters occur with some frequency as the only trace of organic life (Table 1).

141–T–15. Marble Falls. Small, north-flowing branch of Sulphur Branch, near old railroad right-of-way, 2¼ miles south-southwest of the courthouse in Lampasas. The mottled white and buff, loose, soft clay washes to a large concentrate of rounded and etched sand grains and an abundance of secondary calcite. Ostracodes are rare, and the only foraminifer is *Tetrataxis?* (VR).

Llano County

149–T–6. Smithwick. Bluff on east side of South Fork of Honey Creek about 0.1 mile northwest of Slaughter ranch house and 0.4 mile west of cemetery, about 10 miles southeast of Llano in the isolated outlier of Marble Falls and Smithwick surrounded by Ellenburger limestone. This very compact, hard, dark-gray, somewhat fissile to nodular shale washes to a very small concentrate composed of a few thin platy partings of consolidated silt and minute aggregations of fine silt cemented by ferruginous matter, numerous black flakes, few rounded grains of quartz, frequent hard clay nodules or microscopic concretions, and a scattering of foraminiferal tests of four species: *Ammodiscus semiconstrictus* Waters (F), *Hyperammina spinescens* Cushman and Waters (F), *Haplophragmoides confragosus*, n.sp. (F), and *Thuramminoides sphaeroidalis*, n.sp. (VF).

149–T–7. Smithwick. On Slaughter ranch about 11 miles southeast of Llano, in a shale bank near north end of Boulder Ridge, along a small branch of South Fork of Honey Creek, 0.8 mile south-southwest of the ranch house.

This nodular, medium-gray, rather hard clay, which is darker in the center of nodules, washes readily to a very small concentrate composed of considerable resistant argillaceous matter, very few rounded quartz grains, some ferruginous stain and cement, many conodonts, and numerous foraminiferal tests of six species (Table 1).

McCulloch County

153–T–6. Smithwick. Small gully about 3½ miles due east of Rochelle and 0.9 mile south of the Rochelle-San Saba highway at a point 2.8 miles by road east of the corner north of Rochelle where the highway turns east. This is the well-known exposure of black, fossiliferous Smithwick shales from which five species of ammonites have been recorded.[14] Overlying the steeply dipping black shales are pink, almost horizontal shales probably of late Strawn age. Samples of the dark Smithwick shale wash to small concentrates that carry frequent protoconchs of ammonites, numerous conodonts, casts of pelecypods and gastropods, very rare specimens of *Cumminsia aplata* (Cummins), spines, frequent ostracodes, and many foraminiferal tests (Table 1).

153–T–81. Marble Falls. Exposure of shales in bank of Brady Creek at Pioneer Crossing, 2.3 miles in direct line southeast of the courthouse in Brady. The compact, dark gray, laminated shale washed readily to a rather large concentrate composed of silt, rare shell fragments, very rare bryozoa, numerous ostracodes, many fish scales (representing probably the order Acanthodii, according to Prof. A. S. Romer), few conodonts, and very rare tests of *Ammodiscus semiconstrictus* Waters.

153–T–136. Marble Falls. Right bank of Onion Creek, about 300 feet south of Richards Crossing, 6½ miles east and 2½ miles north of the courthouse in Brady. This interesting exposure, found by F. B. Plummer after this paper had gone to press, will be found on the geologic map of the Brady area in a forthcoming publication by F. B. Plummer. The highly calcareous and fossiliferous shale characterized in the outcrop by hard calcareous nodules lies about 15 feet above the Barnett formation. The material washed to a moderate concentrate composed largely of minute selenite particles, considerable calcareous matter in rounded grains, much fragmentary fossil material, many spines and plates of *Archeocidaris*, some productid spines and shells, few bryozoa, few conodonts, abundance of ostracodes, and a generous scattering of a few calcareous foraminiferal species: *Fusulina* sp. (VR), *Staffella?* sp. (VR), *Millerella* sp. (C, up to 0.75 mm. diameter), *Endothyra rotaliformis* Warthin (F), *Globivalvulina biserialis* Cushman and Waters (VF), *Cribrostomum marblense*, n.sp. (R). It is unfortunate that this exposure cannot be included in Table 1, where specific identification of the *Globivalvulina* in the Marble Falls fauna has not been recorded, but it is likely that the very small tests at Sta. 134–T-6 are young forms of *G. biserialis*, which is typical in this exposure on Onion Creek.

San Saba County

205–T–1. Smithwick. Extensive shale slopes on right bank of Colorado River from one-half to three-quarters of a mile southwest of Bend between the highway and the river (Pl. 11, in paper by F. B. Plummer, this publication). This black fissile shale slope has been the collecting ground for many geologists throughout several decades, for several species of large fossils weather out onto the surface rapidly and are commonly well preserved. Many samples in different parts of the exposure have been washed, but so far no foraminiferal tests have been found, but the locality is included in this list largely because it is so well known and some positive record of foraminiferal content should be made. One sample from here has been reduced to a small concentrate rich in delicate, glassy sponge spicules of several types; conodonts are rare and small.

205–T–2. Marble Falls. About 35 feet of dark, calcareous shales and few limestone layers in high bank on east side of San Saba-Llano highway, near top of slope south of first Simpson Creek crossing, 2.7 miles by road south of traffic light on the main street in San Saba (Pl. 11, in paper by F. B. Plummer, this publication). This argillaceous zone comprises the lower part of the upper half of the Marble Falls formation, which measures about 150 feet thick from the contact with the Barnett at the second Simpson Creek crossing 1.3 miles south of this exposure northward into the city of San Saba. The outcrop is faunally conspicuous because chonetid valves abound in the 10-foot shale in the upper half of this shaly exposure, and this is the type locality for *Chonetes dominus* R. H. King.[15] Four samples were taken from this upward stratigraphic sequence: *A*, a very calcareous shale just below the lowermost limestone layer; *B*, about the middle of the alternating dark shales and thin limestones about 5 feet below the yellow band in the overlying *Chonetes* shale; *C*, about 1 foot above the 12-inch yellow band in the base of the *Chonetes* shale; and *D*, about 3 feet above the yellow band and about central in the *Chonetes* shale. Sample *C* is the richest in species and carries all the species present in the other samples, except *Polytaxis* sp., which was found frequent in samples *A* and *B*. Table 1 presents a composite of the four samples. In the concentrates other fossil remains comprise a small trilobite fragment, chonetids, many bryozoa, echinoid parts, few gastropods and pelecypods, rare conodonts, and numerous ostracodes.

205–T–3. Marble Falls. Steep bank on both sides of the San Saba-Llano highway, just north of Simpson Creek crossing, 2.25 miles by road south of the traffic light on the main street in San Saba. A sample of soft marl was taken from the base of the west bank. This washed

[14]Plummer, F. B., and Scott, Gayle, Upper Paleozoic ammonites in Texas: Univ. Texas Bull. 3701, pp. 1-518, pls. 1-41, figs. 1-88, 1937.

[15]King, Ralph H., New Chonetidae and Productidae from Pennsylvanian and Permian strata of north-central Texas. Jour. Paleont., vol. 12, p. 259, pl. 36, figs. 1-7, 1938.

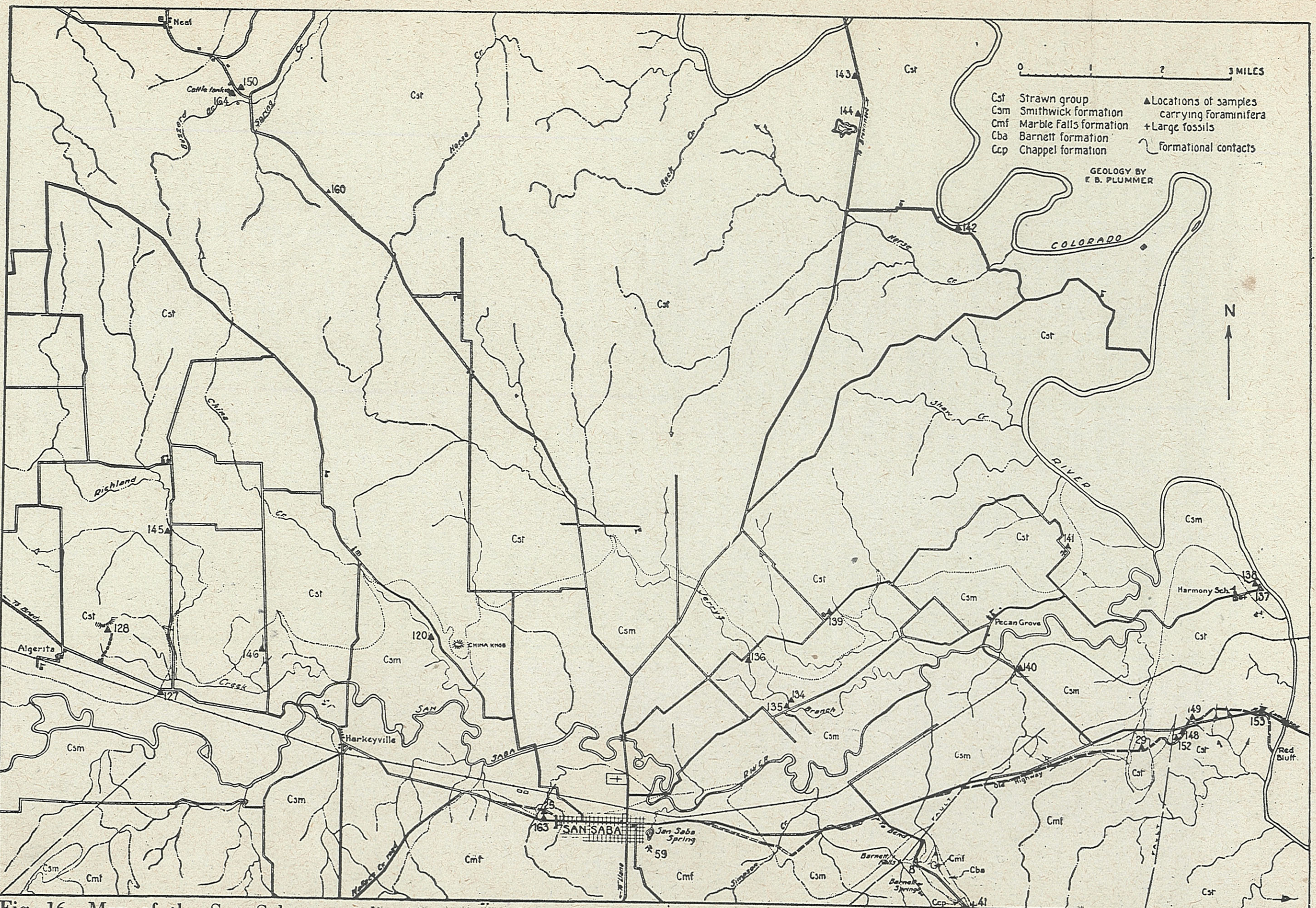


Fig. 16. Map of the San Saba area showing some of the more important localities of samples taken in the Marble Falls, Smithwick, and Strawn strata. (Geology by F. B. Plummer.)

with little reduction to a concentrate of fine hard fragments and particles of white limestone with no loose fossils. Many chips revealed the presence of an endothyroid test. This barren condition is typical of the white soft marls in the Marble Falls formation, whereas the calcareous shales yield better foraminiferal faunas.

205–T–5. Marble Falls. Roadside slopes in east edge of Richland Springs across from Locker Service Station and in the slope leading up from the creek crossing east of the main part of the business district (Pl. 11, in paper by F. B. Plummer, this publication). Brown and thinly laminated shales alternate with hard ledges of pale buff limestone in the *Marginifera roemeri* zone. A composite sample was taken from the 4– to 6–inch soft layers, and this material washed to a rather small concentrate composed of considerable calcareous matter, numerous spines and shell fragments, frequent bryozoa, rare conodonts, rare crinoid fragments, abundance of ostracodes, and rare foraminiferal tests of few species: *Endothyra distensa,* n.sp. (VR), *Polytaxis?* sp. (VR), *Hyperammina* sp. (R).

205–T–25. Marble Falls. Steep 15-foot bank 1.3 miles by the old San Saba-Rochelle highway west of Hotel San Saba in San Saba. This well-known and conspicuous road cut at the top of a hill now lies about 0.1 of a mile north of the new highway (fig. 16). At the base of the section exposed is a bed of gray-white calcareous shale carrying a few shells of *Chonetes dominus* R. H. King. Some samples from this shale are almost barren; others are fairly rich in forms that consist of frequent ostracodes, few bryozoa, and numerous foraminiferal tests of several species (Table 1). This is the type locality for *Endothyranella armstrongi sobrina,* n.subsp.

205–T–29. Strawn. Steep bank on north side of old San Saba-Lampasas highway at top of hill, 7.5 miles by old road east of the courthouse in San Saba. This exposure now lies about 0.3 of a mile south of the new highway (fig. 16). Gray, unctuous clays with sand streaks and two conspicuous sandstone layers comprise about 15 feet of vertical section along the road, and this is probably the type locality for *Mooreinella biserialis, Proteonina cervicifera, Thurammina texana,* and *Hyperamminella protea* named by Cushman and Waters. Three of these species are more numerous and better developed in this outcrop than in near-by outcrops of similar age. Samples were taken from several positions and all washed readily to rather small concentrates of very fine sand and silt. Conodonts are rare; foraminiferal tests are abundant and varied (Table 1). This outcrop falls in Bed No. 8 of Drake's section.

205–T–43. Marble Falls (base). Steep creek bank west of the Wallace Creek road at point about 12 miles by road southwest of San Saba (Pl. 11, in paper by F. B. Plummer, this publication). This steep bank of rather soft, heavy-bedded, buff limestone lies 15 feet above the top of the Chappel formation (Mississippian). From the softer layers good specimens of crinoids have weathered out, and this is type locality for *Cibolocrinus punctatus* Moore and Plummer and *Ethelocrinus texasensis* Moore and Plummer.[16] In a paper by Moore and Jeffords in this publication four coral species are recorded from these beds. Two samples of the softest marl washed to bulky concentrates of much calcareous matter, some glauconite, numerous fossil fragments, frequent ostracodes, and a few foraminiferal tests of four species: *Endothyra distensa,* n.sp., *Endothyranella armstrongi sobrina,* n.subsp., *Polytaxis?* sp., and *Nummulostegina* sp.

205–T–57. Marble Falls. Banks on both sides of the San Saba-Llano highway, 2.6 miles by road south of the traffic light on the main street in San Saba, or 0.2 mile south of the first Simpson Creek crossing. These beds of limestone and shale lie about 30 feet below the *Chonetes* zone that outcrops 0.1 of a mile farther south (Sta. 205–T–2), and they represent a shallow-water bed in which most of the fossil material is badly broken, so that few shells are recognizable. Several samples have been collected, and their concentrates consist of comminuted shell matter, spines, broken ostracodes, few bryozoa, frequent crinoid fragments, rare whole valves of brachiopods, rare gastropods, and frequent conodonts. Glauconite is common in the usual granular form and as casts of small gastropods, calcareous Foraminifera, and ostracodes. All the foraminiferal tests are strongly collapsed and otherwise deformed and consist of the species listed in Table 1.

205–T–59. Marble Falls. Quarry in southeast corner of the city of San Saba just east of the road to Chappel. Heavy-bedded limestone outcrops in this excavation with a few marly partings that carry no Foraminifera. On the floor of the quarry are several sphaeroidal masses of black, thinly laminated, calcareous, fossiliferous shale from a few feet to several feet in diameter. Over and around these masses the limestone layers dip away in all directions in miniature dome structure. Samples of the dark shale washed readily to rather large concentrates rich in badly preserved and broken fossils, crinoid remains, bryozoa, brachiopod shells, rare conodonts, few ostracodes, and a trace of Foraminifera in *Polytaxis?* sp. (VR), *Cribrostomum marblense,* n.sp., **(VR).**

205–T–62. Marble Falls. Low bank on east side of San Saba-Llano highway, 3.3 miles by road south of the traffic light on the main street in San Saba, and 1 mile south of the first Simpson Creek crossing. From the 5-foot section of thin limestones and interbedded marls two samples were taken. These washed to moderate concentrates of calcareous fragments, some sand and silt, some dark-green glauconite in small grains, few shell fragments, one specimen of *Chonetes,* spines, frequent conodonts, broken ostracodes with few good carapaces, trace of *Ammodiscus semiconstrictus* Waters.

205–T–76. Smithwick. Deep gully parallel to the north-south road past Sloan school and

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[16]Moore, R. C., and Plummer, F. B., Crinoids from the Upper Carboniferous and Permian strata in Texas: Univ. Texas Bull. 3945, pp. 86, 379 pl. 1, figs. 2–4, pl. 20, fig. 6, 1940.

church and about 250 feet west of road, about 4¼ miles in direct line southwest of Algerita. Black laminated and nodular shale with an abundance of yellow sulphur partings outcrop on both sides of this gully. One good specimen of an ammonite has been found in these slopes. Several samples from this exposure washed with some difficulty to small concentrates of some tough argillaceous matter, hard flakes of limonite and black material, and a scattering of foraminiferal tests of four species (Table 1).

205–T–79A. Smithwick. Large gullies on Leonard ranch just south of new cattle tank, 3 miles in direct line due west of the crossroads in Algerita (Pl. 11, in paper by F. B. Plummer, this publication). The pinkish-buff, laminated and very fossiliferous shales are especially rich in *Cumminsia aplata* (Cummins), which is exceptionally well developed and excellently preserved (Pl. 14, in paper by Moore and Jeffords, this publication). Other fossils present are *Ambocoelia*, ammonites, and few gastropods. The three samples taken in different parts of the outcrop washed to moderate concentrates rich in fossil fragments, such as spines, brachiopod shells, rare ammonites, rare orthocerids, frequent gastropods, frequent conodonts, rare bryozoa, and scattered foraminiferal tests of few species (Table 1) including a few tests of a large *Nummulostegina?*

205–T–79B. Smithwick. Creek bank about 0.1 mile south of Sta. 205–T–79A. Here a dark shale section lies on black Marble Falls limestone in the creek bed. Sample *A* was taken 2 feet above the formational contact in black fissile shale that washed to a small concentrate composed of tough shale fragments, few crinoid remains, few conodonts, few fish scales, spines, and teeth, many ostracodes, and a scattering of foraminiferal tests that consist largely of *Ammodiscus semiconstrictus* Waters and *Hyperammina spinescens* Cushman and Waters. *Endothyra whitesidei* Galloway and Ryniker is very rare, but the single test found is unusually large; it may be reworked from the Marble Falls strata. Sample *B* taken 6 feet above the contact in nodular dark shale washed to a small concentrate carrying some glauconite, numerous conodonts, fish scales, spines, and teeth, and a generous scattering of two foraminiferal species: *Ammodiscus semiconstrictus* Waters and *Reophax glennensis* (Waters), which in this bed is unusually coarse and large with an abundance of glauconite built into its masonry. In Table 1, the species found in the two levels in this exposure are combined.

205–T–92. Marble Falls. Extensive exposures around a broad excavation for road material about 0.4 mile in direct line northeast of Jack Sloan's new rock house, 6¼ miles southwest of Algerita (Pl. 11, in paper by F. B. Plummer, this publication). These buff shales and a few thin limestones comprise about 15 feet of vertical section about 20 feet above the top of the Barnett shale which lies farther down the valley slope. The surface of the shale slope is rich in bryozoa, many crinoid stems, few gastropods, few pelecypods, some brachiopods, and numerous specimens of *Stereocorypha annectans* Moore and Jeffords (see paper by Moore and Jeffords, this bulletin). Seven samples were taken from the succession of beds and each washed readily to small or medium concentrates rich in shell fragments and other forms seen over the slopes. Ostracodes are frequent in some zones. Foraminifera are rare and comprise only endothyroid forms (Table 1).

205–T–112. Smithwick. North of Pool Branch near its junction with Rough Creek about one-quarter mile west of Rough Creek crossing on San Saba-Bend highway, about 5 miles northwest of Bend. The soft, dull-gray shale washed readily to a small concentrate carrying considerable gypsum, concretionary pellets, some fragments of resistant shale, rare ostracodes, and a generous scattering of foraminiferal tests: *Thuramminoides sphaeroidalis*, n.sp. (F), *Hyperammina spinescens* Cushman and Waters (C), *Ammodiscus semiconstrictus* Waters (C), *Haplophragmoides confragosus*, n.sp. (F), and *Ammobaculites minutus* Waters (F).

205–T–113. Marble Falls. Steep 8-foot bank along picturesque winding road leading from Leonard ranch house to Berry Springs at point 0.85 mile by road south of the ranch house, 4¼ miles southwest of Algerita. This very compact, nodular, calcareous gray shale with thin layers of hard limestone lies below the middle massive beds of the formation in the lower part of the Marble Falls sequence. Samples of the shale washed to small concentrates rich in fragments of larger fossils (*Chonetes* frequent), numerous spines, rare bryozoa, one fragment of ammonite, numerous ostracodes and frequent tests of *Endothyranella armstrongi sobrina*, n.subsp.

205–T–120. Smithwick. Creek bank just west of the San Saba-China Creek road, 1.8 miles by road southeast of the small community of China Creek, 4 miles in direct line northwest of the courthouse in San Saba, and 2 miles in direct line northeast of Harkeyville (fig. 16). This tough, black, laminated shale, weathering gray, washes to a rather large concentrate composed of small to large loosely cemented aggregations of silt and fine sand. Conodonts are rare, and foraminiferal tests are sparsely scattered through the mineral matter, but persistence in examination of concentrates will yield eight species (Table 1). Though field work has designated this exposure as Smithwick, it is possible that it should be included in the Strawn sequence.

205–T–126. Marble Falls. Steep bank of large creek 2½ miles west by north of Richland Springs and about 0.15 mile north of San Saba-Rochelle highway. In this bank on the south side of the creek yellow clay lies above the typical white Marble Falls limestone. Samples of the clay washed to large concentrates of earthy flakes, few quartz grains, crinoid fragments, frequent ostracodes, rare holothurians, and very few foraminiferal tests: *Reophax bendensis*, n.sp. (R), *Endothyra distensa*, n.sp. (R), *Endothyranella armstrongi sobrina*, n.subsp. (VR), *Cribrostomum marblense?*, n.sp. (VR, only 2 specimens in biserial stage), and *Nummulostegina* sp. (VF).

205–T–127. Smithwick. Deep roadside ditch on south side of San Saba-Rochelle highway, 1.55 miles by road east of the crossroads in the north edge of Algerita, and 7.4 miles by road west of Hotel San Saba in San Saba (fig. 16). This exposure originally was erroneously recorded as "3 miles east of Algerita" in stating the type locality for *Glomospira umbilicata* Cushman and Waters. This ditch is rapidly being filled by blocks of Marble Falls limestone which are being hauled in from a near-by exposure, and the shale exposure may not be available to collectors in the near future. From 8 to 10 feet of typical black fissile shales are capped by a very hard, dark, petroliferous limestone. Numerous samples from different parts of the outcrop have yielded the same results. The shale washes rather readily to a moderate concentrate of some resistant shale particles, an abundance of flaky, black carbonaceous matter, numerous well-rounded and etched large quartz grains grading down into small and more angular grains. The only fossils comprise rare conodonts and abundant foraminiferal tests of 9 species (Table 1). This is the type locality for *Glomospirella umbilicata* (Cushman and Waters).

205–T–128. Strawn. Steep bank of shale and thin layers and partings of fine sandstone in southeastward-facing slope about three-quarters of a mile in direct line from crossroads in north edge of Algerita (fig. 16). To reach this slope, follow a poor trail for 0.3 of a mile northward from the highway at a farm house that lies 0.6 of a mile east of the Algerita crossroads; the best material for study is to be found in the lower 15 feet of the slope. All samples of compact gray shale from this zone washed to small concentrates of some fine sand and silt, considerable resistant shale particles, and an abundance of foraminiferal tests of many species (Table 1). This is type locality for *Hyperammina clavacoidea*, n.sp., *Hyperamminoides expansus*, n.sp., *Reophax minutissimus*, n.sp., *R. tumidulus*, n.sp., *Glomospira articulosa*, n.sp., and *Haplophragmoides confragosus*, n.sp. This outcrop probably lies near the top of Drake's Big Valley bed.

205–T–129. Marble Falls. Steep bank on south side of Richland Creek in northeast corner of the town of Richland Springs. At the base of a 75-foot exposure consisting almost wholly of massive limestone strata is a 5-foot bed of black, tough shale overlying dense black limestone at the water's edge. This shale washes with considerable difficulty to a small concentrate rich in ostracodes accompanied by frequent tests of *Endothyranella armstrongi sobrina*, n.subsp.

205–T–130. Marble Falls. Shallow. 3-foot hole in pasture near gate about 0.1 mile south of Richland Creek in northeast corner of Richland Springs. This hole penetrated some fossiliferous, soft, buff marl carrying crinoids. The marl washes to a moderate concentrate rich in small fossil fragments, much secondary calcitic matter, some sand, lumps of limestone, spines, bryozoa, few crinoid stems, abundance of ostracodes, and a trace of foraminiferal tests (Table 1) including rare tests of *Nummulostegina*.

205–T–131. Marble Falls. Excavation in limestone slope on east side of small branch in east edge of Richland Springs and about 250 feet north of highway. This very shallow excavation exposes typical hard strata of Marble Falls limestone with few interbedded layers of compact yellow shale, from which a sample was taken. This shale is tough and washes with some difficulty to a rather small concentrate rich in numerous species of ostracodes but no foraminiferal tests. Perhaps a larger suite of samples of this shale would have yielded some trace of Foraminifera, for the yellow shale at Sta. 205–T–126 carries rare tests.

205–T–132. Marble Falls. Branch of Dry Creek on King ranch south of Richland Springs. This soft, calcareous shale washes readily to a small concentrate rich in fine shell fragments and several larger fragments of productids and a chonetid, rare bryozoa, abundant ostracodes, and numerous casts and tests of *Endothyranella armstrongi sobrina*, n.subsp.

205–T–134. Smithwick. Steep bank along creek, about 100 yards north of Harmony School road at point 3 miles in direct line northeast of San Saba courthouse (fig. 16). This 8-foot exposure of black, fissile shale carries frequent reddish-purple concretions that shatter readily to angular fragments. The shale weathers gray, and some of the layers are nodular. The material washes to a very small concentrate of small, resistant shale particles carrying flakes of carbonaceous matter, frequent conodonts, and a scattering of a few species of Foraminifera: *Hyperammina* sp. (VR), *Ammodiscus semiconstrictus* Waters (C), *Proteonina cervicifera* Cushman and Waters (R), and *Thuramminoides sphaeroidalis*, n.sp. (C).

205–T–135. Smithwick. Creek bank near road down-creek from Sta. 205–T–134 (fig. 16). The black, fissile to nodular shale weathers greenish-gray, and reddish-purple ironstone concretions are common and shatter with the slightest impact. The shale washes to a very small concentrate of some resistant argillaceous matter, carbonaceous particles, few quartz grains, frequent conodonts, and numerous foraminiferal tests (Table 1).

205–T–136. Smithwick. Creek bank about 600 feet south of a small bridge, 3 miles in direct line north-northeast of San Saba courthouse and about a mile northwest of Sta. 205–T–134 (fig. 16). This compact, nodular black shale weathers buff-gray and washes to a very small concentrate of small argillaceous and carbonaceous particles, few conodonts, and a generous scattering of several species of Foraminifera (Table 1).

205–T–137. Smithwick. Steep gullies at end of road leading past Harmony School, about half a mile east of the school, about quarter of a mile west of Colorado River, and 7 miles in direct line east-northeast of San Saba (fig. 16). The sample taken came from a deep narrow gully about 0.15 of a mile north of the road in the field. It washed to a moderate concentrate of silt, some resistant shale matter, and a metallic black mineral. The only fossil is *Glomospirella* *umbilicata* (Cushman and Waters) which shows a rather weak development of the early irregularly coiled stage but an unusually large number of planispiral coils.

205–T–138. Smithwick. Steep gully about 250 feet north of the road just south of Sta. 205–T–137 (fig. 16). This shale yields a greater abundance of foraminiferal tests but only two species are represented: *Glomospirella umbilicata* (Cushman and Waters) (VA), *Hyperammina spinescens* Cushman and Waters (F).

205–T–139. Strawn. Greenish-gray shale in road ditch, 0.15 mile northeast of a cemetery and 4½ miles in direct line northeast of San Saba (fig. 16). This poor exposure yields rather loosely consolidated clay, which washes to a small concentrate of poorly sorted sand, abundance of secondary calcite, conodonts, and frequent foraminiferal tests (Table 1).

205–T–140. Strawn. Roadside bank just south of railroad tracks on a ranch road leading southward to the San Saba highway and 6 miles east-northeast of the courthouse in San Saba (fig. 16). In this low bank of gray laminated shales are partings of hard calcareous sandstone showing tracks and trails, and in the immediate vicinity are the typical heavy beds of hard sandstone. Sample of shale washed readily to moderate concentrates of fine sand and silt, a black mineral with a metallic sheen, thin fragments of sandstone partings, frequent conodonts, and frequent foraminiferal tests of few species (Table 1). This exposure is about in Drake's Bed No. 8.

The map, fig. 16, made by F. B. Plummer, places this exposure in the area of the Smithwick formation, but the present author disagrees in this formational identification.

205–T–141. Strawn. Roadside bank on Harmony School road across from gravel pit at point 7½ miles in direct line northeast of San Saba (fig. 16). From this exposure of silty, laminated, gray shales and sandstones, the sample of shale washed to a moderate concentrate of some resistant argillaceous matter, some fine loose sand, little secondary calcite, and frequent tests of Foraminifera of few species (Table 1). This exposure lies in the area of Drake's Bed No. 8.

205–T–142. Strawn. Excellent exposures of heavy sandstone beds on right bank of Colorado River 10 miles in direct line north-northeast of San Saba (fig. 16). A country road leading past Flat Rock School passes this conspicuous exposure. A parting of greenish-gray shale between two heavy beds of reddish sandstone was sampled and washed to a moderate concentrate of fine sand, silt, and lumps and particles of fine sandstone, a little secondary calcite and a few foraminiferal tests of *Ammodiscus semiconstrictus* Waters and rare tests of *Glomospirella umbilicata* (Cushman and Waters). This shale parting belongs to Drake's Fox Ford sandstone.

205–T–143. Strawn. New roadside exposures on the San Saba-Goldthwaite highway, 0.7 mile by road south of Colorado River, 1 mile north of a small lake, and about 11½ miles in direct line north-northeast of San Saba (fig. 16). This silty, laminated gray clay washes to a moderate concentrate of fine sand and silt and lumps of hard fine-grained sandstone and thin sandstone partings. Conodonts are rare; foraminiferal tests common and representing several species (Table 1). This outcrop belongs to the Big Valley beds of Drake.

205–T–144. Strawn. Rather poor roadside exposure of clay associated with typical Strawn sandstones both above and below, west side of San Saba-Goldthwaite highway, 9.45 miles by road north-northeast of the bridge over San Saba River in north edge of the city of San Saba, and one-third mile north of a lake (fig. 16). The clay washes to a moderate concentrate of buff silt and fine sand, of which the larger grains are subangular to rounded and etched. Conodonts are rare, and rather weakly developed foraminiferal tests of very few species are sparsely scattered through the mineral matter: *Ammodiscus semiconstrictus* Waters (C), *Haplophragmoides confragosus* n.sp. (VR), *Mooreinella biserialis* Cushman and Waters (VR). This lies within the band of outcrop of the Big Valley beds as mapped by Drake.

205–T–145. Strawn. Steep roadside bank 2.2 miles by road north of the San Saba-Rochelle highway at a point 1.75 miles by highway east of the crossroads in the north edge of the town of Algerita (fig. 16). About 12 feet of compact nodular gray shales broken by thin, flaggy, hard sandstones typical of the lower Strawn are exposed conspicuously on the west side of the road about 0.1 of a mile south of a bridge over Richland Creek. The shale washes readily to rather small concentrates of many thin platy fragments of cemented silt, loose sand and silt, and the usual small aggregations of silt lightly bound by cement. Ostracodes are scarce; foraminiferal tests very common and representing many species (Table 1). This exposure seems to lie in the top of the unit called Big Valley beds by Drake.

205–T–146. Smithwick. Steep creek bank on west side of small branch of Richland Creek, which parallels a north-south road that turns north from the San Saba-Rochelle highway at a point 3.2 miles by highway east of the crossroads in the north edge of the town of Algerita and 0.9 of a mile north of the highway (fig. 16). This 20-foot bank consists of tough, nodular black shale that weathers to a buff-gray in the upper part where leaching has affected the strata for the longest period. These shales are rather typical of the upper portion of the Smithwick formation where the fissile character has given way to a more nodular structure. Several samples from this outcrop of uniform beds washed readily to rather small concentrates of fine gray silt and few rounded quartz grains. Conodonts are very rare, and abundant foraminiferal tests represent several species (Table 1).

205–T–147. Smithwick. On east-west secondary ranch road leading east from the San Saba-Wallace Creek road at a point 6.4 miles by road southwest of the junction of the Wallace Creek road and the San Saba-Rochelle highway (measurement made along old road which has now been slightly straightened). This is the ranch road that leads to Ernest Conner's place. The high bank of black fissile shale and some nodular shale is uniform, and three samples taken yielded about the same results. The tough material washed with difficulty to small concentrates composed of some resistant argillaceous matter, trace of silt, rare conodonts, and a generous scattering of foraminiferal tests of few species (Table 1).

205–T–148. Strawn. Bank on northwest side of old San Saba-Lampasas highway, 8.3 miles by road east of the courthouse in San Saba. This is about 1½ miles by the new highway west of the Colorado River bridge and just south of the new highway west of a valley that cuts across the highway (fig. 16). Many samples have been taken from this gray, slightly silty, unctuous clay carrying a few thin laminae of loosely cemented fine gray sand. All washed readily to moderate concentrates of very fine sand and silt and frequent to abundant foraminiferal tests. Table 1 presents the average frequency for each species. This is the type locality for *Thuramminoides sphaeroidalis*, n.sp. This outcrop lies in Bed No. 8 of Drake's section.

205–T–149. Strawn. Roadside bank at sharp turn in old San Saba-Lampasas highway 0.25 mile east of Sta. 205–T–148 and 8.5 miles by old road east of the courthouse in San Saba. The new highway passes south of this exposure about 1½ miles by new road west of the new Colorado River bridge (fig. 16). Along this road curve are 10 to 15 feet of alternating fine-grained sandstones and gray unctuous clay. Several samples of the clay taken in different parts of the exposure yielded concentrates of fine sand and silt with frequent foraminiferal tests, and Table 1 presents the average frequency for each species. This exposure lies in Bed No. 8 of Drake's section.

205–T–150. Strawn. Excellent exposures of gray shale and interbedded reddish calcareous sandstone ledges on the east side of the San Saba-Regency highway, 11.05 miles by road northwest of the bridge over San Saba River in the north edge of the city of San Saba, and 1.4 miles by road southeast of the small community of Neal (fig. 16). East of the fence a good section is exposed in a gentle slope to a point about 0.2 of a mile east of the road, and to the west low banks of similar strata lie near a cattle tank (Sta. 205–T–160). This roadside bank must be the type locality for two Cushman and Waters species, *Hyperammina spinescens* and *Hyperamminella* (now *Earlandia*) *minuta*. These same authors recorded this as the type locality for *Hemigordius calcareus*, but Mr. Waters now states (verbal communication) that this is an error and that the holotype must have been taken from geologically later material collected farther north. Numerous samples from this exposure have been washed, and they all reduce to rather small concentrates composed largely of limonitic flakes and particles, some sand, rare conodonts, rare ostracodes, and many foraminiferal tests of many species (Table 1). This is now made the type locality for *Hyperammina elegantissima*, n.sp., and *Reophax expatiatus*, n.sp. These extensive exposures lie near the top of the unit named the Spring Creek beds by Drake.

205–T–151. Strawn. Sandy clays under bridge along Richland Creek just northwest of the town of Richland Springs. These typical sandy strata carry some layers with comparatively little sand, and these were sampled for study. The material washes to a rather large concentrate of buff-gray sand and silt, some limonitic matter, very rare conodonts, and frequent foraminiferal tests of several species (Table 1).

205–T–152. Strawn. Steep roadside bank on northwest side of old San Saba-Lampasas highway, 8.2 miles by road east of the courthouse in San Saba. Now the new highway passes north of this exposure, which can be easily reached, however (fig. 16). Here the Strawn strata are faulted down against the Marble Falls limestone, which comprises most of the topographic feature in this vicinity. The Strawn clay along this slope carries very few foraminiferal tests and only two species are represented, *Ammodiscus semiconstrictus* Waters (VF) and *Thuramminoides sphaeroidalis*, n.sp. (F). This outcrop is a part of Bed No. 8 of Drake's Strawn section.

205–T–153. Strawn. Exposure of clays and sandstones just west of the new bridge over Colorado River on the San Saba-Lampasas highway (fig. 16). The exact site of the exposure originally sampled lies under the new highway but the same material can be found in the immediate vicinity. Two samples of gray unctuous clay about 20 feet apart stratigraphically were studied and found rather lean in foraminiferal tests of four species: *Ammodiscus semiconstrictus* Waters (F), *Hyperammina bulbosa* Cushman and Waters (F), *Proteonina cervicifera* Cushman and Waters (F), and *Thurammina texana* Cushman and Waters (F). This thin shale lies in the upper part of the Shadrick Mill sandstone of Drake's section.

205–T–154. Strawn. Highway bank northwest of Richland Springs, 0.1 mile southeast of the railroad station. This low bank near a road corner exposes about 4 feet of laminated greenish-gray to buff-gray shale with hard sandstone partings. A sample of the shale washed to a rather large concentrate of fine sand and silt with considerable secondary calcite in rounded and irregular lumps. Foraminiferal tests are frequent and represent several species (Table 1).

205–T–155. Strawn. About 850 feet north of the San Saba-Rochelle highway and 3000 feet west of stone house and 2000 feet south of the railroad, 4½ miles west of Richland Springs. Buff-gray, laminated, nodular, silty clay washes to a moderate concentrate of fine sand, silt, and lumps of loosely cemented silt. Foraminiferal tests are not abundant but represent several species: *Hyperammina spinescens* Cushman and Waters (F), *Glomospirella umbilicata* (Cushman and Waters) (VF), *Reophax expatiatus*, n.sp. (C), *R. arenatus* Cushman and Waters (F), *R. asper* Cushman and Waters (VF), and *Ammobaculites stenomecus* Cushman and Waters (R).

205–T–156. Strawn. Bed of Richland Creek, one-half mile north of Richland Springs and about 0.1 mile west of the bridge. This gray, well-laminated shale with buff streaks washes to a rather large concentrate of fine sand and silt and hard thin partings of cemented silt. Foraminiferal tests are frequent and represent several species: *Hyperammina spinescens* Cushman and Waters (F), *Glomospirella umbilicata* (VF), *Reophax expatiatus*, n.sp. (C), *R. arenatus* Cushman and Waters (R), *Ammobaculites stenomecus* Cushman and Waters (F), and *Mooreinella biserialis* Cushman and Waters (F). This seems to be a part of the Hanna Valley bed of Drake's section.

205–T–157. Strawn. Low bank at broad turn in road on south side of San Saba-Rochelle highway, 1.7 miles by road west of the railroad crossing in the west edge of Richland Springs. This bank exposes about 5 feet of gray laminated shale and hard sandstone layers. A sample of shale washed to a rather large concentrate of ferruginous, silty and argillaceous flakes, loose fine sand and silt, secondary calcite, and a trace of foraminiferal tests (Table 1).

205–T–158. Strawn. Deep roadside ditch on west side of north-south road 3 miles in direct line north-northeast of Hall. This tough, nodular to laminated, somewhat silty, gray shale washed to a moderate concentrate of fine sand, so typical of Strawn concentrates. Foraminiferal tests are sparsely scattered through each of the two samples taken, and all are poorly developed (Table 1). This is the highest Strawn sample collected in northern San Saba County for this study.

205–T–159. Strawn. Low exposure along edge of cattle tank just south of house on a north-south road at a point 4½ miles in direct line east-northeast of Hall. Typical Strawn sandstones in thin layers are exposed at the edge of this excavation, and a thin clay bed in the section furnished a sample, which washed to a concentrate of fine sand and silt and lumps of fine-grained sandstone with a sparse scattering of foraminiferal tests and rare conodonts (Table 1).

205–T–160. Strawn. Small exposure in ditch on east side of San Saba-Regency highway, 9.05 miles by road north-northwest of the San Saba River bridge in the north edge of San Saba (fig. 16). This dense, unctuous, gray clay with minute siltstone partings comprise a small exposure from which the clay was chosen for examination. The material washed readily to a small concentrate of angular quartz grains, few fragments of well-cemented sandstone, and a generous scattering of foraminiferal tests of several species: *Proteonina cervicifera* Cushman and Waters (VR), *Glomospirella umbilicata* (Cushman and Waters) (F), *Thuramminoides sphaeroidalis*, n.sp. (VF), *Hyperammina bulbosa* Cushman and Waters (C), *H. spinescens* Cushman and Waters (C), *Reophax emaciatus* n.sp. (F), *R. minutissimus*, n.sp. (C), *R. arenatus* Cushman and Waters (R), and *Mooreinella biserialis* Cushman and Waters (F).

205–T–164. Strawn. Exposures of shales and sandstones just east of a cattle tank that lies about 0.1 mile west of the San Saba-Neal highway and of the exposures at Sta. 205–T–150, 12.7 miles by road north-northwest of the main street in San Saba (fig. 16). It is possible that this is the true type locality for the Cushman and Waters species mentioned in the description of Sta. 205–T–150, for the road passed close to the site of the cattle tank many years ago, possibly at the time that Mr. Waters made his collections. It makes little difference about the precise bank of shale, however, as the same shale beds are exposed continuously for a considerable distance, and all yield approximately the same assemblage of foraminiferal species. Table 1 presents the faunule found in the shales near the tank at this locality, which is the type locality for *Reophax emaciatus*, n.sp. The extensive exposures of alternating shales and sandstones in this vicinity lie near the top of the Spring Creek bed of Drake.

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Differences in environmental conditions in present-day waters contribute to differences in shell construction and must have constituted a factor in the earlier seas.

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——— Arenaceous Paleozoic Foraminifera from Texas: Cushman Lab. Foram. Res., Contrib., vol. 3, pp. 146–153, pls. 26, 27, 1927 (Sept.). Of the 15 new species described and figured from eight outcrops in north-central Texas, one is from the Smithwick (*Glomospira umbilicata*), one from the Millsap Lake, five from the Mineral Wells, two from the Brad, five from the Graham, and one from the Thrifty formation.

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——— Some Pennsylvanian Foraminifera of Oklahoma with special reference to the genus *Orobias*: Jour. Paleont., vol. 2, pp. 338–357, pls. 45, 46, 1928 (Dec.). Character of shell walls is discussed in relation to evolution of Foraminifera. The genus *Orobias* is described and is followed by a list of previously published species that the authors believe should be referred to this genus. Seven species of *Orobias*, of which three are new, are formally described and figured from Oklahoma and Texas outcrops. Of the other 12 species described from Oklahoma outcrops, six are new. A new genus *Tuberitina* is offered as a possible foraminifer. (For a later discussion of the position of *Orobias*, see M. L. Thompson, Jour. Paleont., vol. 9, pp. 111–120, pl. 13, 1935.)

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Basin (Oklahoma): Jour. Paleont., vol. 1, pp. 129–133, pl. 22, 1927. The pure shales lying between the Jolliff and Otterville limestones in Carter County carry ten species and subspecies, all new.

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PLATE 15

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FIGURES—

1. *Proteonina cervicifera* Cushman and Waters, topotype, x40. Strawn group, Sta. 205–T–29. Typical well-developed test 217

2, 3. *Thurammina texana* Cushman and Waters, topotypes, x40. Strawn group, Sta. 205–T–29 218
   2. Well-developed test showing several apertural protuberances.
   3. Test showing only two protuberances, which is average.

4. *Thuramminoides sphaeroidalis*, n.sp., holotype, x40. Strawn group, Sta. 205–T–148. Well-developed test, moderately compressed by forces of compaction and bearing no protuberances, the most common external character 218

5, 6. *Thuramminoides sphaeroidalis*, n.sp., x40. Smithwick formation, Sta. 205–T–127 218
   5. Strongly deformed test showing several apertural protuberances.
   6. Common smooth test showing moderate secondary compression.

7–9. *Thuramminoides sphaeroidalis*, n.sp., x40. Strawn group, Sta. 205–T–128 218
   7. Broken, compressed test showing irregularly reticulate pattern on interior wall.
   8. Strongly compressed test bearing an unusual number of protuberances.
   9. Labyrinthic interior of a specimen devoid of its test.

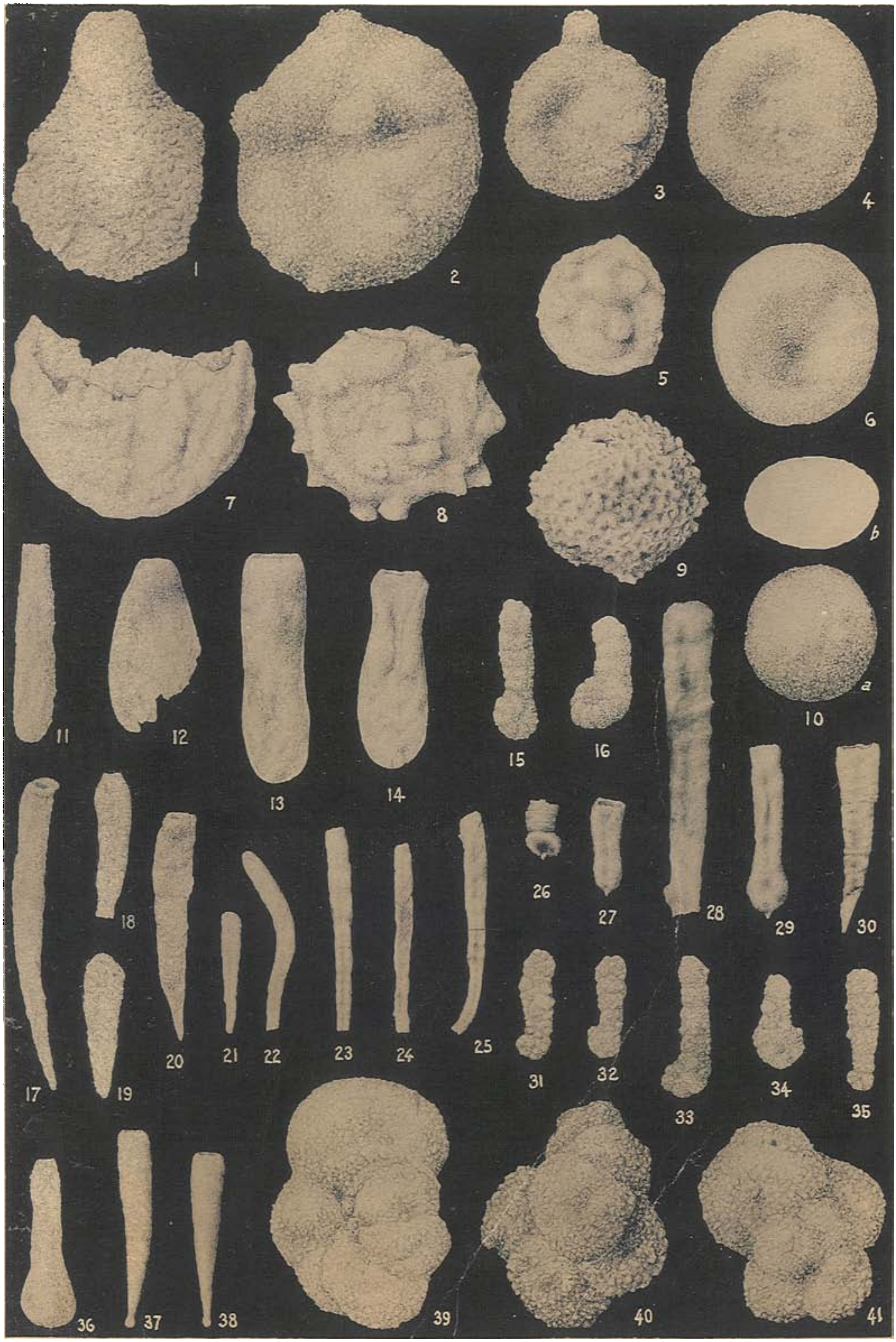
10. *Thuramminoides sphaeroidalis*, n.sp., x40. Smithwick formation, Sta. 153–T–6. Rare test showing probably no secondary compression, so that this is regarded as the original rotundity of the test. *a*, Lateral view. *b*, Peripheral view 218

11. *Hyperammina clavacoidea*, n.sp., holotype, x30. Strawn group, Sta. 205–T–128. Lateral view of the initial extremity showing typical club-shaped outline and finely rugose texture 221

12–14. *Hyperammina clavacoidea*, n.sp., x30. Smithwick formation, Sta. 205–T–127 221
   12. Fragment of apertural extremity.
   13. Lateral view of a typical initial extremity.
   14. Lateral view of an initial extremity separated from its tubular second chamber by somewhat more marked constriction than in average test.

15, 16. *Ammobaculites minutus* Waters, x40. Smithwick formation, Sta. 153–T–6 236
   15. Fully mature test showing a somewhat deformed coil in which only chambers of the final whorl are visible.
   16. Somewhat less mature test with a large early coil so well preserved that a few chambers of the penultimate whorl are visible.

17–25. *Hyperammina elegantissima*, n.sp., x30. Strawn group, Sta. 205–T–150 222
   17. Holotype. Test of average size and proportions where species is common and well developed; aperture deformed.
   18. Apertural extremity showing normal constriction of tube around the orifice.
   19. Youthful test in which deformational forces acting almost axially have produced transverse corrugations.
   20. Test with faint transverse constrictions.
   21–25. Very slender tests that are common in large suites of specimens, but all gradations from the normal (figs. 17–20) make distinctions impossible.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26–30. *Hyperammina spinescens* Cushman and Waters, topotypes, x15. Strawn group, Sta. 205–T–150 223

26. Early portion of test deformed by forces directed almost axially.
27. Early portion of a test showing unusually slight constrictions between proloculum and second chamber.
28. Fragment of second chamber showing some irregular transverse growth constrictions and the normal diametric expansion.
29. Early portion of a test showing characteristic spine on bulbous proloculum.
30. Microspheric? test.

31, 32. *Ammobaculites stenomecus* Cushman and Waters, x40. Strawn group, Sta. 205–T–128 236

31. Test showing almost no sutural constrictions.
32. Test showing traces of sutures.

33, 34. *Ammobaculites stenomecus* Cushman and Waters, x40. Strawn group, Sta. 205–T–150 236

33. Test of rather unusual development showing well-developed chambers in coil and faint sutures between rectilinear chambers.
34. Small test showing unusually large coil and only traces of sutures.

35. *Ammobaculites stenomecus* Cushman and Waters, x40. Strawn group, Sta. 205–T–148. Well-developed test with unusually small coil 236

36. *Hyperammina bulbosa* Cushman and Waters, x15. Strawn group, Sta. 205–T–128. Initial extremity of a test showing typical bulbous proloculum 220

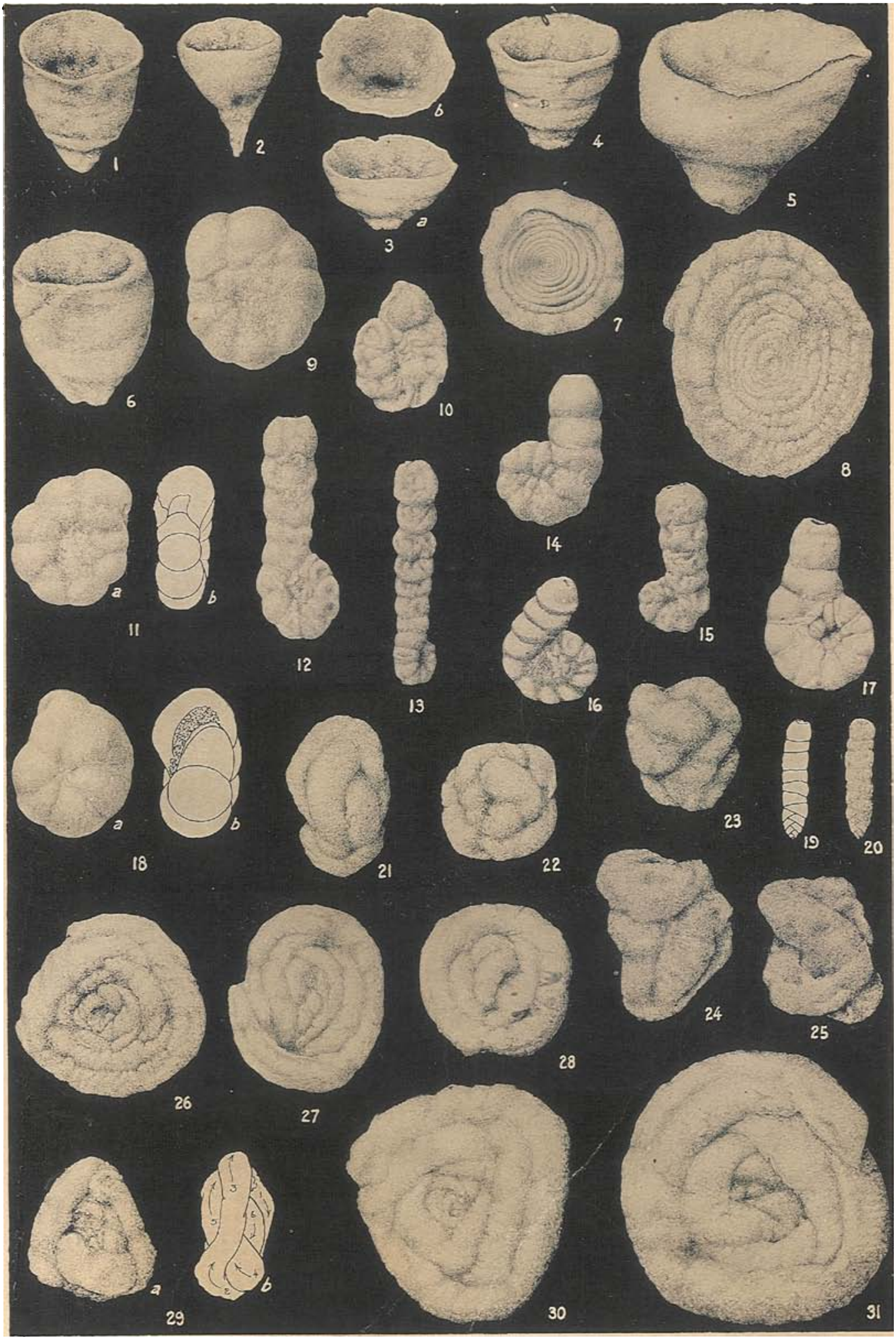
37, 38. *Earlandia minuta* (Cushman and Waters), x50. Metatypes from Waters' original collection. Strawn group, Sta. 205–T–150 224

37. Slightly arcuate test.
38. Normal straight test of average size and proportions.

39–41. *Haplophragmoides confragosus*, n.sp., x40. Strawn group, Sta. 205–T–128 235

39. Holotype. This test is the closest to its original state of any found. Secondary compression has acted rather uniformly against the lateral faces at an angle to the plane of coiling.
40. Test twisted so completely out of its original plan of arrangement, that analysis of chamber relationships is impossible. Such a condition is most common.
41. Badly deformed test.

PLATE 16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17. *Endothyranella armstrongi* subsp. *sobrina*, n.subsp., x40. Marble Falls formation, Sta. 205–T–129. An unusually well-preserved test for this formation. Crystallization of the shell matter is only partial, and consequently reflection of light reveals sharply the characteristic shell thickening along sutures and inner extremities of chambers 242

18. *Endothyra rotaliformis* Warthin, x40. Marble Falls formation, Sta. 134–T–6. Uncollapsed test showing only slight deformation of the final chamber. *a*, Dorsal view; *b*, peripheral view showing characteristic asymmetry in mode of coiling. The aperture is filled with secondary calcareous matter 240

19, 20. *Bigenerina perexigua*, n.sp., holotype, x40. Strawn group, Sta. 134–T–33 243
   19. Line drawing showing sharply all individual chambers as seen when test is dampened.
   20. Same test as seen in relief.

21, 22. *Glomospira articulosa*, n.sp., x40. Smithwick formation, Sta. 205–T–127. Two of the many different forms assumed by this tangle of whorls 233

23–25. *Glomospira articulosa*, n.sp., x40. Strawn group, Sta. 205–T–128. Tests showing by their differences in general form that no definite plan of coiling is followed. 23, Holotype. 24, 25, Form variants 233

26–28. *Glomospirella umbilicata* (Cushman and Waters), topotypes, x40. Smithwick formation, Sta. 205–T–127 233
   26. Mature test showing regular overlapping of coils in second stage, which give rise to a subtriangular outline and regular pattern on lateral faces, a structure common in the species but rather uncommon in this exposure (type locality). Final whorl planispiral.
   27. Mature test in which earliest stage is weakly developed and therefore occupies a depressed area in the center of the lateral faces and contributes to the umbilicate test. Coils in the second stage overlap irregularly and give rise to no geometrical pattern.
   28. Mature test showing one of the very early whorls lying almost at right angles to the general plane of the discoid test, a character common in this exposure. Such tests are not umbilicate. Coils in the second stage have shifted too irregularly to produce any pattern on the lateral faces, a character of most tests in this outcrop.

29–31. *Glomospirella umbilicata* (Cushman and Waters), x40. Strawn group, Sta. 205–T–128 233
   29. Youthful test in its second stage of development. *a*, Lateral view showing the subtriangular outline and crushed apertural extremity near top of figure. *b*, Peripheral view showing interlocking convolutions. The numbered arrows follow the tube backward from the aperture as far as it is in view.
   30. Mature subtriangular test.
   31. Mature umbilicate test showing the overlapping convolutions in the second stage followed by one planispiral convolution.

PLATE 17

PAGE

FIGURES—

1–3. *Reophax arenatus* (Cushman and Waters), x40. Strawn group, Sta. 205–T–150 225

1. Two-chambered test of unusually fine and uniform texture and with an unusually large proloculum.
2. Coarse-grained test of average size with only the third chamber defined by a strong sutural depression.
3. Small test showing small proloculum, a weakly developed second chamber, and a subpyriform third chamber.

4–6. *Reophax expatiatus*, n.sp., x40. Strawn group, Sta. 205–T–150 228

4. Holotype showing typical flaring test and very obscure sutures.
5. Somewhat irregularly developed and moderately flaring test with almost no trace of sutures.
6. Small test of typical texture.

7–9. *Reophax bendensis*, n.sp., x40. Marble Falls formation, Sta. 205–T–2 226

7. Very large final chamber, 0.75 mm. in length, showing terminal round aperture.
8. Series of youthful chambers wholly collapsed. Earliest chamber is probably the first beyond the missing proloculum.
9. Holotype. Three-chambered fragment of a test showing characteristic texture of mature chambers, characteristic form with greatest breadth posterior to the center, and broad shallow sutural depression.

10, 11. *Reophax fittsi* (Warthin), x40. Strawn group, Sta. 134–T–31 228

10. Coarse test showing characteristic curvature of early end of axis. *a*, Lateral view; *b*, apertural view showing totally compressed test due to compaction of sedimentary forces.
11. Unusually coarse test for species. The straight axis is frequent but not typical.

12–15. *Reophax fittsi* (Warthin), x40. Strawn group, Sta. 205–T–150 228

12. Young test showing arcuate axis.
13. Young test of perhaps three chambers, the maximum development reached in some strata.
14. Faintly arcuate test in early maturity, showing rather indistinct sutures and characteristic protruding apertural extremity.
15. Mature test of four (perhaps five) chambers along rather unusually straight axis.

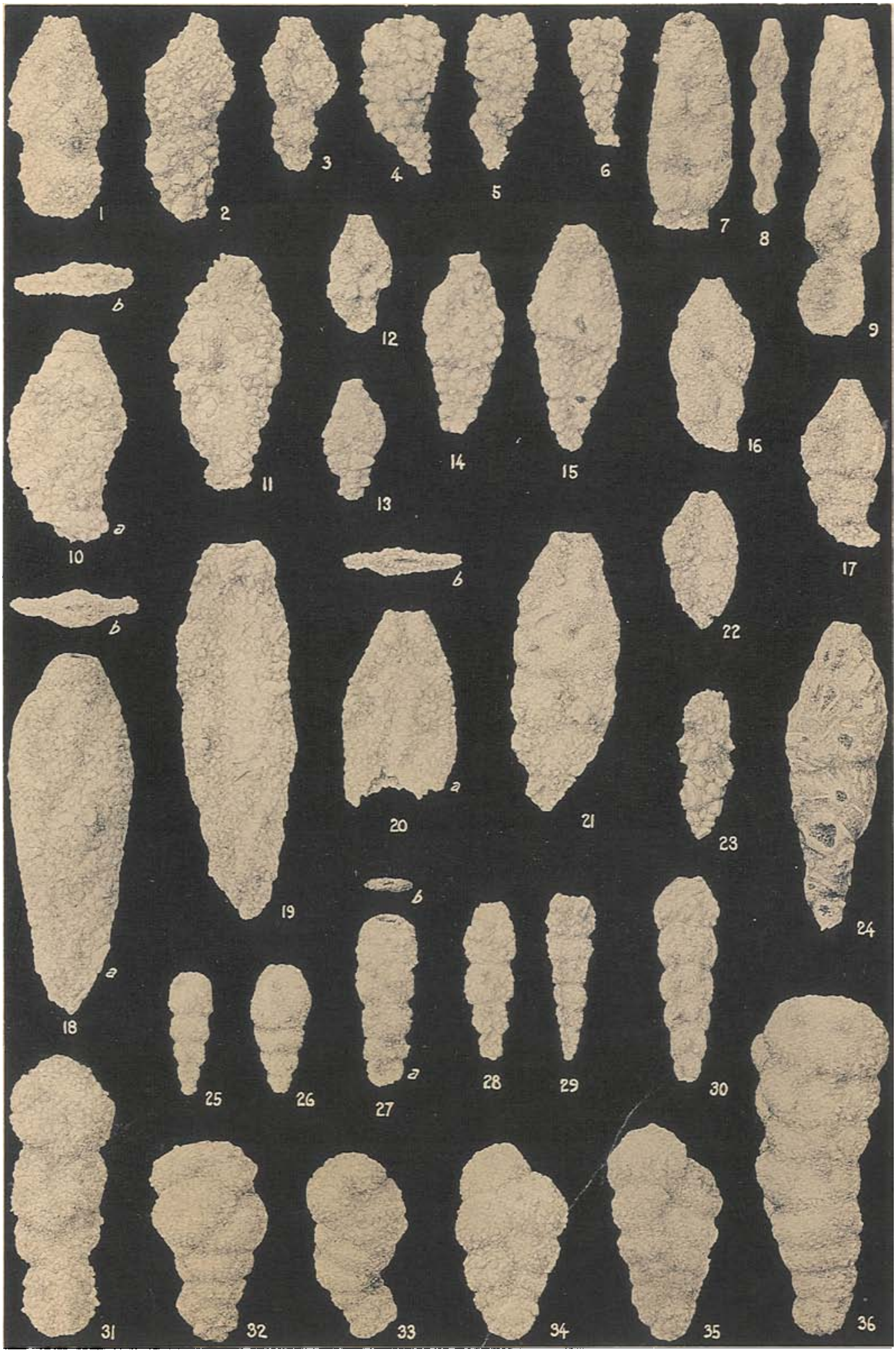
16, 17. *Reophax fittsi* (Warthin), x40. Strawn group, Sta. 134–T–5 228

16. Test of average size showing distinct curvature of early extremity of axis.
17. Test showing unusually strong curvature of early end of axis and exceptionally well-developed sutural constrictions. This may be a microspheric test.

18. *Reophax emaciatus*, n.sp., holotype, x40. Strawn group, Sta. 205–T–164. Typical test of average size showing gradual enlargement of successive chambers, and the usual complete collapse of walls to fragile, thin fossil specimens. Dampening the test shows faintly six (possibly seven) chambers. Specimens so complete are rare. *a*, Lateral view; *b*, apertural view, showing flattened condition of fossil specimens 227

19–22. *Reophax emaciatus*, n.sp., x40. Strawn group, Sta. 205–T–150 227

19. Unusually large and perfect specimen, typically devoid of sutural constrictions but comprising about six chambers as revealed by dampening test.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20. Final chamber of a large test, which is the most common state of this fragile species in washed material. *a*, Lateral view; *b*, apertural view showing typical flattening of fossil tests.
21. Average full-sized test showing final sutures. The succession shows each chamber embracing its preceding one by about one-half.
22. Young test of three chambers.

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OSTEOLOGY AND RELATIONSHIPS OF *TRILOPHOSAURUS*

Joseph T. Gregory

INTRODUCTION

Trilophosaurus buettneri Case is a medium-sized reptile from the Triassic of western Texas, whose most striking characters are an edentulous beak and transversely broadened, sharp-edged cheek teeth. This peculiar reptile was named by Case in 1928 from a fragment of a dentary. At that time, and in a subsequent detailed study of the dentition, Case suggested that its affinities might be with the Cotylosauria, some of which (*Diadectes, Procolophon)* it resembles in tooth implantation and transversely broadened teeth. Recently The University of Texas has obtained a large collection of Triassic vertebrate fossils which includes many specimens of *Trilophosaurus,* among them an articulated skeleton. It is now possible to give a fairly complete account of the osteology of *Trilophosaurus*, and from this more surely to determine its affinities. This new material reveals that *Trilophosaurus* does not belong to the solid-skulled Cotylosauria, but is more properly referred to the *Protorosauria,* an order of primitive reptiles whose skulls possess a single pair of fenestrae situated high on the top of the temporal region.

Early in January, 1940, Mr. Grayson Meade, who had been in charge of a W.P.A. project prospecting for and collecting fossils in Howard County since the previous September, reported cautiously that he thought he had found a quarry in the Triassic beds southeast of Big Spring. A few days later he sent to the laboratory some jaw fragments with transversely widened, sharp-edged teeth. By the time that this specimen had been identified as *Trilophosaurus*, Meade had opened a large quarry which contained numerous remains of this reptile. This site, known as Quarry 1, was excavated for six months, and at intervals thereafter until March, 1941. One nearly complete articulated skeleton, lacking only the preorbital portion of the skull and right manus, was collected early in 1940. Fortunately a second skull, lacking the basicranium, but with the edentulous beak well preserved, was discovered later. Besides these specimens a large number of vertebrae, girdle elements and limb bones, and several jaws and maxillaries were collected. A near-by quarry also contained mostly *Trilophosaurus* material, but all specimens from this site, known as Quarry 2, are much smaller than those of Quarry 1 and presumably are immature individuals. A few small specimens were found in Quarry 1. The matrix of the two quarries differed slightly, that of Quarry 1 being a fat clay, that of Quarry 2 a micaceous sandy shale. The meaning of this distribution of the individuals is not known. The location of these quarries is shown in figure 1.

GEOLOGIC OCCURRENCE

The *Trilophosaurus* specimens described in this paper were obtained from two quarries about 100 yards apart, in the Upper Triassic Dockum formation of southwestern Howard County, Texas. Quarry 1 is situated 800 feet south and 1100 feet west of the northeast corner of a 4-section tract belonging to Mrs. Sarah Mina Hyman, Mrs. Otis Chalk, and Mrs. Doris Roberts. It lies in the extreme southeast corner of sec. 58, blk. 29, Waco and Northwestern Railroad Company Survey, about 3 miles north of Otis Chalk, Texas. The locality is reached from Big Spring by following the highway toward San Angelo southeast to the Howard-Glasscock oil field, about 14 miles from Big Spring. A quarter of a mile beyond the Howard-Glasscock County line a road turns left through the oil field and runs northeast and then east to the town of Otis Chalk (1 mile east of Ross City on 1936 County highway map), a distance of 9 miles from the highway. Here take the left fork of the road which leads north and continue 1.4 miles to near the top of the first hill. A road branches to the left, leads in a short distance through the cattle guard into the Hyman heirs tract, roughly follows the fence northward for about 2

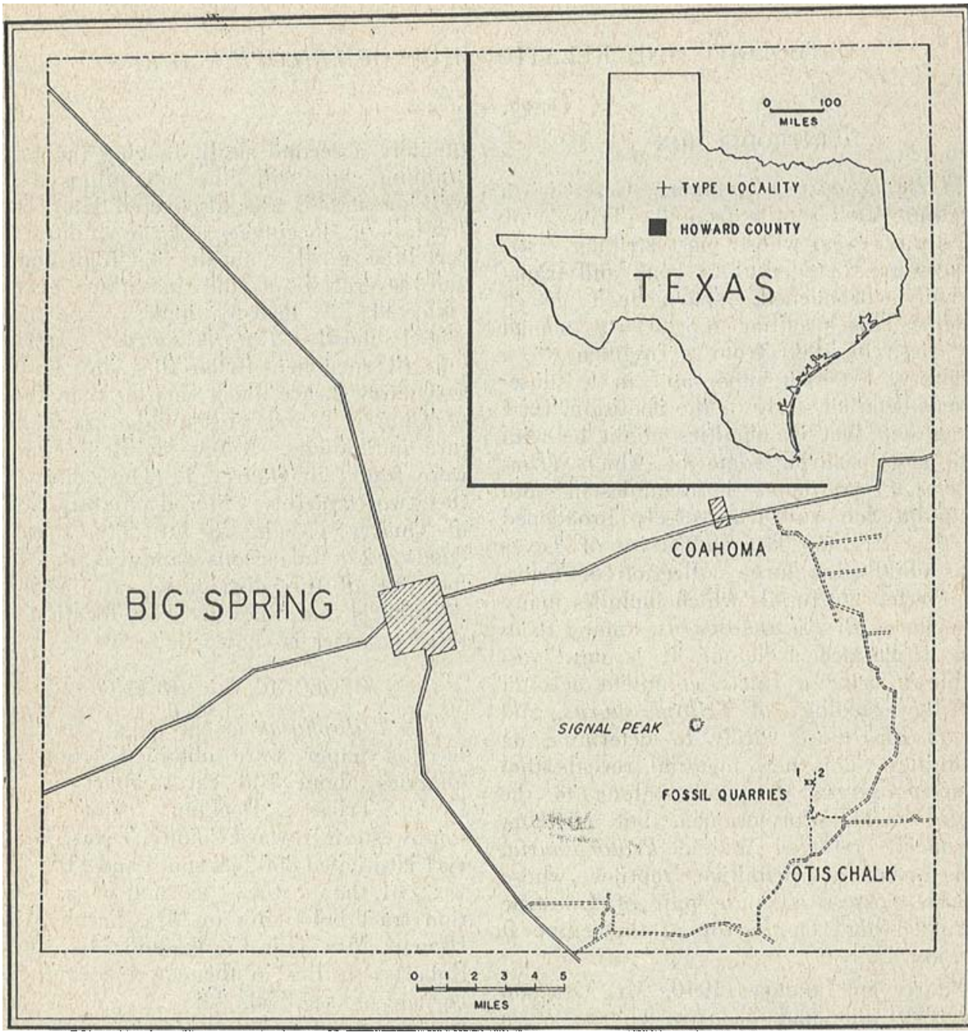

Fig. 1. Map of Howard County, Texas, showing location of Triassic fossil quarries.

miles, and then leaves the field by a gate. Take the first left fork of the road beyond this gate and follow it for one-fourth of mile to a point overlooking the badland area to the west. The quarries are on the first low hill between this point and Signal Peak, a prominent landmark with the shape of a truncated cone.

Quarry 1 is on the south side of this hill (see Pl. 18) and extends along it for 150 feet. The matrix is a massive variegated red, green, purple, and yellowish shale with waxy luster and smooth, greasy feeling to the hand. The bones commonly are covered with a thin hard concretion of calcite and hematite. Sometimes this is readily flaked from the surface of the bone, but on other specimens it is extremely difficült to remove. The bones are fairly well preserved, although cut by many joints. Their color varies from light brick-red and reddish brown to white and bluish white. Some of the larger pieces have been crushed and distorted, but the direction and amount of this are usually readily determinable. The bones occur mainly in one layer about a foot thick, 6 inches above a resistant calcareous bed. They are thickly distributed throughout this layer. Isolated elements were most commonly encountered, but one complete skeleton and parts of several others were found in articulation.

A number of faults of small displacement cut the deposit; the most prominent of these terminates the worked portion of the quarry on the west. Its western side is downthrown 2 feet.

Quarry 2 is about 100 yards east of Quarry 1 at the base of the eastern end of the hill where a much smaller area was worked. The matrix here is a bright brick-red, slightly sandy, micaceous shale. The bones are of smaller individuals than the average of those found in Quarry 1. A heavy concretion incrusts these bones as it does the others. The white bone is exceedingly soft, brittle, and surrounds a hard core from which it readily breaks. Hence preparation is difficult.

Quarry 2 lies 20 feet lower than Quarry 1. The faulting which is known to occur throughout this area makes accurate determination of the relationships of the two beds impossible; it is reasonable to assume that they are near the same stratigraphic level. The present difference in elevation is probably not significant. Even if a greater actual stratigraphic separation than the possible 20 feet were demonstrable, both would be close in age according to standards applicable to the Dockum formation. In the absence of any evidence to the contrary, the specimens from Quarry 2 are provisionally regarded as immature specimens of the same species which occurs in Quarry 1.

No positive correlation has been established between the fossil quarries of Howard County and the locality in Dickens County from which Case obtained the type specimen of *Trilophosaurus*. Both localities are within the Dockum formation, which is a well-defined and continuous unit. But the stratigraphic relations within the Dockum and relative positions of the various localities remain to be determined. Near-by localities in Howard County have yielded a fauna of phytosaurs and amphibians similar to the Cedar Mountain area in Crosby County. The following forms have been identified to date:

Buettneria sp.
Angistorhinus sp.
Promystriosuchus sp.
Desmatosuchus sp.
Coelophysis sp.

No attempt has been made to determine the species of the reptiles. The faunae on the whole are very similar, and careful comparisons of material from both localities will have to be made before any decision can be reached as to the exact relationships. Accordingly the *Trilophosaurus* material from Howard County is provisionally referred to the type species, *T. buettneri*, from which it differs in no important manner. The chief aim of this paper is to discuss the genus and its relationships rather than to establish species, upon undemonstrable and hypothetical distinctions in age and distribution.

The present paper is not an exhaustive study of the abundant *Trilophosaurus* material at The University of Texas; it is limited mainly to a description of the skeleton and discussion of ordinal relationships. The descriptions are based largely upon a single articulated specimen, No. 31025–140, supplemented by data from a second skull, No. 31025–143, a braincase, No. 31025–142, a complete lower jaw, No. 31025–5, and occasional isolated bones which are better preserved than those of the articulated skeleton. Abundant material is at hand for further studies of skeletal variation, growth rates, special anatomical features, and other biological problems. It is to be hoped that the yet unprepared material contains specimens which will throw more light on the structure of the braincase. Final determination of the palatal structure waits upon the discovery of uncrushed skulls. Better material is needed to determine the sutures delimiting many of the skull roofing bones.

ACKNOWLEDGMENTS

An extensive program of exploration of vertebrate fossil localities in Texas has been carried on by the State-Wide Paleontologic-Mineralogic Survey (Official Project No. 665–66–3–233), a Work Projects Administration project sponsored by the Bureau of Economic Geology of The University of Texas. The deposit from which this material was obtained was discovered by a field unit of this project; the specimens were collected by the field unit and prepared by the laboratory unit of the project; and preparation of illustrations and manuscript has been done by the headquarters unit. Dr. E. H. Sellards, Director of the Bureau of Economic Geology, is responsible for the initiation of the program and has taken great interest in the work on the Triassic. I am indebted to him for the opportunity to study this splendid material. For permission to collect fossils on their lands in Howard County, acknowledgment is made to Mrs. Sarah Mina Hyman, Mrs. Otis Chalk, and Mrs. Doris Roberts of Big Spring, Texas.

The keen eyes of Mr. Grayson Meade, Supervisor of the Howard County field unit, are responsible for discovery of the rich quarry of *Trilophosaurus* bones. The collection of these and many other specimens from the Dockum beds of Howard County has been carefully done under his direction. I recall with the greatest pleasure the hospitality extended by Mr. and Mrs. Meade during my visits to the Howard County localities, and their kind efforts to show me the fossil quarries and their relationships.

Preparation of the skulls was started by Mr. Meade and completed by myself with assistance from Mr. Otto C. Schoen. The articulated skeleton was prepared by Mr. Schoen, whose painstaking work has freed the bone from an often tenacious incrustation. Throughout the preparation and description of the material I have benefited from stimulating discussion with Mr. Wm. N. McAnulty, who has also aided me in many other ways. The illustrations have been prepared with care by Mr. Chester G. Wallace, staff artist of the Paleontologic-Mineralogic Survey, and are accurate representations of the specimens. Dr. H. J. Sawin has generously loaned me Recent osteological material for comparative study and has photographed the specimens. I wish to thank Dr. C. L. Camp for advice and for reading the manuscript and Dr. E. C. Case for a number of valuable suggestions.

SKULL

Text figs. 2, 3

The skull of *Trilophosaurus* is short and deep, moderately wide in the orbital region, narrowing slightly posteriorly and tapering in front to a rounded, edentulous beak. A short sagittal crest rises from the posterior part of the parietals. In front of this the dorsal surface of the skull is straight to a point in front of the

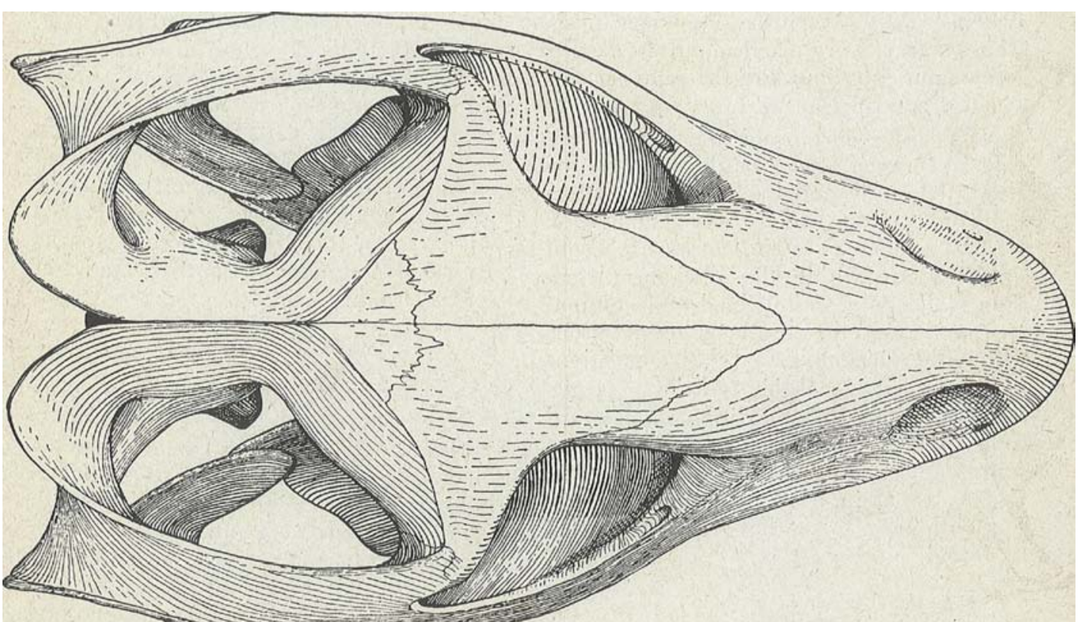

Fig. 2. *Trilophosaurus buettneri* Case, xl; restoration of skull, dorsal view.

orbits, where it begins to curve downward to the beak. In the center of the skull lie the large, elongate orbits facing outward and forward. The narrowest interorbital point is near the middle, behind which the superior border, formed by the frontal, turns strongly outward. The prefrontals swell outward above the anterior portion. Above the beak, close to the front of the skull, are large, oval, laterally opening, external nares. A well-developed septomaxillary lies within them. Its poor preservation makes observation of a septomaxillary foramen impossible. A pair of large superior temporal fenestrae lie on the upper surface of the skull behind the orbits, separated from each other posteriorly only by the thin sagittal crest. The posterior border of the temporal region bows out behind these openings to increase the area of muscle attachment. Lateral to the fenestrae the side of the skull drops vertically to its lower margin. The lateral temporal region is deep and solidly covered by a thin sheet of bone. Neither lateral temporal fenestra nor antorbital vacuity are present. The ventral margin of the skull is straight from the tip of the beak to the rear of the tooth row. Thence it descends gradually posteriorly to the downward projecting quadrate condyles, at the rear margin of the skull.

The top and sides of the skull are essentially flat surfaces meeting at a pronounced angle. In the preorbital region the upper surface becomes rounded. The superior temporal fenestrae have destroyed the primitive "table" in the postorbital region, which is narrowed to a parietal crest.

The temporal opening is bounded above by parietals, behind and somewhat to the side by the squamosal, and in front by postfrontal. Unfortunately the preservation of the material does not permit tracing sutures between the various bones at the side of the temporal region. Whether the postorbital entered the boundary of the temporal fenestra can not be determined at present. It seems reasonable, however, to interpret the opening as a superior fenestra homologous with that in the sauropterygians and protorosaurs, and perhaps the upper opening of the diapsids, and not as an expanded lateral opening such as occurs in the therapsids.

Behind the temporal fenestrae the parietals swing downward and outward from the sagittal crest and are overlapped anteriorly by the squamosals which continue the arch outward to the heads of

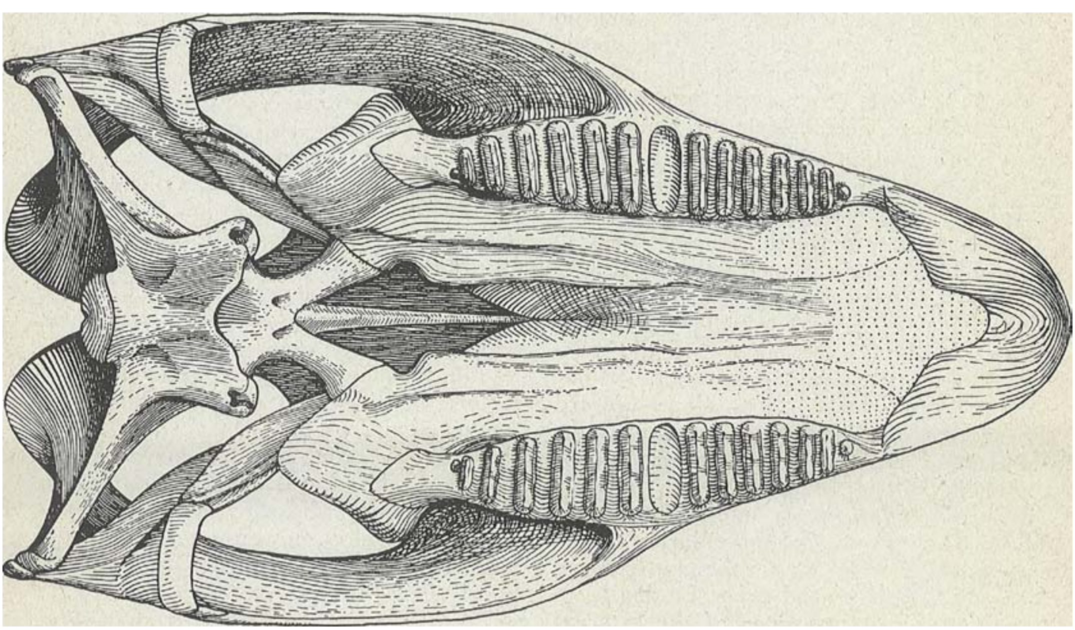

Fig. 3. *Trilophosaurus buettneri Case*, x1; restoration of skull, palatal view.

the quadrates. Large posttemporal fenestrae separate the posterior temporal arches from the paroccipitals. The lateral surfaces of the skull are bounded posteriorly by the tall quadrates which descend far below the level of the occipital condyle. The tubera project downward strongly on either side of the midline. A large occipital plate rises nearly vertically above the foramen magnum; its upper edge is strongly overhung by the posttemporal arch. The condyle is single, convex, and ventrally directed.

Dermal Bones of the Skull Roof

Pls. 19, 20

The skull of *Trilophosaurus* has advanced over the primitive tetrapod pattern by fenestration of the temporal region and attendant loss of several primitive elements. No trace can be found of intertemporal, supratemporal, or tabular bones. The interparietals likewise are no longer distinct elements in the adult, although they may be incorporated in the supraoccipital plate, as in some mammals. No sutures can be detected separating the lacrimal and jugal from the maxillary, or the postorbital, jugal, quadratojugal, and squamosal from one another. The boundary between prefrontals and nasals is also obscure, and no sutures save the median sagittal are at all distinct. In the description that follows, therefore, regions will sometimes be dealt with instead of separate bones.

Premaxillaries.—At the front of the skull is a large rounded beak formed by the premaxillaries. These bones meet in a median suture which remains open in the adult skull on which they are preserved. The lower margin forms a sharp-edged edentulous beak, which continues the line of the alveolar margin of the maxillary forward to the tip of the skull. The inner or palatal surfaces slope upward from the edge. Due to crushing, the palatal extent and relations are uncertain, but it is likely that the anterior lateral boundary of the internal nares was formed by the premaxillaries. Tall ascending processes form the convex front end of the snout and taper gradually to a point above the center of the external nares. This point is embraced by the nasals. The anterior and lower margins of the oval nares are formed by the premaxillary.

Septomaxillary.—The badly crushed remains of this bone lie within the lower and posterior half of the external naris. The bone was apparently well developed as in many other reptiles. If a septomaxillary foramen was present, it has been obliterated by crushing.

Nasals.—The region between nares and orbit is both crushed and lacking in sutures. It would seem that the nasals were fairly extensive, extending from a transverse suture with the frontals just anterior to the orbit, to the top of the narial opening, at the sides of the premaxillaries. A slender lateral process lying inside the premaxillaries forms the upper half of the anterior edge of the external naris. Anterior to the prefrontals they may have widened and extended down onto the side of the skull.

Prefrontals.—These thin bones form a a conspicuous swelling over the anterior corner of the orbit. They extend inward and downward, forming the smooth anterodorsal surface of the orbit above the lacrimal. The boundary with nasal and maxillary is obscure. The interior of the bone is hollow, perhaps containing a pneumatic sinus.

Frontals.—The broad flat interorbital region is formed by the frontals (Pl. 22). Together, these make an equilateral triangle with a nearly straight posterior base and slightly concave lateral sides. A transverse suture separates them from the parietals, another from the nasals. The postfrontals attach to the posterolateral corners. The frontals form the posterodorsal borders of the orbit. Here they have a thin, wedge-shaped edge which is slightly rugose. Anterior to the middle of the bone the prefrontals fit against its sides and swell outward over the remainder of the orbit. The sides of the frontals continue to converge anteriorly. The dorsal surface is flat, in some specimens bearing a slight transverse depression on either side at the posterior end, just in front of the temporal ridges.

The lower surface of the frontals presents a broad longitudinal median concavity above the braincase, which is separated from the upward sloping roof of the orbits by an evenly rounded ridge which terminates at the rear end of the prefrontal suture. Anterior to this a pair of grooves diverge slightly as they pass anteriorly, leading into the prefrontal sinus. There are no ridges or other indications of contact with the chondrocranium.

Parietals.—The parietals are as broad as the frontals at the postorbital processes but rapidly contract to a thin sagittal crest in their posterior half. The crest is continued forward by prominent ridges at the rear corners of the postorbital processes. In front of these ridges the parietals extend to a transverse frontoparietal suture and participate laterally in the depressions already mentioned which lie in front of the temporal ridges. Below the anterior portion of the sagittal crest the parietals bulge outward to roof the brain cavity. The lateral margin in this region is directed downward and is concave. A small groove traverses the margin, which may indicate the epipterygoid articulation.

Posteriorly the parietals diverge and form the median portion of the posttemporal arch. They are overlapped anteriorly by the squamosal and end about one-third the length of the arch from its beginning. Strong ventral processes extend downward from the middle of the constricted region. These rest upon the supraoccipital plate and also extend forward somewhat protecting the sides of

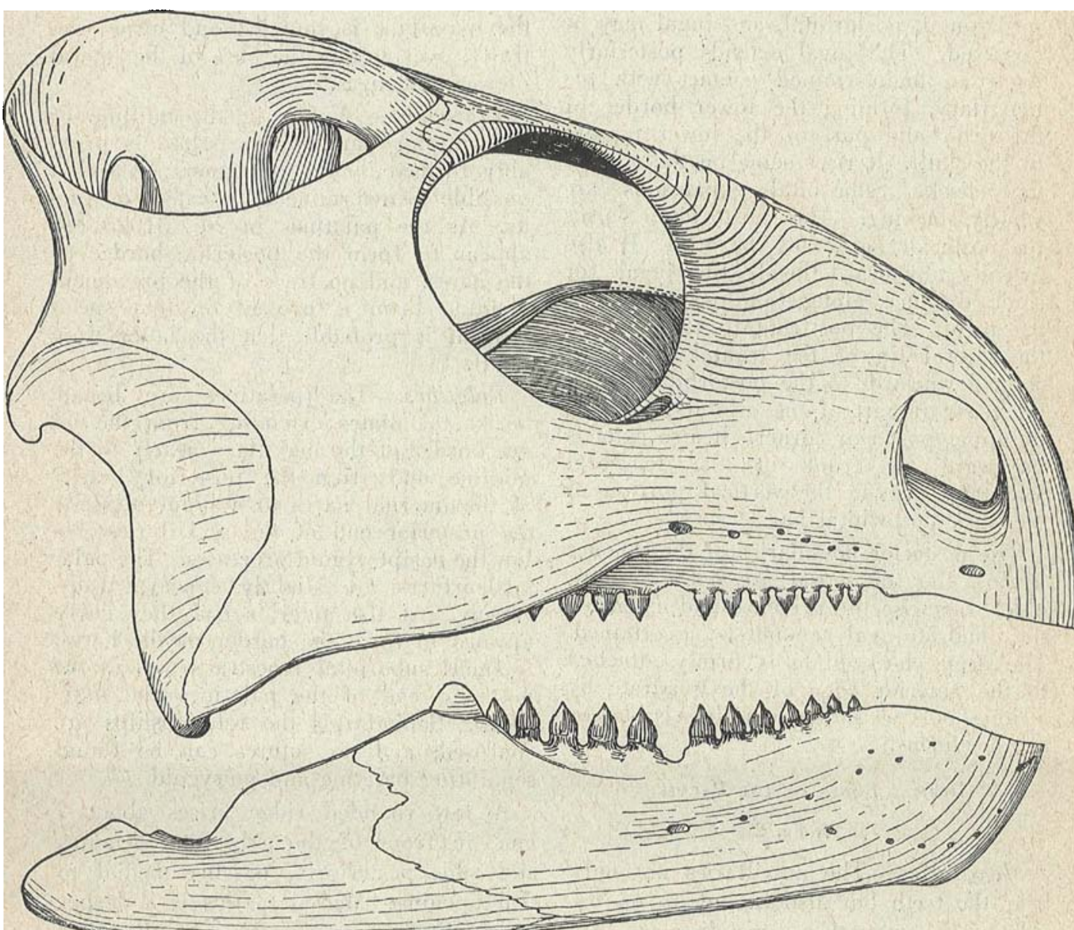

Fig. 4. *Trilophosaurus buettneri* Case, xl; restoration of skull and jaw, side view.

the braincase. The lower surface, anterior to the supraoccipital suture, slopes upward steeply to about the level of the postorbital bar and then flattens to meet the frontal. It is broadly concave in transverse section. This portion roofs the midbrain. There is no trace of a pineal foramen.

Lacrimal.—No sutures delimiting this bone have been found. A single large lacrimal foramen lies at the lower anterior point of the orbit, just within its margin.

Temporal region.—The side of the skull below the orbit and temporal fenestra, and anterior to the quadrate, is covered by a large thin plate of bone in which no sutures can be distinguished. Around the orbital margin of skull No. 31025–143, however, the ends of sutures between postfrontal, postorbital, and jugal may be observed. The jugal extends posteriorly from an undetermined contact with the maxillary, forming the lower border of the orbit and part of the lower margin of the skull. It rises some on the side of the cheek. Suborbital expansions are wholly lacking. The postorbital forms the posterior border of the orbit. It also extends downward inside the jugal for some distance along the lower edge of the orbit. The postfrontal extends from the lateral tip of the frontal and parietals downward, to the postorbital, forming a small part of the orbital border at its upper posterior corner. It also extends backward in front of the temporal fenestra, forming the vertical portion of the thick postorbital bar.

The posterior boundaries of these bones against the squamosal are not determinable. Likewise the presence and extent of the quadratojugal can not be ascertained. The deep cheek plate is firmly attached to the anterior edge of the quadrate by a long curved suture readily visible on all specimens.

Dermal Bones of the Palate

Pl. 19, fig. 2

Maxillaries.—The maxillaries not only bear the teeth but also extend up on the side of the snout for some distance. Below the front of the orbit an overhanging ridge arises outside the alveolar portion and gradually widens posteriorly to a point beneath the middle of the orbit where it separates from the alveolar ramus as a distinct process articulating with the jugal.

The alveolar ramus is heavy, deep, and straight, running parallel to that of the opposite side. It bears 12 to 15 transversely broadened, sharp-edged, three-cusped teeth. The tooth implantation, as will be demonstrated in a subsequent section, is thecodont.

The lingual wall of the maxillary rises vertically for some distance and is then overlapped by the palatine. Anteriorly it participates in the border of the internal nares. No horizontal palatine flanges or secondary palate occur.

Behind the teeth the posterior end of the maxillary is rounded and turns ventrally, overlapping the base of the lateral pterygoid flanges.

Prevomers.—A bar in the midline of the anterior part of the palate is probably formed by the prevomers; it is not possible to determine their extent or limits. As the palatines in No. 31025–140 appear to form the posterior border of the nares, and no trace of the prevomers dividing them is present on that specimen, it is probable that the latter were small.

Palatines.—The palatines are broad, horizontal plates extending from the inner border of the maxillary nearly to the midline and from the posterior border of the internal nares to a point opposite the posterior end of the maxillaries, below the basipterygoid processes. The palatal surfaces are slightly concave transversely. At the anterior end they curve upward to form the border of the nares. A small suborbital fenestra separates the posterior end of the palatines and maxillary. Behind this the relationships are confused, and no sutures can be found separating palatine and pterygoid.

A low rounded ridge arises about 7 mm. in front of the suborbital fenestra and runs posteriorly, passing medial to that opening. Medial to this is a deeper longitudinal groove which is bounded medially by a rather sharp high ridge.

Anteriorly, this ridge extends nearly to the level of the internal nares. It is strongest near its middle. The ridge terminates abruptly posteriorly in a rounded surface a little behind the back of the suborbital fenestra. A vertical flange arises from the internal ridge and forms the side of a deep longitudinal median groove between the palatines. The flanges rise posteriorly to the level of the basipterygoid processes. Their dorsal borders run forward, curving upward to opposite the middle of the orbit. In the specimen they converge and join near this point, but this may be the result of crushing. The median groove of the palate is open above posteriorly. Slightly behind the high point on the bounding ridges, mentioned above, it is roofed over by plates which can not be separated from the palatines. The depth of the groove decreases anteriorly. A third pair of ridges is present at the anterior end of the palatine, their posterior ends merging with the horizontal plate between the anterior ends of the median ridges and the depression leading to the nares. These run forward, becoming sharp edged, and separate the medial palatal groove from the narial opening.

It can not be definitely determined whether the median groove of the palate is roofed by an extension of the palatines or by prevomers, because the bone surface is poorly preserved in this portion and no sutures are apparent. The palate is badly displaced, especially on the left side, so it is possible that the groove was not completely roofed in life. It is clear that the palatines were largely separate in life and that no tendency toward development of a secondary palate was present.

The posterior end of the palatine is a nearly vertical plate, apparently in extensive contact with the pterygoid along the medial side of the latter's palatal flanges.

The dorsal surface of the palatine forms the extensive bony floor of the orbit, curving inward and upward from the orbital rim to its summit opposite the middle of the orbits.

Pterygoid.—The pterygoid consists of a deep vertical quadrate ramus and a moderate-sized palatal flange. The latter portion slopes steeply outward and downward from the basipterygoid articulation to a point below and behind the end of the alveolar ramus of the maxillary. Its palatal surface faces forward and somewhat inward. A strong rounded process extends outward into the temporal fossa at the level of the maxillary border. Ventrally the surface of the pterygoid tapers smoothly from this boss to the tip of the flange; dorsally it turns inward slightly and then extends upward to the basipterygoid articulation.

The upper side of the palatal flange faces posteriorly. It passes inward from the rounded boss, becomes slightly concave behind the tip of the process, and curves around sharply to the outer side of the quadrate ramus, forming a deep pocket directed downward and backward between the two.

The anterior extent of the pterygoids can not be determined in the material at hand—no suture with the palatine can be detected on the vertical plate which runs forward from the basipterygoid processes and is continuous below with the palatines. If ectopterygoids are present they are small and confined to the palatal flanges, on which no definite sutures can be detected.

The quadrate ramus is high and thin anteriorly, rising above the palatine flange nearly to the level of the temporal fenestra. Its upper border is concave and connects the base of the basipterygoid process with the inner edge of the head of the quadrate. The ventral border commences about 1 cm. above the inner end of the palatal flange and passes downward and backward along the medial side of the quadrate. The posterior border drops abruptly from the top to below the middle of the quadrate and then curves back. The process ends in a stout rod appressed to the inner side of the quadrate, directed downward and backward toward the condyle. It is displaced in the specimen and probably rested along the lower edge of the quadrate originally. The flange is thin, vertical, extending outward and backward from the palate.

Ossifications of the Palatoquadrate Arch

Text fig. 5; Pl. 22, fig. 2

Epipterygoid.—The epipterygoids are misplaced badly; the left is best preserved. It appears to have a flat base which rests on the outer side of the pterygoid just lateral to the basipterygoid articulation and extends backward for some distance. The anterior edge is rounded, the outer surface slightly concave. The anterior and posterior borders converge upward to a waist above the center of the pillar. Above this the top widens again to a flange, the upper edge of which curves outward. Due to displacement, its articulations can not be determined. It is suggestive, however, that a narrow groove is found in the under side of the parietal where that bone turns outward toward the postorbital process, at the position in which the top of the epipterygoid would lie if it had the same articulations as occur in *Sphenodon* and the Lacertilia. Possibly this groove received the head of the epipterygoid. I am indebted to Mr. Wallace for this observation.

Quadrate.—The large tall quadrate of *Trilophosaurus* is as distinctive as the transversely broadened teeth. It is exposed at the side of the skull along the entire posterior margin of the deep cheek region and extends well below the level of the teeth. The condyle is transverse, about 1 cm. wide, slightly concave near the center, and short and convex anteroposteriorly. Behind it the posterior border extends upward for 1 to 2 cm., bounded by abruptly rounded edges which converge slightly above. At the level of the tooth row the inner ridge turns outward and joins the lateral one which continues up to the top of the bone. Above this point the posterior edge is directed slightly inward. In the middle region a second ridge develops, roughly above the lower portion of the inner ridge at the base. Near the top, the back of the quadrate curves backward sharply and forms an overhanging suprastapedial process. The vertical pterygoid flange extends forward, passing lateral to the pterygoid and reaching nearly to the palatal flanges of the latter along the ventral border. Dorsally its anterior extension is more restricted, being less than that of the facial portion. The lateral face of the quadrate is flat, vertical. From the condyle it passes upward and slightly forward for a short distance without appreciably widening. The anterior edge then curves forward and sweeps upward in a broadly convex spiral over the top of the bone to the overhanging suprastapedial process. The posterior border rises nearly vertically from the condyle, then turns forward at the junction of the two ridges bounding the posterior face and curves upward and backward to the top, where it curves backward strongly to the tip. The entire anterior edge above

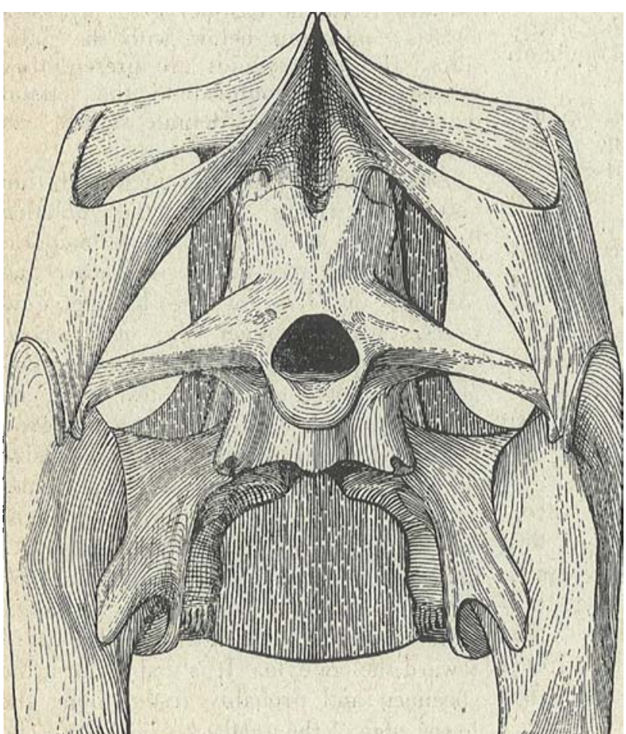

Fig. 5. *Trilophosaurus buettneri* Case, x1; restoration of occiput.

the condylar stem is suturally joined to the cheek plate (squamosal et al.) which has been described in detail above.

A facet for the paroccipital is found near the top of the medial surface of the pterygoid ramus of the quadrate, just internal to the backward hook of the head and below the squamosal suture.

The anterior aspect of the quadrate presents a deep, vertical, V-shaped groove between the pterygoid and facial rami. This surface bounds the temporal fossa posteriorly. There is no quadrate foramen. The quadratojugal, if present, is reduced to a portion of the cheek plate.

Braincase

The lateral wall of the braincase has been exposed on the left side of the skull belonging to the articulated skeleton. Part of the braincase of a smaller individual, No. 31025–142, has been prepared both inside and out. The latter specimen is broken off in front of the otic capsules, behind the dorsum sellae, and also lacks the ends of most of the processes, and has the right paroccipital slightly displaced. From these specimens it has been possible to reconstruct the braincase with but little conjecture. The bones of the braincase are indistinguishably fused in the larger specimen, but in the smaller the basioccipital-basisphenoid suture is distinct, and there are suggestions of sutures between supraoccipital, prootic, and paroccipital. All specimens indicate that the suture between the occipital plate and parietals remained open until at least late in life; in the best skull this suture has been badly displaced, and other specimens show characteristic rough surfaces of the bones at this point.

The braincase combines lacertilian and archosaurian features in its general form. The large periotic ossifications lie high on the sides of the skull and constrict the cranial cavity between them. A typical sauropsidan flexure of the brain is indicated by the high dorsum sellae. The stapes is slender and fenestra ovalis small. Well-developed tubera, strong, downwardly directed basipterygoid processes, and particularly the deep pit which lies anterior to the tubera strongly resemble the archosaurian braincase. In contrast to the archosaur skull, there are no ossified laterosphenoids in the anterior wall of the braincase, and the internal carotid foramina are situated at the base of the basipterygoid processes, as in primitive reptiles.

The laterally open sella turcica and the open notch for the 5th nerve are primitive features found in the Cotylosauria (*Captorhinomorpha,* Price, 1935) and Pelycosauria (Romer, 1940), which are retained by the Rhynchocephalia and Lacertilia among modern reptiles.

The foramen magnum is diamond-shaped, wider than high. It slightly exceeds the condyle in size. The occipital plate, formed largely of supraoccipital, rises above it to the overhanging parietals. From the sides of the plate the strong paroccipital processes extend outward, curving backward.

Basioccipital.—The single condyle is convex with little or no trace of a notochordal pit. Its upper surface is flat or slightly concave. Below, it is strongly downturned and overhanging, indicating that the skull could be strongly flexed upon the neck. The upper surface of the bone bears a shallow longitudinal groove. Sutures with the exoccipitals can not be determined on the available material. The ventral surface of the bone turns downward almost vertically in front of the condylar neck. Two deep wings extend forward and outward to the tubera, where they unite with posteriorly directed processes of the basisphenoid to enclose a deep ventrally directed pit. The basioccipital-basisphenoid suture runs transversely through the tubera and through the bottom of this pit. The posterior surface of the ventrally directed plate of the basioccipital bears a sharp median ridge. The plate and tubera furnished insertions for powerful rectus capitus muscles. The ends of the tubera are rugose to strongly pitted.

Exoccipitals and paroccipitals.—These elements are indistinguishably fused; moreover the suture separating exoccipital and basioccipital can not be made out. Hence the extent to which the exoccipitals participated in the condyle can not be determined at present. A single moderately large hypoglossal foramen opens just inside the foramen magnum on either side near the lateral edge of the floor of the braincase.

Inside the lateral angle of the foramen magnum, lateral to the hypoglossal foramen, is a small recess in the exoccipital. This lies in line with the elongate jugular foramen and is separated from it by a low ridge. The external opening of the hypoglossal foramen is laterally directed, at the level of the top of the condyle, and just beneath a ridge extending from the side of the condyle to the posterior edge of the paroccipital. A ridge runs from the base of the tubera to the lower keel of the paroccipital process. Between these ridges is a deep recess which is divided by a longitudinal ridge into a lateral deep portion and a medial shallow portion. The hypoglossal foramen opens into the posterior edge of the shallow part of the pit; the large jugular foramen opens laterally into the bottom of the recess, where it is concealed from external view by the ridge. The jugular foramen opens into the braincase between the otic capsule and basioccipital, in front of and lateral to the hypoglossal foramen.

Long paroccipital processes extend outward and backward from the sides of the occipital plate. A sharp ridge runs from the center of the upper edge near the base along the upper anterior margin to the tip of the process. A much weaker ridge arises near the lateral angle of the foramen magnum and runs upward to the outer end. Between these angles is a surface which is broad, concave, and posteriorly directed at the base, but which turns upward and becomes flat and narrow distally. A third sharp angle is present along the lower edge of the process, rising at the side of the tubera, and a fourth, on its anterior surface, begins above the fenestra ovalis and joins the ventral angle before reaching the tip of the process. Proximally the lower surfaces are concave, forming grooves above the jugular foramen posteriorly and stapes anteriorly. A short ridge runs outward from the upper edge of the condyle and joins the lower ridge of the paroccipital process just lateral to the pit into which the jugular and hypoglossal foramina open. The distal ends of the processes curve downward. Their anterior faces, laterally directed at the tips, fit into facets at the inside of the head of the quadrates, and also articulate with the squamosal. The posterior border of the small fenestra ovalis is formed by the paroccipital. There is a suggestion on the small cranium that the paroccipital-prootic suture runs nearly vertically upward from the center of the fenestra ovalis to the supraoccipital. A straight suture separates the paroccipital and exoccipital from the supraoccipital.

Supraoccipital.—Above the foramen magnum is a flat plate of bone which slopes forward over the posterior part of the braincase. Its upper portion rises more nearly vertically. At the summit of the plate is a median U-shaped notch, from which a shallow groove descends on the outside to the base of the vertical portion. On either side of this depression are low, rounded ridges which continue upward to the inner edge of the pillars which support the parietals. These dorsal processes of the supraoccipital are wide and curve gently forward. Above the base of the paroccipital processes they abruptly turn forward to meet the prootics at the side of the braincase.

The supraoccipital is thickened on either side above the jugular foramen and anterior to it, so that the cranial cavity is narrow dorsally in the otic region. In front of the otic capsule the brain cavity suddenly widens, a small fossa being present on either side, lying in the prootic and in front of the supraoccipital. A narrow groove connects this fossa with the canal for the facial nerve.

Prootic.—This bone forms the anterior border of the fenestra ovalis and contains the anterior portion of the labyrinth. It does not extend onto the floor of the braincase in the preserved portion of the smaller cranium, and in the larger specimen its relationships to the dorsum sellae are not determinable due to the absence of sutures. It is in contact with basisphenoid along a line separating the bottom and side of the cranial cavity. Above the capsular portion the cranial cavity expands over it into a well-defined fossa. The prootic forms a wall for this region to its free anterior edge. A groove runs forward along the lower edge of the wall of the brain cavity, lateral to the floor of the braincase, from a point just in front of the jugular foramen to above the basipterygoid processes, where it turns downward abruptly and passes out through a ventrally directed foramen. This must indicate the course of the facial nerve.

The fenestra ovalis lies just anterior to the base of the paroccipital process. It is small and directed downward. The head of the slender stapes is inserted in it and fills the opening with possible exception of the posterior end. The prootic projects laterally beyond the basisphenoid and forms a strong overhanging ridge along the side of the braincase which runs forward above the fenestra ovalis from the anterior ridge of the paroccipital process to the stella turcica. Below the ridge, in front of the fenestra ovalis, is a low swelling on the surface of the basisphenoid, which disappears quickly toward the tubera. Anterior to the raised area is a depression in the basisphenoid. The foramen for the facial (VII) nerve opens into this cavity from beneath the overhanging ridge of the prootic, entirely concealed in lateral view.

The upper margin of the braincase descends steeply in front of the pillars which support the parietals. A notch of moderate size indents the border directly above the facial foramen. Below and behind this notch and connecting with it is a moderately deep, round pit in the side of the prootic. It extends to just above the ridge which overhangs the facial foramen. Presumably the notch is the exit of the trigeminal nerve and the pit lodged its Gasserian ganglion.

In front of the trigeminal notch the upper margin rises sharply at the sides of the dorsum sellae.

The inner ear, like that of lizards, crocodilians, phytosaurs, and dinosaurs, lies at the side of the braincase, well above the level of the base of the brain. The labyrinth is separated from the brain cavity by bone.

On one side of specimen No. 31025-142 a hole perforates the side of the prootic from the angle of the canal for the facial nerve and opens backward into a rounded pit at the level of the fenestra ovalis. This pit appears to be a natural smooth bone surface. However, no corresponding structure may be found on the opposite side of the specimen, and there is no pit with these relations on the larger skull. It is more probably a result of injury during preparation rather than a separate opening for the hyomandibular branch of the VII nerve.

Basisphenoid.—The floor of the braincase anterior to the basioccipital is formed by the thick basisphenoid bone. It bears a low, rounded, median ridge and shallow longitudinal grooves on either side. At the sides it curves upward to meet the proötics at the sides of the braincase. Its ventral or palatal surface descends steeply from the basioccipital suture in the base of the deep pit between the tubera, forward to below the sella turcica. Here strong rounded procesases diverge laterally and posteriorly at about 90 degrees with one another, to join the tubera basisphenoidales and form the sides of the pit. These buttresses firmly unite the descending flange of the basioccipital and its tubera to the basicranial axis. The rectus capitis muscles presumably inserted on the posterior surface of the basioccipital and especially at the tubera. The buttress provides a means for transmitting their force to the rest of the skull. This suggests that they had a strong action. The function of the deep pit in front of the basioccipital flange is problematical. It seems unlikely that the rectus muscles inserted in it, not only because their normal insertion in reptiles is on the tubera, but also because the deep plate behind the pit would force them to take a circuitous course unless the head were constantly flexed upon the neck to an extreme degree. More probably the pit represents space where bone formation would be structurally insignificant and productive only of excess weight. It may have been occupied by a connective tissue mass or more likely by a pneumatic sinus. It is in the position of the median diverticulum of the eustachian tubes in crocodilians.

Just anterior to these processes, at the front of the pit, on the flat ventral surface of the basisphenoid, are the paired foramina for the internal carotid arteries.

They pass upward through the bone in normal fashion, and emerge through a common opening in the base of the sella turcica. The basipterygoid processes arise just anterior to the carotid foramina, diverge slightly, and continue downward in the same plane as the base of the basisphenoid proper to their articulations.

In front of the basipterygoid processes the sphenoid bone contracts abruptly to a narrow, high, vertical plate. Its ventral edge is sharp, and rises rapidly to above the level of the sella. Thence the bone continues forward as an attenuate rostrum, sharply keeled below, its sides diverging nearly at right angles, and shallowly grooved above. It is not higher than broad. Anteriorly it lay on or slightly above the top of the ascending processes of the palatines. It extended as far as the specimen is preserved. The rostrum is fused to the basisphenoid, as is that of lizards, so that no distinction between basisphenoid, presphenoid, or parasphenoid is possible.

The outer surface of the basisphenoid is plain, sloping downward and outward from the region of the fenestra ovalis and facial foramen. Above the basipterygoid processes the basisphenoid contracts strongly, and then slowly widens upward to the sella turcica. The dorsum sellae is high, keeled in front. Unfortunately this structure was largely destroyed in preparation. It is clear that its posterior edge, which formed the floor of the midbrain, was a rounded trough rising sharply from the relatively horizontal posterior floor of the braincase. No sutures are discernible here, so one cannot determine whether it is formed by basisphenoid or proötic. The sella is widely open laterally.

As noted previously there are no ossifications preserved in the laterosphenoid or ethmoid regions; evidently the braincase was membranous in this region.

Stapes.—The preserved portion of the stapes consists of a rod 7 mm. long extending downward from the fenestra ovalis. Presumably the stapes extended downward and somewhat backward, passing beneath the paroccipital process and connecting with a tympanic membrane situated in the typical lacertilian position behind the quadrate. The preserved section of the shaft is round, 1.5 mm. in diameter. It appears to widen slightly toward the foot, which need not be large to fill the small fenestra ovalis. It is imperforate.

Hyoid

A pair of moderately stout, straight, oval rods of bone were found in place between the skull and lower jaw. They were partly held between the teeth, so that it was necessary to break part of them to clean the skull. The anterior ends of the bones are broken away; the preserved portions are about 4 cm. long and 5 mm. in diameter. The proximal ends are slightly enlarged and rounded. They lie below the posterior part of the palate. These bones are very probably a portion of the hyoid apparatus. No cervical ribs appear to be displaced so they are not likely to be portions of these.

The presence of these large hyoid elements suggests that *Trilophosaurus* had a well-developed tongue which may have served to push its food into proper position for mastication.

General Comparisons

It should be evident from the foregoing description that *Trilophosaurus* possessed an essentially reptilian and, in the main, primitive type of skull. Its chief modifications from the primitive type are related to its peculiar dentition and associated habits which in all probability included chewing its food. These modifications, in brief, consist of shortening of the skull, lowering of the point of jaw articulation, increasing the length of the adductor mandibulae muscle, and strengthening of the palate.

The mesocranial region is much shortened, the basipterygoid articulation lying in the line of the rear part of the maxillary teeth, actually in front of the pterygoid flanges. The beak rounds off closely in front of the anterior cheek teeth. The temporal region has deepened greatly, resulting in both lowering of the jaw articulation below the tooth line and also increasing the area for the adductor mandibuli muscle. The development of a temporal fenestra provides further room for that muscle's expansion. The quadrate remains solidly attached to the cheek bones, which support it strongly.

The structure of the palate is such that it supports the maxillaries. There is an extensive palatine-maxillary contact, and the former bone is in turn strongly supported by the pterygoids and basipterygoid processes. The pterygoid flanges are so constructed that they directly transmit pressure from the maxillaries to the basicranium. In other respects the palatal structure, in so far as has been ascertained, is of the primitive reptilian pattern, with anterior nares, divided palatines and pterygoids, an anterior basipterygoid articulation, and deep quadrate rami of the pterygoids. The parasphenoid is well developed, more lacertilian than primitive.

Kinetism.—The only suture in the posterior part of the skull on which displacement occurred was that between the supraoccipitals and parietals. The paroccipital processes extend out at right angles to the axis of the skull and articulate with the quadrates nearly on a line through the occipital condyle. The quadrato-paroccipital articulation does not appear to have been firm (the skull was separated here in preparation and no rugosities were found). If then, the basipterygoid articulation was movable, the braincase could move slightly upon the roof and palate of the skull (metakinetic). The absence of the braincase from specimen No. 31025–143 suggests that it was somewhat loosely connected.

Relationships.—The braincase presents a mixture of primitive and archosaurian characters. The open upper border of the proötic, with open trigeminal notch and laterally open sella turcica are primitive reptilian features. So also is the position of the internal carotid foramina. The enclosed, dorsally placed inner ear and small fenestra ovalis and rod-like stapes are advanced features characteristic of the Sauropsida generally (in contrast to the Therapsida). Special resemblance to the archosaurs, and in particular to the Theropoda, is to be found in the exceptionally strong tubera basisphenoidales, large pit for the rectus capitis, and long diverging basipterygoid processes. However, the absence of a lateral wall to the braincase anterior to the infundibulum is in strong contrast to the archosaur condition. The development of the epipterygoid is advanced in the general direction shown by both therapsids and sauropsids. Lack of details prevents clear interpretation of this element.

The braincase is more elongate posteriorly than that of the pelycosaurs, the distance between the trigeminal notch and pituitary fossa being far greater. There is no external venous notch posterior to the trigeminal opening, and the border in this region rises smoothly to the supraoccipital.

MANDIBLE

Text fig. 6; Pl. 21

The lower jaws exceed the skull in length. They are deep and thick anteriorly, nearly straight in ventral profile beneath the tooth row, behind which the lower border slopes upward a little to the angular process. In lateral view the symphyseal region appears steep yet smoothly rounded into the ventral border. The dorsal outline of the edentulous beak is slightly concave above and rises gradually to the first tooth. The alveolar border is straight and parallel to the lower margin of the jaw. A low but well-defined, round-topped coronoid process rises lateral to the last four teeth. Behind this the superior border continues at a higher level to the articular region where it drops abruptly into the cotylus. The retroarticular process tapers posteriorly both above and below to its bluntly rounded termination. The angular region, and especially the retroarticular process, is twisted outward ventrally and inward dorsally.

The dentaries and splenials meet in a coarsely interdigitating symphyseal suture. The massive symphysis is spoon-shaped in superior aspect and bounded laterally by a sharp-edged rim. It is similar to the beak of a turtle and probably was covered by a horny sheath in life, although the bone lacks the rough pitted surface such as occurs beneath the beaks of turtles.

The lower jaw is of the complex reptilian type, with a large wide Meckelian fossa between the coronoid process and articular region, a small inframeckelian

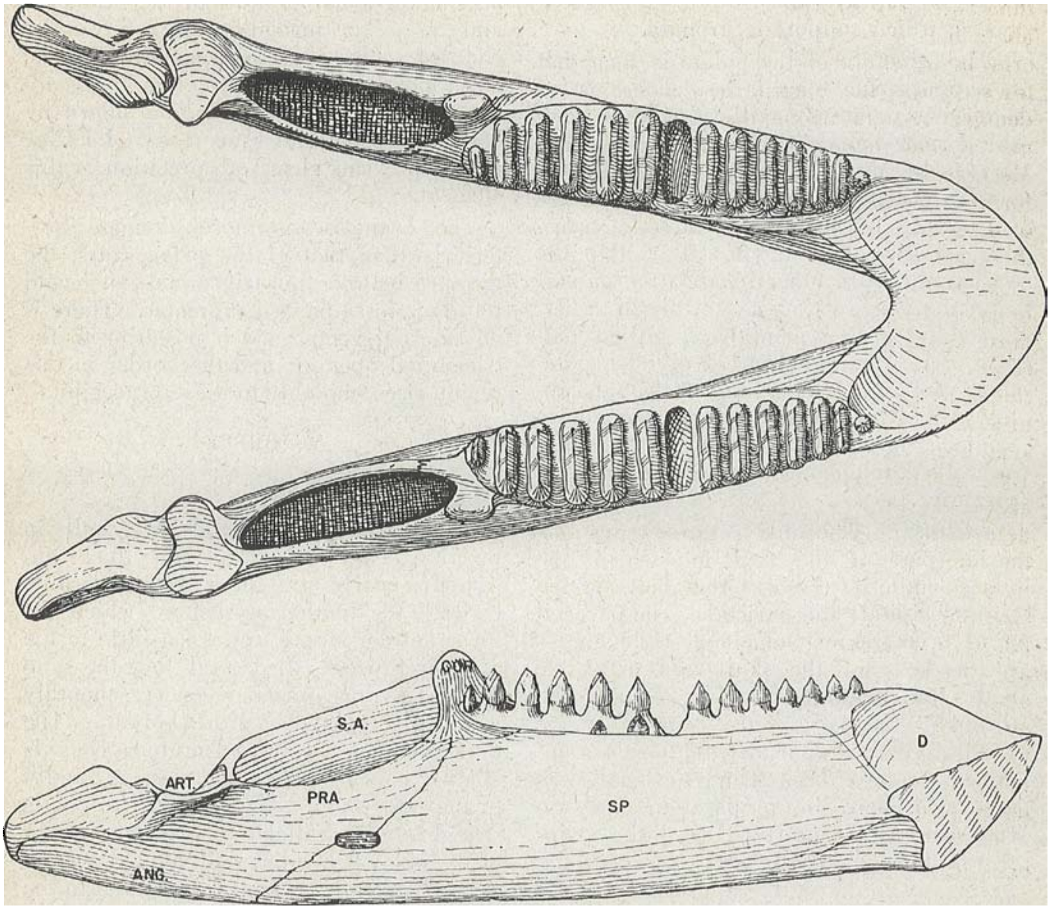

Fig. 6. *Trilophosaurus buettneri* Case, x1; restoration of mandible. Dorsal and mesial views.

fossa on the internal side beneath the middle of this region, but no external or mandibular foramen. It has been difficult to distinguish sutures, and some uncertainty exists concerning the boundaries and even the presence of certain elements. In particular, I have found it difficult to determine whether a coronoid is present or if the coronoid process is formed wholly by the dentary. The dentary, splenial, surangular, angular, and articular are surely present, and a prearticular and single coronoid seem to be indicated.

Dentary.—Most of the deep symphysis is formed by the dentary, the splenials meeting only at the postero-ventral end. The sharp outer edge, concave inner surface, and rounded anterior outline of the beak have already been mentioned. The dentaries form the entire lateral wall of the anterior half of the jaw. Internally it is concealed behind the symphyseal region by the splenial, except for a thin strip at the alveolar border. Opposite the 11th tooth (in adult specimens) the lateral border begins to rise above the alveolar level to form the outer surface of the coronoid process. Thence it extends backward about 1 cm., overlapping the surangular in a squamous suture. Its posterior edge drops irregularly to the middle of the jaw and then slopes forward to the ventral border of the jaw beneath the posterior teeth.

Its alveolar border is straight, widening posteriorly to the base of the ascending process, and then narrowing as it passes internal to that process, rising slightly at the end. In it are moderately deep, strongly transverse alveoli separated by extremely thin lamellae. The depth of the thick alveolar portion of the dentary is about four times the height of the exposed crowns of the teeth, increasing slightly toward the front. Below the alveoli the dentary recedes from the splenial. Its medial edge extends below the roof of the Meckelian or primordial canal, which forms a rounded groove on the lower side of the bone, and decreases in height toward the front of the jaw.

A series of small nutrient foramina open on the outer side of the dentary. The most anterior of these is near the upper edge of the front of the beak, and is continued by a groove which runs forward and upward toward the upper point of the symphysis. It is shown best by No. 31025–125. Behind this the foramina extend to about the middle of the dental series, descending from near the upper edge of the bone to slightly above its center, but in no regular fashion. The number and spacing of the foramina is variable. On No. 31025–125, a small specimen, there are 10 foramina on one side and 11 on the other; No. 31025–5, which is larger, has 10 or 11 on the left side but only 6 visible on the right. The foramina at the posterior end of the series are larger and more widely spaced than the remainder.

These foramina presumably provided exits for branches of the mandibular nerve and artery from the primordial (Meckelian) canal of the jaw, and are homologous to the mental foramina of mammals. Unlike the foramina of ceratopsian jaws, they bear no relation to the teeth.

Splenial.—The splenial is a thin bone covering the entire inner surface of the jaw beneath the teeth, extending forward to meet that of the opposite side at the posterior end of the symphysis, and overlapping the medial side of the angular to some extent in the posterior part of the jaw. It curves outward beneath the Meckelian canal and forms the lower border of the jaw between the symphysis and angular. Its suture with the dentary may be seen along the ventrolateral border; frequently there is some displacement along it. A small exposure of the splenial on the lateral surface of the jaw beneath the surangular is found behind the dentary. On the medial surface of the jaw the splenial slopes downward behind the posterior tooth to the inframeckelian foramen, whose lower border it forms. Posteriorly it is not distinguishable, but probably soon vanished in squamous suture with the angular.

Coronoid.—Three specimens show what appears to be a suture between the outer lamina of the dentary and the main rounded portion of the coronoid process. On two of these are some traces of a splenio-coronoid suture. In other jaws the coronoid process arises without a break from the posterior end of the alveolar border and appears to be formed entirely by the dentary. Inasmuch as a coronoid bone is to be expected in an otherwise primitive jaw, it is here described from those specimens which appear to show it; but the sutures described may be cracks.

The coronoid (if it be a distinct element) forms a small, thick, rounded process immediately behind and somewhat lateral to the most posterior tooth of the jaw. A longitudinal suture separates it from the ascending process of the dentary on the outside. Posteriorly it forms the anterior end of the Meckelian fossa. The surangular meets it lateral to this, the prearticular (?) medial to it. A short, thin, pointed process extends forward and downward on the medial side of the jaw, behind the alveolar ramus of the dentary and overlapping the splenial.

Angular region.—No suture has been observed between the surangular and angular. The ventral border of the jaw is constricted behind the splenial, so that it is thin and outwardly directed in the angular region. It slopes upward to the retroarticular process, of which it forms the lateral border. The internal surface is concave and directed more ventrally than medially below the articular. The external surface is likewise concave and directed upward, a broad groove passing obliquely forward and downward between the retroarticular process and articular bone. The posterior end of the jaw is thickened and rounded; it presents an unfinished rough surface for ligamentous attachments.

On the medial surface of the jaw the angular extends forward beneath the splenial for an undetermined distance. It apparently forms the posterior border of the inframeckelian fossa and is exposed shortly posterior to this on the inner surface of the jaw behind the splenial. No suture separating it from the prearticular has been observed, so it is possible that it includes the region referred to that element.

?Prearticular.—The medial border of the Meckelian fossa lies considerably below the external margin. It is bounded by a thin bone, suturally separated from the splenial and (?) coronoid, which bounds the inframeckelian fossa dorsally and appears to continue back beneath the articular to the lower surface of the retroarticular process. No certain suture with the angular can be seen; if the heavy crack on No. 31025–5 is a suture, the angular is a greatly reduced element and the prearticular unusually large. It seems likely that the anterior portion of this bone, at least, is a separate prearticular.

Articular.—The cotylus is a horizontal transversely widened concave facet directed strictly upward. Its lateral portion is larger than the medial projection, which is confined to the posterior half. The cylindrical surfaces have a transverse axis and must have limited the jaw to orthal and slight transverse movement.

The cotylus is bounded posteriorly by a low transverse ridge. Behind this ridge the articular expands strongly inward and downward, its upper surface concave. The medial border turns inward around this expansion and then slightly outward to join the inner edge of the retroarticular process. A short process of the articular extends forward and downward from the anterior edge of the cotylus, forms the postero-internal edge of the Meckelian fossa, and ends along the median wall of the same, covered by the prearticular.

Comparisons.—The deep, massive tooth-bearing portion of the jaw and large Meckelian fossa of *Trilophosaurus* are similar to the Cotylosauria, and especially the diadectomorphs, with which *Trilophosaurus* also agrees in having transversely broadened teeth. The characters are not necessarily primitive, however, for they are functionally associated with a massive dentition and may have been secondarily acquired.

The transverse, cylindrical, articular cotylus differs strikingly from that of *Diadectes*, which bears a median longitudinal ridge and permits extensive anteroposterior movement. The large splenials meeting in symphysis are found in primitive reptiles but not, according to Romer, in the Pelycosauria. They occur in Therapsida, Rhynchocephalia, and some other orders. The absence of an external foramen distinguishes the jaw from that of the Archosauria and is again a primitive feature. It is seldom found in pelycosaurs, never in Rhynchocephalia. The inframeckelian fossa is of wide distribution among primitive reptiles. There is no angular hook such as characterizes the therapsids and some of the pelycosaurs. Except for the thecodont teeth, the jaw is not unlike that of rhynchosaurs and other rhynchocephalians. The moderate coronoid process is found in these, and in sauropterygians, ornithischians, and other durophagous forms. It is of different form from that of the therapsids. The unreduced elements of the angular and articular region and the lack of a strong coronoid process of the dentary separate the jaw from the therapsid type.

DENTITION

Pls. 20, 21

Dental formula.—As noted elsewhere, the premaxillaries and symphyseal region of the lower jaw are edentulous, bearing sharply ridged occlusal borders which probably were covered in life with a beak-like horny sheath. The maxillaries and dentaries bear long series of transversely widened teeth which are so similar in upper and lower jaws that a single description will suffice for both. The maxillary teeth are set almost at right angles to the elongation of the alveolar border; in the dentaries, however, numerous specimens show an oblique position of the teeth, the internal end lying well anterior to the posterior. The angle varies considerably, and frequently is more oblique in the anterior portion of the jaw than the posterior. The difference may well be due to the angle between the rami of the jaw, the teeth being set normal to the median longitudinal axis in every case, so that they occlude between those of the maxillaries. This oblique position may be due in part to effects of decomposition or preservation, for in those jaws in which the teeth are most oblique they are most widely and irregularly spaced. Case (1928, p. 2) describes the teeth of the type as having the cutting edge sloping inward and downward and the outer cusp higher than the others. Most of the material examined for this present paper fails to show such a slope, and some jaws, indeed, have the inner edge higher.

The skull associated with the skeleton has 13 teeth preserved in the right maxillary. The most anterior of these is definitely 3 lobed and was certainly preceded by one and very possibly 2 more anterior teeth. The second skull has the anterior portion preserved, but the posterior ends of the maxillaries are broken. Thirteen teeth are indicated on each side, but it is possible that a minute 14th tooth, like that at the posterior end of the row on the first skull, may have been present. Two other moderately complete maxillaries in the collection each have 12 teeth, one with strong indications of additional teeth, the other suggesting that the series is complete although the anterior and posterior small teeth are missing. From this it may be concluded that the adult maxillaries of *Trilophosaurus* bore from 12 to 14 or possibly more teeth, with 13 or 14 probably the normal number. More evidence is present concerning the lower dentition. Of 15 jaws, 2 have 12 teeth, 7 have 13, 5 have 14, and one has 15 teeth. It is probable that some of the specimens in which 13 teeth were counted have lost traces of the anterior small tooth, so the mode may properly belong at 14. Thus it seems likely that the upper and lower jaws of an individual had nearly or exactly the same number of teeth.

Immature specimens have as many teeth as adults.

The mean length of the maxillary tooth-row in 4 specimens is 48 mm. The tooth-rows in 13 lower jaws have a mean length of 45.7 mm., the extreme being 24.6 mm. and 53.2 mm. Two presumably immature specimens, one from Quarry 1 and one from Quarry 2, with lengths 37 mm. and 24.6 mm. respectively are included. Omitting these, the mean length of the lower tooth-row in 11 adult specimens from Quarry 1 is 48.4 mm., close to the mean of the upper tooth-row length. The standard deviation of this series is 3.56 mm. and its coefficient of variability is V=7.4.

Case (1928B, p. 2) has concisely described the form of the individual teeth. The first tooth in both upper and lower jaws is small, round, and conical. The following teeth are all short and greatly widened transverse to the jaw. Their width slowly increases posteriorly from the 2nd to the 8th to 10th tooth of the maxillary and to the 10th or 11th tooth of the dentary, beyond which it decreases slightly to the penultimate. The last tooth is again minute and may be either slightly widened transversely or nearly round; in all specimens in which its crown is preserved one may detect three cusps. The round teeth found in some specimens have the central cusp distinctly larger and higher than the minute lateral cuspules. In the skull there are two small teeth at the posterior end of the maxillary series, the last being round, the next to the last still transverse. The associated jaws, however, have only a single small posterior tooth; this appears to be the general condition in the lower jaws, in none of which were two small posterior teeth observed. There is not sufficient material available to be certain concerning the maxillary.

The remaining teeth have sharp-edged transversely set crowns which swell at the center and ends to form minute conical cusps connected by a slightly concave blade. The anterior and posterior faces are shallowly concave on either side of the central cusp as far down as the cingula. These run from inside to outside just above the basal swelling, rising slightly toward either end where they disappear into the smooth ends of the teeth. At the base of the enamel the crown suddenly constricts and then drops straight to the alveolar border. At either end the crown is rounded, conical, appearing slightly swollen above the basal constriction. The teeth are symmetrical to both longitudinal and transverse planes.

The mean length of the widest tooth in 10 lower jaws from Quarry 1 is 10.5 mm. This value excludes two immature specimens, one of which, from Quarry 2, has a maximum tooth width of only 5.7 mm. The standard deviation of the series from Quarry 1 is 0.73 mm., and its coefficient of variability is 7.3.

In 8 maxillaries the mean width of the widest tooth is 11.5 mm., with a standard deviation of 0.93 mm. and coefficient variability of 8.1.

The implantation is thecodont, with widely open roots. The septa between the alveoli are thin. Case regarded the functional teeth as solidly grown to the borders of the alveoli in a pseudo-acrodont fashion. A longitudinal section of a maxillary shows deep, open roots of the teeth set in alveoli separated by thin laminae of bone. It is, however, difficult to decide the exact limits of the jaw and tooth near the alveolar rim.

A series of fine vertical striations in the bone at the edges of the alveoli may be observed in some specimens. On the sides of corroded jaws these lines radiate outward from the ends of each tooth. The contact of tooth with bone merges in this striated zone like the infolded bases of labyrinthodont or acrodont teeth. The implantation thus appears as a combination of thecodont and acrodont types. The thecodont condition is, in *Trilophosaurus*, undoubtedly more primitive and of real systematic significance. The firm intergrowth of tooth roots and jaws may be a secondary adaptive development related to the specialized, chewing function of the teeth. It is not clear what role this condition played in the periodic shedding and replacement of the teeth.

Succession of teeth. — Almost every specimen shows a gap at some point in the dental series where a tooth is missing. In a few specimens two teeth are missing, one near the front and one far back. One jaw has two adjacent empty alveoli on one side but only one opposite. This is probably abnormal. On the eroded sides of many of the jaws (both upper and lower) can be seen the crowns of successional teeth lying in the pulp cavities of their functional predecessors. The succession was vertical; as each tooth became worn or injured it dropped out and was rapidly replaced from below by the already formed replacement tooth. The gaps are interpreted as indicating the position of a tooth shed just prior to the death of the animal. The replacing tooth, not yet firmly attached to the bone, fell out, leaving a gap in the dental series. In all cases the alevolus thus left extends deeply into the jaw.

In some weathered specimens the replacing teeth may be seen directly below the functional teeth, their points extending up into the pulp cavities of the latter. In longitudinal section of the maxillary the developing crowns can be seen within the pulp cavity—a well-developed tooth beneath a tooth about to be replaced and rudiments of a second below that; beneath each of the other teeth is a single replacing tooth.

In a weathered lower jaw (No. 31025–108), in the pair of jaws numbered 31025–5, in the longitudinal section of a maxillary (No. 31025–105) (Pl. 20), and to a slight extent in some other specimens, one may observe evidence of a regular order of tooth replacement. Beginning at the anterior end of the series the teeth were replaced one at a time, in regular sequence posteriorly. The next renewal of the front teeth commenced about the time the last of the cheek teeth had been replaced. When the waves of replacement became crowded, perhaps due to accidental injury of some tooth, two gaps might occur.

The evidence for this hypothesis of orderly succession is found in the position of the crowns of the successional teeth beneath their functional predecessors. Beneath that tooth lying just behind the vacant alveolus, regardless of its place in the entire series, the successional tooth has grown well up into the pulp cavity and almost appears to have been pushing the functional tooth out. Each more posterior tooth has its successor less advanced and lower beneath its crown, so far as they are at all visible. Anterior to the gap, however, where the teeth had recently been replaced, the permanent teeth are firmly rooted with no trace of the successional tooth visible from the exterior.

The pair of jaws No. 31025–5 has the vacant alveolus near the back of the series. Behind it one can see the well-developed successional teeth pushing upward below the crowns of their predecessors. At the anterior end of the series, too, the successional teeth also are fully developed and high in the sockets, ready for the next wave of replacement.

In every specimen in which both rami of the jaws are preserved the vacant alveoli of each side are exactly opposite, or in rare cases one tooth apart. In the associated skull and jaws the maxillaries have opposite alveoli vacant, and these are directly above the empty alveolus in the lower jaw. Thus it appears that the succession was not only regular from front to back in the jaws, but also ordinarily progressed simultaneously and at the same rate in both upper and lower jaws, and on both sides of the mouth.

I have carefully scrutinized the specimens for evidence of worn crowns on the teeth about to be replaced but failed to find any noticeable differences between these and the unworn teeth just preceding the diastemata.

Occlusion.—The teeth apparently intermeshed with those of the opposite jaw, the wedge-shaped transverse crowns of the upper cheek teeth fitting into the V-shaped valleys between the lower teeth, and vice-versa. The lower jaw was restricted to orthal and perhaps some strictly transverse motion, so the teeth occluded more or less perfectly, the points of the crowns never opposing one another. In the skull and jaws belonging to the complete skeleton, the teeth were found with the crowns intermeshed in this fashion (although somewhat displaced laterally.) The most posterior maxillary tooth occluded behind the last tooth of the lower jaw.

This interlocking of the teeth may account for the sharp crowns always observed on unbroken specimens; any wear between teeth of upper and lower jaws would be on the sloping front and back sides of the crowns and tend to sharpen the edge. The occlusion of *Trilophosaurus* thus contrasts strongly with that of *Diadectes*, in which the crowns of the teeth opposed each other and were worn down by grinding or crushing action.

VERTEBRAE

Pl. 32

Trilophosaurus has 24 presacral vertebrae, excluding the proatlas. The seven anterior vertebrae are cervicals and differ from the dorsals in their procoelous centra, hyposphenes, and slender longitudinally directed ribs. The eighth vertebra is transitional from the cervical to dorsal type and might be regarded as a member of either series. It agrees with the cervicals in being procoelous. The neural spine is short, anteroposteriorly, like those of the anterior dorsal vertebrae. The diapophysis is directed downward as in the cervical vertebrae but is shorter and higher, approaching the position typical of the dorsal series. In the articulated skeleton it lay in front of the scapular blade.

Including the eighth vertebra, there are 17 in the dorsal series. The last three of these have short ribs coössified with the transverse processes and may be regarded as constituting a lumbar region. There are two well-developed sacrals. The 27th to 34th vertebrae are preserved at the base of the tail. Two other sections of caudal vertebrae were preserved. One of 11 articulated vertebrae in line behind the skeleton surely belongs with it, and a near-by loop of 11 more may also. A long tail, of 40 or more vertebrae, is indicated.

The vertebrae are characterized by round or compressed centra with expanded articular ends which are procoelous in the cervical and caudal regions and platycoelous throughout the trunk. The thin neural spines are uniformly low and flat truncate and, except for the anterior thoracic vertebrae, nearly as long anteroposteriorly as their centra. The spines become longer than high in the anterior caudals and are reduced to a faint ridge at the top of the neural arch from the middle of the tail backwards. A primitive feature for the vertebral column of a Triassic reptile is the presence of ossified crescentric intercentra throughout the dorsal region.

Proatlas.—Two thin triangular disks are attached to the occipital region of the skull, somewhat displaced from their natural positions above the upper edges of the foramen magnum, projecting backward toward the atlas. The dorsolateral surface of these ossicles is slightly convex transversely. The outer angle is somewhat obtuse, the long median edge slightly concave. There is no trace of a facet for articulation with neural arch of atlas, as occurs in pelycosaurs. The length of the proatlas is 12 mm.

Atlas.—A pair of well-developed neural arches bearing long, needle-like ribs, and provided with strong, posteriorly directed transverse processes lie on each side of the front of the axis. These arches are provided with articular facets for the side of the occipital condyle. The rib tubercle is confluent with these. Behind this rounded anterior portion the bone rises gradually into the transverse process. This is elevated and thin and curves inward toward the spine of the axis at its tip. Above the body of the arches are broad dorsal processes which probably met along the midline to form a complete shield above the spinal cord. Posterior to this shield a facet is developed on the inner side to articulate with the rounded anterior zygapophysis of the axis.

A splint-like rib extends back more than 47 mm., to the center of the axis.

Intercentrum of atlas.—On the left side, below the head of the atlantal arch, lying below the condyle and between it and the axial intercentrum is a thin, transverse, vertical plate of bone. It is enlarged by a rounded anterior projection on the left side; its right end is concealed. It is probably the intercentrum of the atlas, much reduced over the pelycosaur type.

Intercentrum of axis and odontoid (pleurocentrum of atlas).—In ventral view the axial intercentrum is broad and flat. Above, its posterior edge slopes forward rapidly, so that it is wedge-shaped laterally. Its ventral midline is 8 mm. long, its diameter 15 mm. The atlantal centrum or odontoid lies dorsal to it; it is concealed except from above by the atlas arches.

Trilophosaurus is advanced over primitive reptiles in that the odontoid is reduced and does not reach the ventral surface.

Axis.—The axis and all succeeding vertebrae have the arches and centra fused. The centrum of the axis is moderately elongate (25 mm.), round, its sides slightly concave, and bears a sharp ventral keel. The neural arch is massive; its anterior end bears extensive lateral facets upon which the atlantal arches rest. The neural spine is low in front and projects but slightly over the atlas, whose transverse processes flank it on either side. Posteriorly the spine rises in a smoothly convex curve. Its dorsal border thins from the anterior end to above the center of the vertebra and then rapidly widens to a broad, overhanging posterior end. From the caudal end of the spine lateral flanges spread outward, descending to well-developed processes which extend backward above the postzygapophyses. The latter are directed downward and slightly backward. Between them, just above the neural canal, is a pair of broad flat processes which extend posteriorly, embracing the base of the neural spine of the third vertebra, which lies in the narrow slit between them. These processes, which are characteristic also of the other cervical vertebrae, form a protruding shelf between the postzygapophyses which overlaps the succeeding vertebra and completely covers the neural cord.

A pair of slender splint-like ribs articulate with the anterior end of the centrum, near the middle, and extend back nearly to the end of the following vertebra, a distance of 55 mm. The head of the rib is rounded and bears a minute dorsal tubercle.

Posterior cervicals (Pl. 23).—No ossified intercentra could be found in the remaining cervical region, and facets for them appear just posterior to the sixth vertebra. However, a small splint of bone between the second and third vertebrae may be an intercentrum.

The third, fourth, and fifth cervical vertebrae are similar in structure and differ among themselves only in the gradually increasing length and height of the neural spines and in the increasing length of the transverse processes of the more posterior vertebrae. The centra are elongate (32 mm.), gradually increasing in diameter, with weakly procoelous articular faces strongly inclined downward in front and upward behind. The ventral ends of the articular facets recede slightly. The centra are higher than wide posteriorly but widen greatly in front where the transverse processes arise. A weak median keel arises about two-thirds of the way back on the third vertebra, fading out again completely before reaching the posterior end of the centrum. A still weaker keel is present on the fourth; behind that, none.

The neural arches are moderately heavy, arise without a break from the sides of the centra, and enclose a small circular neural canal. They are not swollen like those of cotylosaurs but more nearly resemble the arches of pelycosaurs or phytosaurs. At the level of the zygapophyses they curve inward rapidly to the base of the thin neural spine. The zygapophyses also are strong and diverge sharply from the arch, so that they give the vertebra an X-shaped appearance from above. The widely separated articular facets are flat transversely and nearly horizontal, with slight downward slope forward. Internal to the prezygapophyses, on the upper sides of their peduncles, are facets for the posterior processes of the next anterior vertebra. No shelf is developed between the prezygapophyses, however, and a minute pit lies at the front of the neural spine. There is no hypantrum.

Strong ridges run from the posterior end of the neural spine to the processes which extend backward above the postzygapophyses. The posterior sides of these ridges drop vertically to the surface of the interzygapophyseal plates, which are similar to those described on the axis.

These paired plates are unlike the median hyposphenes of cotylosaurs and certain dinosaurs. They form a protective roof above the spinal cord in the intervertebral space. They arise from the inner side of the postzygapophyses and extend to the midline. A thin median groove separates them. Their distal ends articulate with the top of the neural arch of the succeeding vertebra but do not fit into a recess or hypantrum. The base of the neural spine recedes to accommodate them. These long projections covering the neural canals of the vertebrae must have greatly restricted the dorsal bending of the neck. The flat zygapophyseal articulation and flat articulation of the paired posterior processes with the neural arches permitted a fair amount of lateral motion. The notch at the base of the anterior border of the neural spine permitted the ends of the posterior processes of the preceding vertebra to pass the midline as the neck was bent from side to side. The neck could only be elevated as a whole from the flexible articulation at its base.

The cervical vertebrae described by Case (1922, pp. 80–81, fig. 31; 1927, p. 211) as *Coelophysis* aff. *longicollis* Cope have similar paired processes from the postzygapophyses. These vertebrae are slightly larger than the largest *Trilophosaurus* vertebrae in The University of Texas collections. The cervical vertebrae differ from those of *Trilophosaurus* in being amphicoelous and in having taller neural spines. The remainder of the *Coelophysis* vertebral column differs in many respects from that of *Trilophosaurus.* It is remarkable that such an unusual structure of the cervical vertebrae has developed so similarly in two reptiles as distantly related as *Trilophosaurus* and a small dinosaur. Perusal of the available literature has revealed no other reptile with such an interzygopophyseal shelf. The cervical vertebrae of *Trilophosaurus* differ from the type of *Ceolophysis longicollis* Cope as redescribed by Huene (1906, p. 118; 1915, pp. 500–502) in having a strong, median, ventral ridge on the centrum of the atlas and following vertebrae instead of the anterior, paired, ventral ridges which occur on the atlas and other cervical vertebrae of *Coelophysis.*

The neural spines arise over the center of the vertebrae; they are low, thin, long, and truncate at the apex. That of the third vertebra is considerably shorter than the centrum. Those of the fourth and fifth expand anteroposteriorly just above the level of the zygapophyses. They are about three-fourths the length of the centra. The spine of the sixth vertebra is again shorter and expands only anteriorly.

Cervical ribs appear to be fused to the transverse processes. Only a single process can be distinguished on the third vertebra. It is situated about midway up the side of the centrum.

The preserved portion of the third cervical rib is the length of the centrum but presumably was originally longer.

The parapophyses of the third vertebra are small round projections from the lower outer edge of the anterior end of the centrum. The diapophyses are a short distance above them at the side of the centrum near the base of the neural arch. They are thin dorsoventrally and extend back about 1 cm. along the side of the centrum. The tip of each is in contact with the rib throughout its length and apparently fused to it. The parapophyses become successively lower on the posterior cervicals, so that the lower anterior edge of the centrum of these vertebrae is nearly straight and wider than the height of the centra. The diapophyses are clearly downgrowths of the neural arches and increase in length to the seventh vertebra. The lower end reaches the level of the bottom of the centrum. They likewise increase in size posteriorly from the third to the sixth vertebrae. That of the seventh, however, is distinctly more slender than the preceding, although longer. The vertebrarterial canal increases in size rapidly posteriorly, as both the transverse processes and heads of the ribs elongate.

The longitudinally placed splint-like cervical ribs appear to be fused to the transverse processes. Beginning with the fourth vertebra, the ribs project slightly anterior to their articulations at the front of the centra and thus overlap the preceding vertebrae. The anterior projections increase in length to the seventh vertebra and then rapidly are reduced to small crests on the anterior edges of the ribs at their angulation.

The neural canal increases in size posteriorly.

The zygapophyses gradually become inclined inward on the posterior cervicals. They remain flat and stout. Strong buttresses above the postzygapophyses end in slight processes which diminish in size to the eighth vertebra, behind which they vanish. The paired processes between the postzygapophyses are similar throughout the cervical series but are absent at the rear of the last cervical.

The last cervical vertebra (7th of series) merits special description as it is transitional to the dorsal type. Besides the absence of interzygapophysial processes, it differs from the preceding cervicals in having a markedly shorter (anteroposterior) neural spine which does not increase in length above the base, in its considerably shorter centrum (24 mm.), and in the pronounced ball-like posterior articulation of the centrum which recedes greatly ventrally to admit the intercentrum of the first thoracic. The lower outline of the round centrum is strongly concave, its posterior end much lower than the anterior. As has already been mentioned, the diapophysis, although still directed downward and reaching the level of the base of the centrum, is more slender than that of preceding vertebrae. Most of these features are further developed in succeeding anterior dorsals.

Dorsal vertebrae (Pl. 25).—The 8th vertebra is regarded as the first dorsal, although it shares some characters of the cervical series not found more posteriorly. Its centrum is short (23 mm.), procoelous, and widened anteriorly as in the cervicals, with parapophyses arising at the lower corners of its anterior face. It is strongly concave in ventral profile.

The neural arch is correspondingly shortened and is less massive than in the cervicals. The neural canal is wider than high. Zygapophyses are large and slope inward at about a 30° angle. The postzygapophyses are buttressed dorsally by strong ridges from the base of the neural spine. The diapophysis of the 8th vertebra arises from the front half of the neural arch opposite the middle of the neural canal and extends forward and laterally, being only slightly depressed. It is horizontal and flat in cross section.

Neural spines of the anterior thoracic vertebrae are moderately tall but short anteroposteriorly, amounting to only one-third the length of the centrum. They are slightly ridged before and behind, thicker than those of other vertebrae, but truncate and unswollen at the top. The spine of the 9th vertebra is most slender, and beginning with the 11th the spines again become elongate and flat topped.

The ninth vertebra is undoubtedly a thoracic dorsal; it has the platycoelous centrum and heavy transversely directed diapophyses typical of the thoracic region. Its zygapophyses are smaller and less widely separated than those of the cervical vertebrae and lack the projecting processes above the posterior pair. The centrum is the shortest in the entire column (22 mm.) with round articular ends, strongly concave at the sides, slightly keeled below. Parapophyses form strong swellings slightly below the middle of the expanded anterior end. The ventral border of the posterior surface is inclined forward to accommodate the succeeding intercentrum. The neural arch is slightly wider than the constricted centrum. Anteriorly it gives off the massive diapophysis, which extends the full height of the neural arch. This process is triangular in section, with its upper side horizontal, the anterior face sloping backward and downward to the ventral angle, and the posterior face slightly convex and nearly vertical. The upper surface of the diapophysis curves downward slightly distally; the process expands to its truncate end which faces outward and downward.

Above the neural canal the arch turns medially abruptly forming a horizontal shelf at the level of the zygapophyses and top of the diapophyses. Small ridges run backward from the prezygapophyses to beyond the middle of the vertebra. From the center of the arch the slender, posteriorly sloping neural spine rises. Ridges run from it to the postzygapophyses, but as these are adjacent to the spine the buttresses are not conspicuous.

The 10th vertebra is similar to the 9th but longer and with a larger spine and more closely placed zygapophyses.

The 11th vertebra differs from the most anterior thoracics in having a slightly broader spine anteroposteriorly and in the form of the transverse processes. The diapophyses are situated just in front of the middle of the vertebra and extend out horizontally from the level of the top of the neural canal. The section is triangular, with the anteroventral face sloping backward. Near the junction of the ventral angle of the diapophysis with the centrum a ridge extends forward and downward to the anterior end of the centrum, swelling to form the parapophysis near its lower end. A small recess lies between this ridge, the buttress of the anterior zygapophysis, and the diapophysis, and a depression of slightly larger size occurs just behind the diapophysis, below the shelf-like top of the neural arch.

The 12th to 21st vertebrae inclusive may be termed the posterior thoracics; they lie behind the pectoral girdle and are so similar in size and form, except for the last two, that they would be difficult to differentiate in a disarticulated specimen. All are characterized by moderately long and slender centra, slightly and symmetrically concave below, the middle of the centra laterally compressed and angulate at the base, though scarcely keeled. The neural arches are not greatly different from those of the preceding vertebrae except that they are longer and narrower. The zygapophyses are close to the midline and have strongly curved facets placed at about a 45° angle to the sagittal plane. Their width decreases to the 19th vertebra and then increases again as they become less curved and more nearly horizontal toward the lumbar region.

The capitula of the ribs no longer articulate with parapophyses arising from the centra but from facets at the end of the lower edges of the diapophyses. Beginning with the 12th vertebra these processes become concave posteriorly. The flat upper surface extends farther posteriorly and withdraws from the anterior zygapophysis until the base of the process is triangular, with its slightly concave anterior surface nearly vertical and its posterior surface sloping sharply forward and downward. The processes extend horizontally from the level of the top of the neural arch and curve back somewhat at their upper ends which thus lie behind the narrow lower end, which is slightly below the level of the base of the process and directly lateral to the middle of the centrum. The change in form thus is brought about by a progressive posterior migration of the upper side of the diapophysis together with development of concave instead of plane anterior and posterior faces and attenuation of the lower edge. Distinct recesses in the neural arches lie in front of and behind the bases of each process. With the 18th vertebra the processes begin to thicken distally, the ventral portion becomes less pronounced, and the sides lose their concavity so the process becomes suboval, with the long axis inclined slightly downward anteriorly, and in the 21st vertebra, rounded triangular with the long side above and obtuse angle below. This condition is obviously transitional to the lumbar region, in which the ribs are fused to similar processes. Throughout the posterior thoracic region the neural spines are of uniform height, flatly truncate dorsally, thin, and nearly as long as the centra.

Lumbar vertebrae.—The last three presacral vertebrae (22–24) are distinguished by the presence of fused ribs. These are single headed and attach to the ends of massive triangular diapophyses. The centra in the lumbar region shorten considerably from the mid-dorsal length and are no longer compressed but round in cross section. The zygapophyses are more massive, with flat or nearly flat facets set at a low angle above horizontal. The spines shorten anteroposteriorly commensurate with the shortening of the centra.

Sacral vertebrae (Pl. 25, fig. 2).—Two well-developed sacral vertebrae are present. No coössification of the sacral vertebrae occurred, and their zygapophyses, platycoelous centra, and crescentic intercentra are all typically developed. The firm attachment to the ilia would have prevented intervertebral movements, however. The neural spines are not different from the adjacent regions.

The transverse process of the first sacral (25th vertebra) arises at the level of the neural canal throughout the entire length of the arch and is strongly buttressed below by a salient toward the anterior end of the centrum. Distally the process curves downward slightly, thickens ventrally in the posterior part, and extends forward and slightly backward so that the distal end is twice as long as the base. The facets for the ilium are vertical and converge posteriorly.

The second sacral vertebra has a more robust centrum, from the sides of which arise the transverse processes. These are deeper dorsoventrally than those of the first sacral but not nearly so long anteroposteriorly, nor do they extend so far from the centrum.

Caudal vertebrae (Pl. 24).—In the caudal region the centra are procoelous, except rare distal caudals which are shallowly amphicoelous. The first 3 caudal vertebrae have short, stout centra, wider than high, sharply concave in ventral profile. The zygapophyses are rather widely separated (comparable to the cervical region), large, and sloping inward at about 45°. The neural spines are somewhat shorter than the centra, as high as those of the dorsal region, and like them truncate above. From the middle of the neural arch at the level of the top of the centrum arise stout horizontally elongate diapophyses which are flat, slightly down-curved, and curved slightly posteriorly at the tips. Crescentic intercentra precede the first two caudals; an elongate Y-shaped haemal arch follows, between the second and third caudal vertebrae.

The fourth caudal (30th of whole series) has a longer and more slender centrum and a somewhat lower neural arch which is correspondingly elongated anteroposteriorly. Thus is initiated a trend which is rapidly carried on by the succeeding vertebrae. The centra become absolutely longer up to a point and then very gradually decline in length, whereas the diameter falls off rapidly at first and then slowly. The neural spines become as long as the centra and steadily decrease in height. Beginning with the 8th caudal the upper end of the spine becomes shallowly emarginate. The spines decrease in height until only a slight keel is present on the top of the neural arch. This structure remains about as wide as the body of the centrum and is flat sided and flat topped, with a distinct lateral angle. It becomes saddle-shaped, high in front and behind, reflecting the tendency seen in the concave topped neural spines.

The zygapophyses decrease in size at first but remain well developed throughout the caudal series, their plane facets inclining inward at a 45° angle. The transverse processes rapidly dwindle to short anteroposteriorly elongated nubbins near the middle of the vertebra at the point of union of centrum and arch. They persist about as far as the neural spines.

Beyond the 8th caudal is a gap in this specimen, so the characters of the transitional vertebrae have been taken from numerous isolated specimens.

The chevron bones rapidly decrease in length and then become elongate anteroposteriorly, extending keel-like beneath the junction of the elongate centra, always overlapping the posterior vertebra more than the anterior. The keel is thin and deep, rounded at the ends, and supported by two short limbs anterior to its mid-point which form the arms of the Y which is fused to the thin crescent that articulates with the vertebrae.

There are no complete specimens of the tail, and the break in the articulated skeleton behind the 8th caudal prevents accurate estimation of the amount of taper. A section of 11 vertebrae was found in line with the skeleton and a short distance behind it. These probably belong to the same individual and may have been nearly in place. A third string of 11 caudal vertebrae, smaller than the second section, was found in a loop near the front of the animal. This may not belong to the same individual but might well, from its size. It shows marked decrease in diameter of the centra and somewhat shorter vertebrae. The end of the tail is not present, however. The extreme elongation of the caudal vertebrae suggests that the animal possessed an unusually long tail—very probably 40 or more vertebrae were present.

Vertebrae of *Trilophosaurus* are similar in size and general appearance to those of a small dinosaur, *Coelophysis* Cope, which occurs in the same deposits (Huene, 1906, p. 118; 1915, pp. 500–507; *Spinosuchus caseanus*, 1932, pp. 37–42; Case, 1922, p. 80; 1927) from which they may be distinguished by the presence of procoelus centra in cervical and caudal regions and spaces for intercentra between the ventral rims of the ends of the centra.

RIBS

Pl. 25, figs. 4–8

The cervical ribs have been described in connection with the vertebrae. They are elongate, straight, slender bones running parallel to the sides of the centra. Those of the atlas and axis are single headed (or practically so); more posteriorly there are double articulations, which remain close together, however. It is uncertain whether the ribs are fused in this region. A slight tendency for the shaft to grow anterior to the capitulum may be noticed in the posterior part of this series.

The seventh, or last cervical, rib has a large capitulum turned inward at a high angle from the shaft, which is directed backward and downward. Its articular facet is oval and slightly concave. The tuberculum is a longer, more slender, laterally compressed process which turns inward from the shaft of the ribs similarly to the head but is directed more dorsally so that there is an open angle between them. A similar but more exaggerated development of these processes is seen on the 8th, or first dorsal, rib. A stout elongate process extends outward from the anterior edge of the shaft of the 8th rib at its point of flexure. The 9th rib has a stout, well-developed shaft which extends downward, curving backward very slightly from the head. The capitulum is in line with the medial edge of the shaft. A moderate notch separates it from the tuberculum, which diverges upward, is somewhat shorter, and has considerably the larger facet. About 1 cm. below the union of the processes a sharp keel arises on the anterior edge of the rib and continues, diminishing gradually, distally. The posterior surface is flat, smoothly rounding into the edges.

The 10th and 11th ribs are similar, with less strongly developed anterior ridges and with a smaller notch between the heads. Beginning with the 12th rib the heads are confluent, forming a short, deep, oval articular surface moderately constricted medially. The slender, round shafts bear slight anterior grooves. The size of the head decreases abruptly behind the 12th rib and then declines very slowly posteriorly. In the posterior dorsal region the rib heads gradually become nearly oval, changing in about the same manner as the facets on the transverse processes of the vertebrae. The ribs also gradually shorten, become straighter, and more laterally directed. As has been noted, the 3 lumbar vertebrae have ribs fused to the transverse processes.

Abdominal ribs.—The trunk region of the articulated specimen was thickly strewn with a mass of thin, slender bones, which had been so disarranged that neither their number nor arrangement could be observed. Such abdominal ribs occur in many reptiles, commonly with a V-shaped arrangement, and frequently segmented. No trace of segmentation was observed, perhaps due to excessive transverse cracks in the bones. The abdominal ribs are thinner than the costal ribs, flattened oval in cross section.

PECTORAL GIRDLE

Text fig. 7; Pl. 26

The scapulocoracoid is primitive and somewhat pelycosaur-like in the anteroventral expansion of the scapula and large coracoid plate. It is distinctly advanced over the primitive condition in the loss of the metacoracoid and strong posterior development of the procoracoid. The glenoid, too, has shortened considerably and lost the primitive screw shape. It is a large, outwardly directed notch with strong dorsal (scapular) and ventral (coracoid) rims and a saddle-shaped articular surface which is concave dorsoventrally and convex anteroposteriorly, with a posteroventral extension which may have limited motion in this direction. The anterior edge turns far inward and the girdle recedes in this direction, indicating that the humerus could be extended anteriorly. Clavicles and interclavicle are normally developed.

Scapula.—The scapula is tall, its upper end blade-like and expanded, higher at the posterior angle, its slightly uneven termination suggesting continuation by a cartilaginous suprascapula. The posterior border is nearly straight to a point just above the glenoid fossa where it turns abruptly backward to the suture with the coracoid. In the glenoid region the bone thickens to such an extent that the suture area immediately medial to the glenoid fossa exceeds that surface in size. The well-developed supraglenoid process already has been mentioned. A short distance above and in front of the glenoid, on the line of sharp curvature separating the lateral and ventral aspects of the scapula, is a stout tubercle which probably indicates the tendinous origin of the lateral head of the triceps.

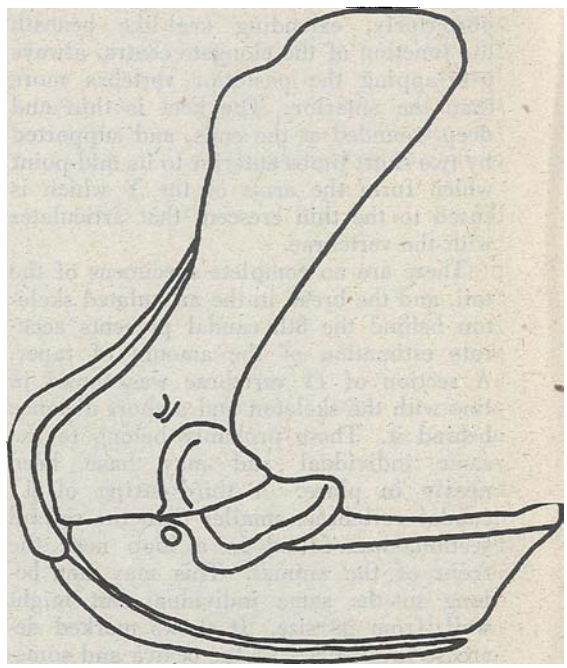

Fig. 7. *Trilophosaurus buettneri* Case, x½; restoration of pectoral girdle, side view.

The supraglenoid buttress is reduced to a small equilateral triangular area between the dorsal extremity of the glenoid fossa and the rounded ridge above the scapulocoracoid suture. It vanishes almost at once dorsally into the rounded posterior edge of the scapular blade. There is no supraglenoid foramen. The anterior border of the scapula is straight above, sloping downward and backward to the acromion region where the blade is reduced to a narrow stem. Here the border is concave. Ventrally the blade swells anteriorly again and turns rather sharply inward (although the extreme angulation in the preserved specimen undoubtedly is largely due to crushing) to form an extensive ventral plate. The anterior border in this region is unfinished, suggesting cartilaginous extension.

Near the narrowest point of the scapular blade a small ridge arises on the lateral surface close to the anterior border and runs upward, soon becoming confluent with that border. Below this ridge the border thins, and its sharpest curvature passes from the outer to the inner side. Most probably the point represents the upper end of clavicular articulation. If this be so, the clavicle was of moderate length and overlapped the lower fourth of the vertical portion of the scapular border, becoming free from it and passing anterior to the procoracoid cartilage.

The homology of the ventral portion of the "scapula" is dubious. It lies anterior to and below the glenoid fossa, in the position of the anterior coracoid of primitive reptiles. No sign of a suture or surface irregularity between this region and the scapular blade can be detected. However, the scapula and anterior coracoid of pelycosaurs frequently fuse without trace of the suture, as noted by Romer (1940, p. 119). There is reason, however, to believe that this bone is actually a part of the scapula; for the coracoid is pierced by the supracoracoid foramen like the procoracoid of primitive reptiles, which is homologous with the archosaur and rhynchocephalian coracoids rather than with the posterior or true coracoid of therapsids and mammals.

Coracoid.—The coracoids are broad, posteriorly elongate, plate-like elements, slightly concave dorsally, and strongly developed in the glenoid region. They fail to reach to anterior edge of the girdle, the anteroventral plate of the scapula separating them from the clavicles. A heavy rounded buttress lies internal to the glenoid socket and articulates with the correspondingly enlarged base of the scapula. The lower lip of the glenoid is thick and overhanging. A coracoid foramen is present close in front of the lower edge of the glenoid rim and shows that the element is homologous with the coracoid of diapsids and anterior coracoid or procoracoid of primitive and mammal-like reptiles.

In front of the glenoid the anterior edge of the coracoid is thin. It runs forward and medially to a rounded point near the midline. It is not clear whether the scapula and coracoid were suturally united along this line, or separated by a narrow notch such as is present in lizards. The medial border of the coracoids is straight and thin. The bone surface is unfinished, suggesting cartilaginous extension or articulation with the stem of the interclavicle. The relationships to the interclavicle are uncertain; in the articulated skeleton the coracoids have been displaced and overlap considerably, entirely ventral to the interclavicle.

Posteriorly the coracoids are well developed. The length of the bone is more than twice its width. Heavy lateral edges extend back from below the glenoid, and turn outward distally to rounded terminal processes. The lateral border is flat and broad and separated from the dorsal surface by a sharp angle which is produced into a slight ridge near the posterior end. The posterior border is somewhat thickened. Although evenly rounded it lacks periosteal lamellae and may have articulated with a cartilaginous sternum.

Clavicles.—The dermal girdle is represented by small clavicles and a slender interclavicle of peculiar construction. Only a portion of the right clavicle is preserved, and its mode of articulation with the scapula is uncertain, although it probably embraced the acromion region in the manner suggested above. The preserved portion is convex anteriorly and deeply grooved posteriorly, especially near the center. Medially the upper ridge drops to the level of the upper surface of the bone over the articulation with the interclavicle; laterally the bone becomes higher and loses the thick lower edge. On the ventral surface at the medial end is an abrupt offset and tapered facet for articulation with the interclavicle.

Interclavicle (Pl. 26, figs. 1, 2; text fig. 8).—As preserved, this element is dorsal to the horizontal plates of the coracoid and scapula and displaced to one side so that it is partially distorted. The anterior end is broad and divided by two rather deep notches into three processes, of which the median is both widest and longest. Behind the notches are shallow depressions on the dorsal surface of the bone in which the medial ends of the clavicles were lodged. The lateral processes diverge strongly and are in reality merely continuations of the lateral borders of the anterior triangular plate of the bone, which thus resembles an arrow-point. The sides converge posteriorly and merge with a short narrow stem which is faintly grooved dorsally. From this stem, slightly anterior to the glenoids, suddenly emerge a pair of flanges which triple its width. The remainder of the bone is a thin plate, slightly concave dorsally as preserved, which gradually narrows posteriorly to a point well in front of the posterior ends of the coracoids. The anterior portion of the bone is convex dorsally anteroposteriorly, but one can not be sure that the present curvature is not entirely the result of crúshing. The total length is 107 mm.

The peculiar form of this element, and the absence of other similar bones from the extensive collection from Quarry 1, leads me to suspect that it may be damaged. A fairly well-preserved interclavicle (No. 31025–144) found in the quarry may possibly belong to *Trilophosaurus*. It resembles the spoon-shaped interclavicle of the pelycosaurs rather closely in its proportions and general form but lacks the cross ridge on the ventral surface of the bowl, which is characteristic of that order. The expanded anterior end of the bone curves upward strongly both in front and at the sides. It is wider than long. The anteroposterior stem forms a median ridge on the lower surface of the bowl. The dorsal surface is produced over the center of the anterior end in a spout-like lip. On

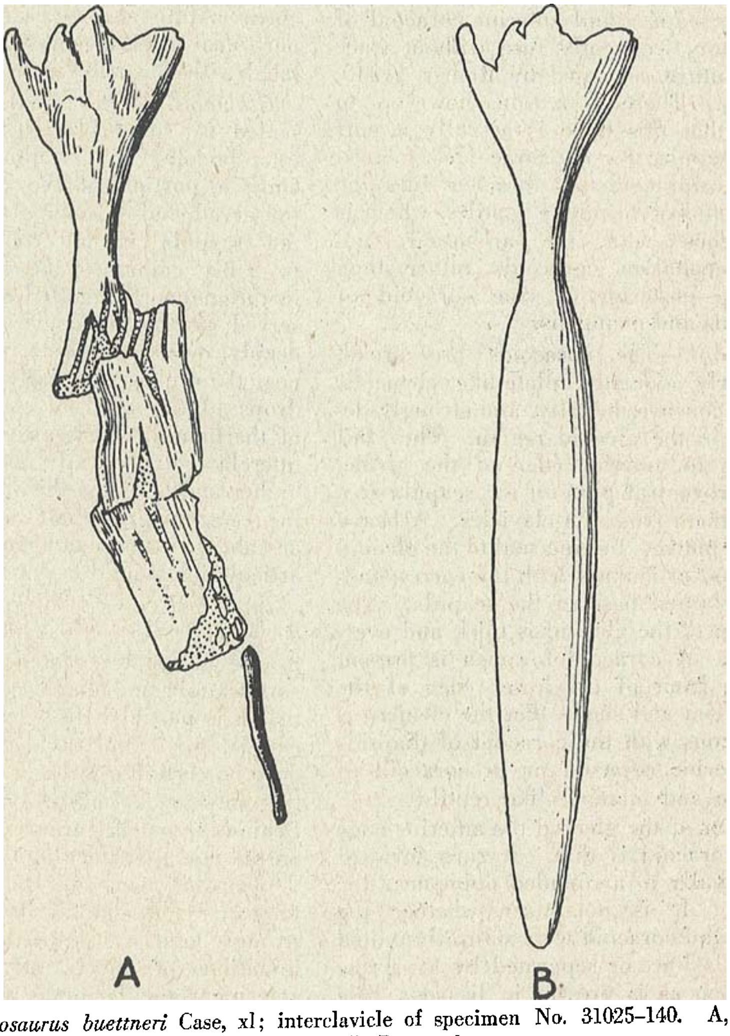

Fig. 8. *Trilophosaurus buettneri* Case, xl; interclavicle of specimen No. 31025–140. A, As preserved, dorsal view. B, Restored.

each side of this are deep grooves for the clavicles, directed forward and downward. The blade of the interclavicle did not extend forward above the clavicles to any extent. The posterior edge of the expanded portion is thin and concave, merging with the sides of the stem. The stem is relatively more stout than of pelycosaur interclavicles, rather thick proximally, and thinning posteriorly. It widens slightly at the center and then tapers toward the end.

This interclavicle is so different from that found with the articulated *Trilophosaurus* skeleton that it is difficult to believe that it belongs to the same animal. But as has been mentioned before, the interclavicle with the complete specimen appears to be imperfect. No other reptile which might have had an interclavicle like that just described has been recognized in Quarry 1. Phytosaurs have a flatter, broader stemmed interclavicle with less expanded anterior end and deeper notches for the clavicles at the front of the ventral surface.

Comparisons.—The pectoral girdle of *Trilophosaurus* has advanced over the primitive reptilian condition found in cotylosaurs and pelycosaurs in the simplification of the glenoid cavity, loss of the metacoracoid, loss of the glenoid and supraglenoid foramina, loss of the cleithra, and increase in size of the procoracoid. Its development has followed a different line from the Therapsida, for there has been no development of an acromion, the metacoracoid is lost, and a small supraglenoid buttress is retained.

The closest resemblances to *Trilophosaurus* are found among the Lepidosauria, that is, the Rhynchocephalia, Squamata, and Eosuchia. The form of the interclavicle, however, is divergent from the T-shape characteristic of these. If specimen No. 144 belongs to *Trilophosaurus*, it is of the primitive reptilian pattern. The girdle is not far removed from the common type which gave rise to both the lepidosaurian and archosaurian girdles. It is specialized chiefly in the strong posterior extension of the coracoid plates. This feature suggests the Sauropterygia, most particularly some plesiosaurs. The resemblance is merely indicative of strong subcoracoid musculature and can not have much phylogenetic significance. The nothosaurs, which are far less specialized sauropterygians, have a strikingly different girdle, with extensive emargination of the medial coracoid border. The high scapula, indicative of terrestrial habits, strongly contrasts with that of the sauropterygians.

The small supraglenoid buttress, no longer sharply separated from the outer surface of the scapular blade, and the anterior tubercle for the triceps, show an intermediate condition between the primitive reptilian type and that found in lizards.

Most archosaurs are advanced over *Trilophosaurus* in the reduction of the clavicular girdle. They differ further in generally having relatively small coracoids which do not extend posteriorly to the glenoid. In the Crocodilia the coracoids are large but differ in position and shape, and the clavicles are completely lost. Phytosaurs retain the clavicles and interclavicle, but have a reduced coracoid.

Altogether, the pectoral girdle of *Trilophosaurus* shows no special affinity to any other group and supports the view that it is an isolated offshoot of a primitive nontherapsid stock.

PELVIC GIRDLE

Text fig. 9; Pl. 28

Although the pelvis of the articulated specimen is badly crushed, broken, and inseparable in part from the sacral vertebrae, numerous isolated elements and several nearly complete pelves are fortunately available for study. The general form is rather primitive and plate-like, narrow and deeply V-shaped in cross section, with the acetabulum high up, close to the ilio-sacral articulation. It thus does not differ greatly from the pelves of pelycosaurs, phytosaurs, rhynchosaurs, and other groups of primitive reptiles.

Ilium.—The ilia have low, thin spines, which project far posteriorly to a point, but have no preacetabular processes. The upper edge is even and flat from the end of the spine to slightly forward of the center of the acetabulum, where it curves downward sharply and joins the anterior edge of the bone. A strong tubercle for the iliofemoralis is developed at the center of the upper edge of the imperforate

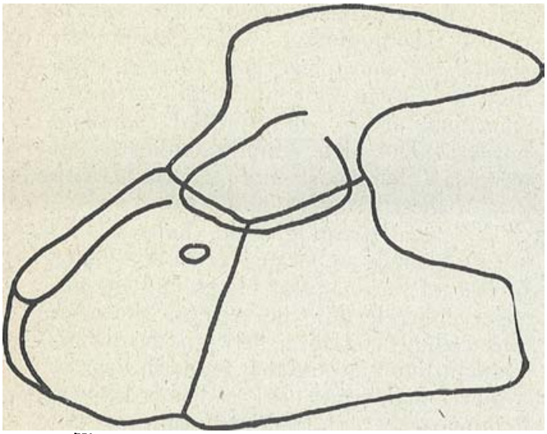

Fig. 9. *Trilophosaurus buettneri* Case, x0.5: lateral view of pelvis.

acetabulum. Behind this is an open notch bounded posteriorly by the thick posterior peduncle. The pubic peduncle is a strong rounded ridge which arises at the ilio-femoralis origin and forms a rounded ridge overhanging the anterior edge of the acetabulum. The medial surface of the spine is slightly concave above the roughened area for sacral attachment. The anterior sacral rib is attached to a strong facet just above the superacetabular constriction, but the second left little impression on any specimen.

The articular surfaces for pubis and ischium are flat and rough and meet at a somewhat variable angle anterior to the center of the acetabulum, so that the ilio-pubic suture is always the shorter. The sutural surfaces widen away from this point, which is very thin in some specimens, to strong areas at the anterior and posterior ends.

The ilium differs from that of rhynchosaurs and archosaurs in the absence of an anterior crest. Among pelycosaurs the closest resemblances are found in primitive forms such as *Ophiacodon* and *Varanops*, which differ from *Trilophosaurus* in the more inclined upper border of the ilium, lesser development of the supra-acetabular crest, and presence of an inwardly directed articular process medial to the spine.

The heavy anterodorsal ridge on the acetabulum, which may mean an upright pose of the rear limbs, and the high position of the acetabulum suggest archosaur affinity, but the accompanying forward growth of the spine is not yet present.

Pubis (Pl. 29, figs. 1, 2).—The pubis is large and plate-like, meeting the ischium in an extensive transverse suture. The plate is concave externally and faces as much backward as outward and only slightly downward. The anterior margin curves outward sharply and is concave to just above its outer end, which rounds rapidly to the lower surface. A moderate-size oval pubic foramen lies near the posterior border slightly below the rim of the acetabulum. Medially the pubis presents two surfaces: a smaller, more posterior, concave area equal in width to the length of the ilio-pubic suture, extending downward and inward from the acetabulum to the symphysis, and a large plane area facing forward and inward, with free lower margin. The pubic foramen pierces the more posterior surface in its upper vertical portion. The symphysis is short and deep, especially anteriorly where it ends abruptly in a vertical line at the junction of the anterior and medial surfaces of the bone.

Ischium (Pl. 28, figs. 3, 4).—The ischia are plate-like, slightly larger than the corresponding pubes, and, unlike the latter, essentially plane. The anterior margin drops straight from the acetabulum to the median symphysis and shows plainly that there was sutural contact with the pubis except for a small median foramen where the corners of all four elements are rounded off. The posterior border is thick and drops somewhat over a third of the height of the plate before curving backward sharply to form a posterior wing. Thence the border runs nearly parallel to the symphysis to the rear of the bone which is rounded-truncate. The thickened buttress from the posterior end of the acetabulum continues as a ridge on the inside of the plate in a straight line sloping posteriorly to the median symphysis, where it meets the corresponding ridge of the opposite ischium in a firm union. The ridge divides the inner surface into two areas, the larger anterior. The outer surface is plane below the slightly outturned lower edge of the acetabulum.

The outwardly directed anterior end of the pubis suggests the trend toward upright position of the rear legs shown in early thecodonts such as *Aetosaurus*, although less developed. The ischium is not more produced posteriorly than in the pelycosaurs, however, and there is no tendency toward forward migration of the iliac spine. The heavy anterodorsal buttress of the acetabulum also suggests upright pose of the limbs, and as will be seen the form of the femur in part substantiates this. However, there has been no emargination of the ventral border of the pelvis, and it is unlikely that *Trilophosaurus* brought its legs into a vertical plane below the body except perhaps when running rapidly.

The pelvis throws little light on the affinities of *Trilophosaurus*. Aside from the obviously primitive features it shows no special resemblances to any of the synapsids and definitely has nothing to do with the more advanced therapsids which have an elongate and forwardly directed iliac spine and large obturator foramen. It bears more resemblance to the Archosauria but is little developed in that direction. Relationships to the Lepidosauria are obscured by the size difference between *Trilophosaurus* and most of the known primitive members of that group. The rhynchosaurs have a similar ischium, but their pubis is specialized by the development of a lateral spine. The difference between the ilia has been noted above. The pelvis suggests an early stage of the pro-diapsidan stock, separate from other known groups and slightly more primitive than other Triassic types.

LIMB BONES

Humerus (Pl. 27, figs. 1–3).—Besides the humeri associated with the articulated *Trilophosaurus* skeleton over 40 isolated specimens have been recovered, which give a good picture of the form and variation of every part of this bone. The humerus is moderately long, with a slender shaft and widely expanded ends. The distal surface is twisted backward through an angle of about 35 degrees from the proximal, a considerable reduction from the primitive condition, comparable to that in modernized reptiles. It is not necessarily indicative of a posterior shifting of the distal end of the humerus correlated with upright pose, for lizards, crocodilians, and other reptiles with sprawling gait have a similar angle. The large development of the coracoids as well as the construction of the glenoid suggest that the humerus was normally held nearly at right angles to the body in walking. A well-developed groove replaces the ectepicondylar foramen, and the entepicondylar foramen is absent.

The head consists of a posterior convex articular surface which continues forward into a narrow concave region and terminates anteriorly in a lesser expansion. This structure conforms closely to the saddle-shaped glenoid with its posterior concave extension.

The proximal border curves downward and away from the head anteriorly to the swollen deltopectoral crest. The posterior part of that border likewise drops away from the head to an equally prominent process for the subcoraco-scapularis. This lies only slightly below the plane of the head, which in some specimens continues posteriorly along the sloping border to the base of the rugose muscular insertion. (See No. 31025–66–I.) Distal to these processes, the anterior and posterior borders converge rapidly to the straight shaft. The proximal dorsal area is rather evenly convex with a slightly flattened area adjacent to the concave portion of the head in those specimens showing the least distortion. A distinct low ridge just above the rounded anterior edge of the bone runs posteriorly from the deltopectoral crest nearly to the straight portion of the shaft; this probably indicates the position of the tendinous insertion of the deltoid. Ventrally the expanded proximal end of the bone is concave, the anterior border turning downward more abruptly than the posterior. The shaft is moderately stout for the length of the bone, of which it forms the middle third. Its anterior face is flattened and confluent with the ventral surface of the distal end; elsewhere the shaft is round and without noticeable ridges.

The distal end is expanded about as much as the proximal. In some specimens one end is wider and in others the opposite end is. This variation may be in part the result of differential crushing. The distal expansion is in a single plane which is tilted posteriorly (considering the upper surface) from the plane of the head at an angle of 25 to 45 degrees in specimens of moderate distortion, the mode, and also mean, of 13 specimens being close to 35°. Its dorsal surface is nearly flat, with a short rounded median ridge leading up to the enlarged portion of the ulnar condyle and separating a groove back of the trochlea from the remainder of the surface. The anterior or external edge is also somewhat swollen above the radial condyle. The ectepicondylar groove is strong and extends back along the anterior edge of the bone to near the junction of the shaft and enlarged distal end. It is open dorsally and laterally except near its distal end where a slender process curves upward outside it from below. There is no supinator crest. The inner epicondyle is well developed but lacks a foramen. Its posterior edge turns sharply proximally from the ulnar condyle, which may partially extend beyond onto the backwardly directed surface. Its proximal end is rugose indicating tendinous origin of strong flexors of the forearm and manus.

The distal ventral surface is slightly convex and extends evenly from the entepicondyle to the rim below the ectepicondylar groove. The two subequal condyles face mainly downward, are separated by a narrow trochlea ventrally, and lie close to the anterior or external side of the bone. Behind them extends the large inner epicondyle. Reference has already been made to the extension of the distal ventral surface along the anterior face of the shaft nearly to the pectoral process. From this it is inferred that the brachialis was well developed in the primitive position, with no tendency to arise from the dorsal side of the humerus proximally.

Among other reptiles the humerus compares well with those of some lizards, and better with larger rhynchocephalians, such as *Champsosaurus,* from which it differs in the slightly lower angle between the ends, the longer shaft, and incomplete ectepicondylar foramen. The rhynchosaur *Stenaulorhynchus* has a similar humerus with an incomplete estepicondylar foramen. The ends of the bone are more expanded than in primitive saurischians, or in phytosaurs; the general proportions of the bone approach the latter group. From therapsids the humerus differs importantly in the presence of an ectepicondylar groove and even more so in the absence of the entepicondylar foramen. The details of the humerus suggest that *Trilophosaurus* is more closely related to the Lepidosauria than to other groups.

Radius (Pl. 27, figs. 4–6).—The radii are shorter than the ulnae, have more slender and, distally, less compressed shafts. The head is prolonged backwards to a point, which is somewhat higher than the anterior edge of the humeral facet, and fits against the outer edge of the head of the ulna. Proximally the shaft is strongly compressed, flat laterally and rounded medially, opposite to the form of the ulna. Its medial surface is smoothly convex. Somewhat below the middle the shaft thickens and becomes equidimensional, somewhat flattened on the sides, and rounded on the anterior and posterior edges. Thence to the distal end it increases slowly in diameter, becomes wider than thick anteroposteriorly and convex behind, flat in front. Most specimens show sigmoid curvature of the shaft, which is concave anteriorly near head and then convex anteriorly to distal end. A small facet is present on the medial side of the posterior point of the head, which fits against the outer side of the ulna just below the facet for the humerus. The distal end has a rounded triangular facet which is slightly concave on the lateral and convex on the medial portion.

Ulna (Pl. 27, figs. 7–9).—Radius and ulna are considerably shorter than the humerus, and of the two the ulna is the longer and stouter. Its shaft is strongly compressed laterally, the medial side flat, the lateral gently convex, with sharp anterior and posterior ridges separating the two. The posterior border is prolonged behind the concave facet for the humerus to about the same extent as in the pelycosaurs. A low ridge extends down the outer surface from near the center of the head for about 2 centimeters and merges into the smooth surface of the bone. In front of this ridge, on the lip of the sigmoid notch, is a small concave facet into which the head of the radius fits. At the posterolateral corner of the head a second weaker ridge arises and passes nearly to the middle of the shaft, forming a slight angle between the lateral and posterior surfaces. The distal end is elongated anteroposteriorly and compressed; it bears a convex articular facet along its entire end. The shaft was somewhat concave anteriorly, but the preservation does not permit determining other flexures or torsions. Radius and ulna were evidently separate distally.

Femur (Pl. 29, figs. 3–6).—Trilophosaurus femora are elongate yet stout, one-fourth longer than the humeri, and have a slight sigmoid flexure. The average length of 38 specimens is 206 mm. Proximally, the end of the shaft is turned forward slightly and bears an elongate ellipsoidal head, which is wider in front than behind, and inclined a little to the long axis of the shaft so that the femur would be directed forward and outward from the acetabulum in normal position. On the ventral side near the middle of the head the strong inner trochanter (Romer, 1922, p. 582) arises abruptly slightly distal to the end of the bone. From it a thick ridge of gradually decreasing height extends distally along the ventral side of the shaft for about one-third its length. Near the distal end of this ridge a slight roughening may be observed on some specimens, which may indicate the insertion of the caudifemoralis tendon. An indistinct adductor ridge passes distally from this point and gradually crosses to the posterior side of the femur where it ends near the external condyle. In some specimens this ridge continues along the middle of the ventral surface to a point near the base of the distal expansion and then disappears. At the proximal end, on either side of the trochanteric ridge, the bone is smoothly concave, the greater depression lying on the posterior side. The ridge, derived from the anterior of the two present in primitive tetrapods, appears displaced posteriorly largely because of the forward growth of the head of the femur. No landmarks are distinguishable on the dorsal surface of the bone.

The posterior portion of the proximal end of the bone may be regarded as a greater trochanter. No constriction separates it from the head, however, and the "unfinished" surface of the bone covers both, and also extends downward onto the inner trochanter.

The distal end is twisted posteriorly on the shaft similarly to the femora of phytosaurs and crocodilians. The condyles are directed posteroventrally to such an extent that they are scarcely to be seen from the dorsal surface. The external condyle is larger than the internal. The intercondylar groove or trochlea extends upwards over the distal end of the bone to the level of the dorsal surface. The entire distal end is bent downward slightly on the shaft. A deep pit is present at the ventral side of the external condyle, above which the rounded epicondyle is strongly developed. A strong groove for the head of the fibula leads from this pit around the epicondyle to the distal end of the bone.

In the collection is a short stout femur differing considerably from those of *Trilophosaurus* in proportions but closely resembling them in form. It may be somewhat shortened by crushing; if it is *Trilophosaurus* it is by far the largest individual represented.

The midventral position of the internal trochanter beneath the head of the femur is similar to that of the advanced therapsids like *Cynognathus*, to *Champsosaurus*, to the lizards, and to *Araeoscelis*. *Trilophosaurus* differs from the therapsids in the less inwardly directed head of the femur, in its poorly developed greater trochanter, and in its somewhat more prominent internal trochanter. From *Champsosaurus* it differs in having a more slender and curved shaft. Close similarities are found among some of the lizards. The femur of *Trilophosaurus* is strikingly similar to that of *Araeoscelis* figured by Williston (1914, p. 131, fig. 5), differing only in size.

Femora of phytosaurs and crocodilians display a greater sigmoid curvature of the shaft, which also is generally stouter, lack the inner trochanter, and have a prominently developed, rugose, fourth trochanter. The rhynchosaurs have a distinctly more primitive, pelycosaur-like femur. *Protorosaurus* femora figured by Meyer (1856, pls. 1, 4, 8, 9) have the head in line with the shaft, which is straighter and stouter than that of *Trilophosaurus,* and have a more primitive trochanteric system. The *Trilophosaurus* femur shows marked advancement over those of the pelycosaurs in its elongation, loss of the posterior branch of the adductor ridge, and slight anterior flexion of the head.

Tibia (Pl. 30, figs. 1, 2).—About 20 fairly good tibiae are present. All are considerably shorter than the femora, the ratio of the average length of the tibiae to that of the femora being 0.82. The shaft is elongated yet stout for the size of the animal; it lacks the massive build of the more primitive forms, and its distal end is but little expanded. Although all specimens are crushed and distorted, they show a convex anterior border almost without exception, so it is probable that the bone was somewhat curved in life. The least distorted shafts are rounded-triangular in cross section. On the head are two slightly concave articular facets, the preaxial (internal) more elongate and running obliquely from the anterointernal (medial) corner of the head to the tip of the poorly developed cnemial crest; the postaxial surface for the external condyle is shorter and narrower. On the ventral (posterior) side of the head is a slight notch between the two projecting facets. The lateral and dorsal or anterior sides of the head are flat and turn smoothly around the low and short cnemial crest. At the distal end is a concave facet for the tibiale which faces somewhat outward as well as downward and is bounded on the preaxial side by a strong rounded internal malleolus.

Compared with pelycosaurian tibiae, that of *Trilophosaurus* is characterized by slightly greater elongation of the shaft, reduction in the diameter of the head, and especially decrease in the size of the distal end of the shaft. The shape of the head remains much the same, but the facets are reduced in size and protrude less from the bone. From dinosaurs it differs in retaining the primitive joint between tibia and astragalus and also in the proportions of tibia to femur.

The tibia is similar in form to that of phytosaurs, champsosaurs, Crocodilia, and other reptiles which hold the limbs outward at the side of the body. It affords little clue to the relationships of the animal.

Fibula (Pl. 30, figs. 3, 4).—The fibulae are elongated slender, laterally compressed bones with slight sigmoid flexure. They slightly exceed the tibiae in length. The head is flattened, narrow, anteroposteriorly elongate with a convex articular surface for the lateral condyle of the femur. The shaft becomes more nearly equidimensional below the upper fourth, and below the center it is compressed triangular with a keeled posterior edge. The distal end turns backward abruptly and ends in an oval posterodistally facing convex facet.

The posterior ridge forks slightly below the middle of the shaft and continues upward as two branches at the inner and outer posterior angles to the base of the expanded head where they merge into the rounded posterior border.

MANUS

Text fig. 10; Pl. 31, fig. 2

The left manus is preserved with the bones little moved from their natural positions. The first digit lay in matrix at right angles to the remaining toes, strongly suggesting that it was divergent in life. The remaining toes were found close together and probably did not diverge greatly. All the digits are well developed and bear large claws. Phalangeal formula 2–3–4–5–3. The fourth toe is longest, the fifth shorter than the second. The hand is large; its length exceeds that of the forearm. Probably it was generally used for locomotion. (Every part of the limb and girdle skeleton suggests that *Trilophosaurus* was quadrupedal.)

Eight carpals are preserved; these are identified as radiale (?), intermedium (?), ulnare, centrale, 1st, 2nd, 3rd, and 4th distal carpals. It seems evident that a fifth distal carpal was originally present and either had been lost from the skeleton prior to fossilization or else was cartilaginous. A well-developed facet for it is present on the fifth metacarpal and also on the fourth distal carpal. The form and articulations of the latter make it impossible for it to have supported the last metacarpal, so it does not represent fused carpalia.

Carpus.—The carpal bones were somewhat displaced, but it has been possible, because of the relatively closely fitting articular surfaces, to restore most of them to nearly their original positions. The distal carpals especially are well formed and conform closely to the contour of the proximal facets of the metacarpals. The fourth distal was moved slightly palmar to its metacarpal, the second distal had moved proximally and laterally

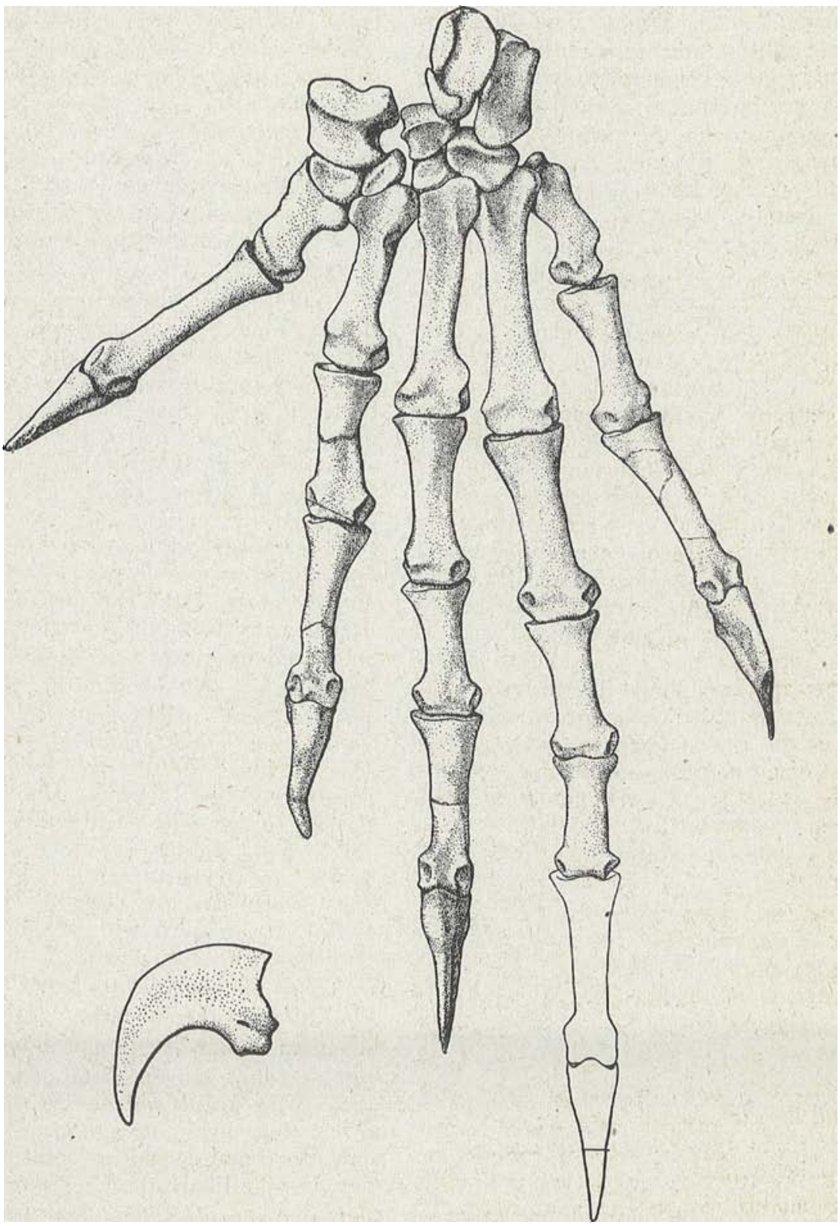

Fig. 10. *Trilophosaurus buettneri* Case, x0.8; dorsal view of manus, carpus restored.

somewhat. The first distal and its metacarpal were displaced to between the heads of the second and third metacarpals. The centrale was below the proximal end of the radiale. The intermedium lay beneath the rest of the proximal carpals, and the ulnare separated the others from the distal row. The fifth metacarpal was most displaced, lying below the first metacarpal in the space between the second and third. The most doubtful point is the position and relationships of the lateral centrale, which, although possessing definite articular faces, does not correspond to any of the possible surrounding bones.

Radiale (?).—The radiale is the largest carpal. In the specimen it lay on the anterior side of the carpus, probably close to its proper position. Viewed from the dorsal surface it is rectangular, wider than long, with a deep concavity on the inner (posterior) side which formed part of the so-called perforating foramen. The dorsal face is shallowly concave. In cross section the bone is wedge-shaped, with the point toward the anterior side of the hand, the thick edge adjacent to the centrale.[*] The radial facet seems large for that element, covering the entire proximal end of the bone; it is flat except for a slight dorsoventral concavity near the internal edge of the bone. The distal facet is similar in size and shape but bears a more pronounced concavity which conforms closely to the proximal surface of the first distal carpal. There can be little doubt that this element is correctly placed, because of its articulations. It lies so far distal to the remainder of the proximal row that one might well argue that it is a median centrale instead of a radiale. In *Protorosaurus* a medial centrale is present, and the radiale is frequently unossified. Against the hypothesis that the bone here described is a centrale is the presence of a well-developed groove for perforating artery on its lateral margin.

Intermedium (?).—A thin, flat, elongated bone, widest at the proximal end and tapering strongly distally, was found beneath the rest of the carpus. Near the distal end, on the dorsal and anterior sides, are smooth bony excrescences which may be ossified tendon attachments. The posterior side bears a slight facet for the ulnare. The rounded proximal end is concave ventrally and forms a portion of the ulnar facet. This bone is either the intermedium or pisiform. It is remarkably thin for an intermedium and lacks a distal facet. Its shape is slightly suggestive of a pelycosaur intermedium. It could not have articulated with the radiale (?) in any reasonable reconstruction of the carpus. Its distal end may have been supported by the centrale.

The rounded distal end of the bone, the ossified tendons attached to its border, and its thinness suggest that it may have been a pisiform. In the drawing it has been placed in the position of the intermedium.

Ulnare.—The ulnare is longer and thicker than the intermedium, its dorsal surface flat except for an overhanging proximal facet. The posterior margin is thin. A large facet for the intermedium occupies the proximal half of the anterior surface; distal to this the anterior edge is thin. A strong ridge runs down the center of the palmar surface. The ulnar facet is convex, wide near the intermedium and thinning posteriorly. At the distal end a convex facet for the fourth distal carpal runs from the anterior point upward and backward.

Centrale.—As mentioned above, the position and articulations of this bone could not be determined satisfactorily. One surface is deeply concave with strongly ridged borders, similar to the dorsal surface of the radiale, and distal carpals. It may be assumed that this is the dorsal surface. The palmar surface is also concave. In cross section the bone is triangular, with a short flat side and two convex surfaces.

None of the distal carpals will fit closely with this element. In the reconstruction it has been placed between the radiale and fourth distal carpal, resting on the third and fourth distals, and supporting the intermedium. The radiale and first distal carpal articulate so closely that it is unlikely that it separated them.

Distal carpals.—The first distal carpal is a broad, short element with convex proximal and distal surfaces which meet at the anterior edge but are separated by a short, straight inner facet. These surfaces closely fit the radiale and first metacarpal. The inner facet articulates with a broad facet at the head of the second metacarpal and probably to a slight extent with the second distal carpal. The dorsal surface is flat with slightly raised borders. The articular faces merge into the bluntly rounded palmar surface.

The second and third distal carpals are small, deep, short, and irregularly shaped; the third exceeds the second in size. The dorsal exposure of each is a small concave polygonal area with raised borders. The distal facets are curved in a complex asymmetric saddle shape which fits the head of the metacarpal; they are wide posteriorly. Two other flat or slightly convex facets are present on each.

The last preserved carpal is the fourth; it greatly exceeds the others in size. Dorsally it presents a deeply concave face of trapezoidal outline, the broader base directed proximally. There is a large convex proximal surface for the ulnare. Distally there are facets for the third carpal, the third metacarpal, the fourth metacarpal, and fifth carpal. When the foot is articulated in the manner indicated by the facets, the fourth carpal overlies the third and fourth digits. The facet for the fifth carpal is concave and directed laterally. The fifth metacarpal has a concave proximal facet, and one must postulate a separate carpal element, whether cartilaginous or osseus, to make the connection.

Metacarpals.—Metacarpal I is short, broad, and flat. Its proximal end bears a slightly concave transversely elongated facet which extends onto a lateral projection. The shaft is almost as broad as long and widens distally into the epicondyles. The strong lateral process at the head of the first metacarpal prevents its being aligned parallel to the remaining metacarpals. Accordingly the first digit must have been permanently divergent.

The second metacarpal is half again as long as the first. Its head is as deep as wide and bears a strong posterior projection of the dorsal surface which extends proximally and evidently made contact with the third distal carpal. A curved articular facet for the second carpal covers the proximal end and anterior side of this process. The anterior margin of the proximal end bears a strong facet for the first carpal. The shaft is more slender than that of the first metacarpal, longitudinally concave above, convex below, flattening and widening distally. The epicondyles are deeply excavated laterally.

The third and fourth metacarpals are similar to the second, each slightly surpassing the more anterior in length, and developing stronger ventral and proximolateral processes. Intermetacarpal articular facets are well developed at the proximal ends of these.

The fifth metacarpal is short, only a trifle longer than the first. It is broad and thin, strongly concave on the anterior side (toward the inside of the hand), and is slightly hook-shaped, that is, with its shaft set out from a line through the center of its proximal articular facet. A strong facet on the anterior side is for the fourth metacarpal, and a transversely concave facet is for the fifth distal carpal. Its distal end is unsymmetrical, appearing to be cut off obliquely on the outer side.

Phalanges.—Proximal and medial phalanges are all similar in form, although differing considerably in lengths and proportions in the various digits. The subterminal phalanx of each digit is the longest. The remaining phalanges decrease regularly in length from the proximal phalanx distally. Consequently there is marked contrast between the subterminal phalanx and that preceding it in the longer toes.

The proximal ends of the phalanges are oval, concave facets, somewhat flattened dorsally. From them the sides converge inward sharply to the shaft. The phalanges are oval in cross section with a flattened or even shallowly grooved palmar surface. The subterminal phalanges are more nearly round. All are strongly concave longitudinally, especially at the sides. At the distal end is an expansion similar to that on the metacarpals. The epicondyles bear distinct pits facing outward and slightly upward. The distal articular surface faces nearly straight out, is concave below and in the central portion, convex from top to bottom. The subterminal phalanges have narrow distal condyles, corresponding to the narrow facets on the claws.

The distal phalanges are all large, strongly compressed laterally, long, recurved, sharp-pointed claws, of subequal size. The proximal articular facets are dorsoventrally concave, narrow, and situated in the upper half of the base of the claw. Below them lies a strong tubercle for the flexor tendons, separated from the articular region by a shallow longitudinal groove. Its lower surface is continuous with the concave ventral edge of the claw.

PES

Text fig. 11; Pl. 31, fig. 1

The hind foot of *Trilophosaurus* exceeds the front foot in size. It is longer than the tibia. The five well-developed toes are provided with large compressed claws like those of the forefoot. The fourth toe is longest; the fifth is divergent from the others and (including the metatarsals) shorter than the second. The fifth metatarsal is "hooked." In the tarsus are seven well-formed ossifications which appear to have articulated closely with one another and with the metatarsals. There is but a single centrale, the lateral one of the primitive pair, homologous to the mammalian navicular. The astragalus (intermedium) and calcaneus (fibulare) are primitive in form. The fourth distal tarsal is enlarged to support the fifth as well as fourth metatarsals, and the fifth tarsale is absent. A typically sauropsidan intratarsal joint was present.

In the following description the terms astragalus, calcaneus, and navicular are used in preference to intermedium, fibulare, and centrale respectively.

Astragalus.—The astragalus retains the rather primitive L-shape found in the pelycosaurs. Its dorsal, or dorsolateral, surface is concave, a shallow longitudinal groove extending along it from the fibular facet to the distal end. A large, flat, quadrate, articular surface for the tibia occupies the medial surface of the body of the bone. Distally this surface is cut off by the navicular facet, which intersects it approximately at right angles. This facet is about twice as deep as wide, shallowly concave, with a straight dorsolateral margin at its intersection with the tibial facet and rounded medial and ventral edges. The posterior or proximal process nearly equals the remainder of the bone in length and is directed slightly outward and downward. Its truncated end forms a subquadrate, posteriorly directed, shallowly concave articulation for the fibula. On its lateral surface is a longitudinal groove which rests on the inner edge of the calcaneus. The lateral border is interrupted opposite the posterior edge of the body of the astragalus by a notch which forms the inner side of the perforating foramen. Distal to this notch a convex facet for the distal end of the calcaneus is developed. A convex surface connects this face to the lateral edge of the navicular facet. It is adjacent to the fourth tarsal, but shows no distinct facet for that bone. The ventral surface is convex, sloping upward, outward, and backward from the thick distal and lateral portions to the thin medial and posterior margins of the tibial articulation, and continuing around the medial surface of the fibular process. No head is developed in contrast to the astragali of advanced therapsids.

Calcaneus.—Like the astragalus this bone is but little modified from the pelycosaurian type. It is a thin blade with a thickened distal foot, which bears two facets. The larger of these articulates with the fourth tarsale; the small medial facet, which meets the lateral at an obtuse angle, is for the distal end of the astragalus. The superior surface of the blade is slightly concave, the lower surface convex. The lateral border curves evenly from the end of the distal facet to the posterior end. Two thickenings are present, at the posterior point of the bone and near the middle of the lateral border. Articulation with the astragalus is limited to the lower half of the medial edge, which bears a broad, longitudinally cylindrical facet for the posterior process of that bone. Contact with the fibula was very slight, if any, and no distinct facet for that bone is discernible. Near the distal end, just above the astragalar facet of the expanded "foot," is a partially closed groove which

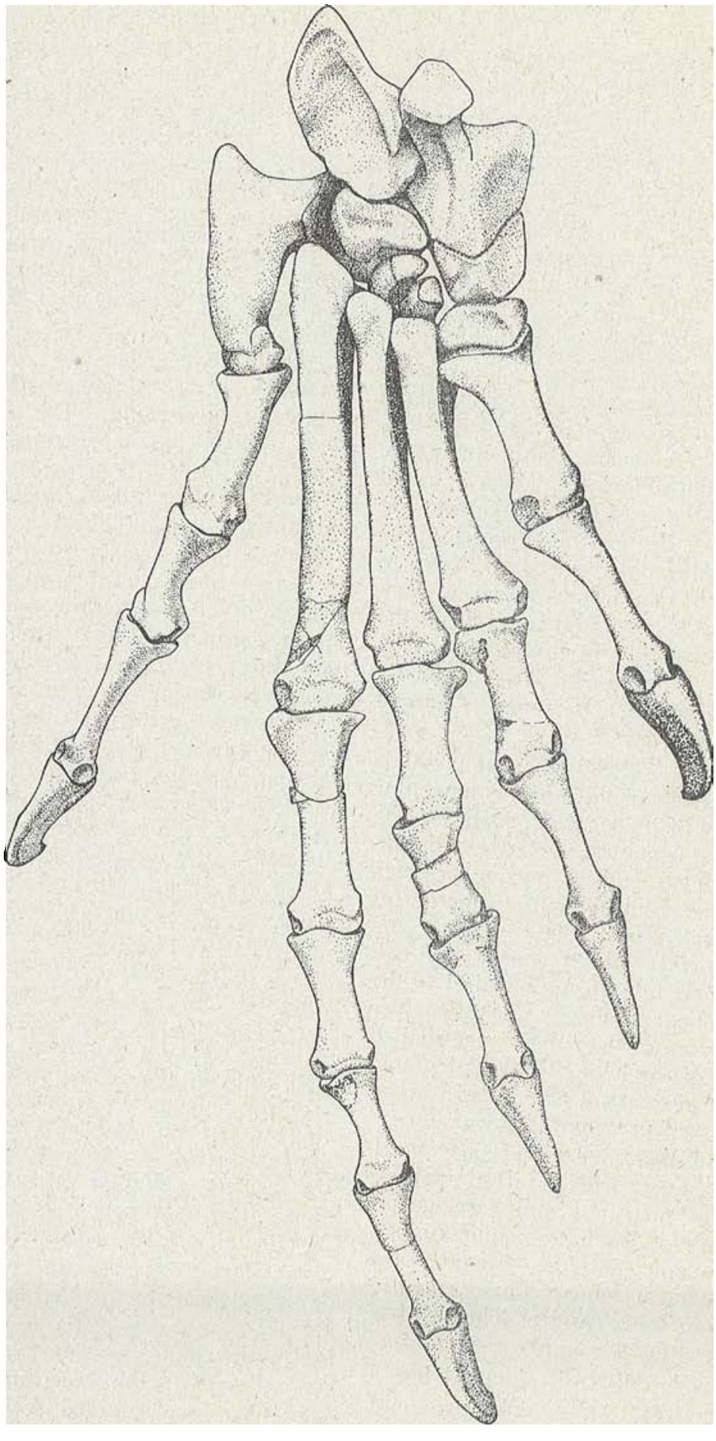

Fig. 11. *Trilophosaurus buettneri* Case, x0.8; dorsal view of pes.

bounded the foramen for the perforating artery laterally.

Navicular.—A large hemispherical navicular with a slightly concave dorsal and a wide, flat proximal surface covers the distal end of the astragalus. The distal, ventral, medial, and lateral aspects of the bone are smoothly rounded, except for a deep pit in the middle of the ventral surface near its proximal edge. Distally the navicular must have articulated with the first, second, and fourth tarsals but was separated by the last from the third tarsal.

Trilophosaurus differs from most Lepidosauria and Archosauria in possessing a well-developed navicular or centrale. This is a primitive element, retained by the Therapsida and Mammalia, which is found only among the more primitive sauropsidan orders. The pes of *Protorosaurus* is shown by Meyer's figures (pls. 8, 9) to have a navicular similar to that of *Trilophosaurus.* A navicular occurs in the foot of *Diadectes* but is absent from *Procolophon.* It is retained by the Eosuchia and some primitive archosaurs *(Chasmatosaurus).*

Distal tarsals.—The first distal tarsal is tabular. A flat surface for the navicular occupies most of its proximal surface. The dorsal surface is convex medially and concave laterally. Its distal outline presents a broad V-like point below the junction of these surfaces. This V is carried across the distal surface which consists of two facets, a larger, lateral one parallel to the proximal plane, and a short medial surface which slopes upward to the wedge-shaped medial edge of the bone. Both articulated with the first metatarsal, which has a broad V-shaped curved proximal surface.

The second and third tarsals are small, short, deep bones, with small dorsal exposure. The proximal ends are nearly straight from top to bottom and slightly convex from side to side. Distally the bones are strongly convex dorsoventrally and slightly so transversely. The third is twice the size of the second.

The enlarged fourth distal tarsal has a somewhat convex, triangular proximal surface on which the calcaneus rests. Its acute apex is at the dorsolateral corner of the bone. Distally the lateral portion expands ventrally, so the lower surface is roughly quadrate. A broad convex facet on the lateral side of the bone for the fifth metatarsal curves distally and forms a swollen articulation with the fourth metatarsal. Medial to this facet the distal surface is deeply concave and extends above the third distal tarsal. Its dorsal surface is rough with a pit-like central depression. The ventral surface is convex and continuous with the lateral portion of the proximal face, behind the calcanear facet.

Metatarsals.—The first metatarsal is much the shortest, being about half the length of the second. The second, third, and fourth increase progressively in length. The fifth is again short, although somewhat longer than the first, and is strongly angulated like that of the Rhynchocephalia.

Unlike the remaining metatarsals, the first is broad and shallow, and has a wide, shallow proximal articulation. The proximal facet is convex dorsoventrally and somewhat concave from side to side, especially near the medial side. It thus corresponds to the double facet on the first tarsal. Distally, the shaft narrows somewhat, and becomes thin, wide, and flat above. At its distal end it expands to the distally and ventrally directed condyles. These are separated ventrally by a wide groove. Deep pits directed upward and outward are present on the epicondyles of metatarsals and phalanges of the pes, similar to those of the manus.

The second to fourth metatarsals are similar. At the proximal end they are deep and narrow; the dorsal edge of the articular surface is wider than the long ventral portion and is raised somewhat above it. Insofar as may be determined, the facets are slightly convex from side to side. There is none of the pronounced asymmetry of the metacarpal heads. Intermetatarsal facets are present. The dorsal surfaces of the shafts are flat, meet the sides at rounded angles in the proximal third, and pass into a gentle curve more distally as the shaft thins. In dorsal aspect the shafts widen from a constriction below the head toward the distal end. The terminal articulation is similar to that of the first metatarsal. The fourth metatarsal differs from the others in the absence of a lateral facet for metatarsal V; its head is triangular with a long straight lateral surface. The hook-shaped fifth metatarsal has a large medially directed head with a deep facet which is narrow and concave above, wider and convex below. A distinct neck sets the head off from the thin wide shaft at a right angle. The shaft is convex above, concave below, and slightly curved, convex laterally. At its distal end it is but little thickened and forms a condyle directed entirely distally. There are no epicondyles or pits.

Phalanges.—The phalanges are so similar to those of the manus that separate description is needless. As in the hand, the phalanges decrease in length distally to the penultimate, which is longer and more slender than the others. The proximal phalanges of the second to fourth digits increase regularly in size. The proximal phalanx of the fifth digit has a more nearly circular proximal articular facet than the others; its shaft curves outward to increase the divergence of this toe from the others. The claws are like those of the manus and not larger in proportion to the size of the feet.

Comparisons.—The pes of *Trilophosaurus* retains many primitive features, such as ossification of most of the tarsals, primitive shape of the astragalus and calcaneus, non-reduction of digits or phalanges. It is advanced in the specialization of the fifth metatarsal, loss of the medial centrale and fifth distal tarsal, and in the strong, compressed claws. The detailed shape of astragalus, calcaneus, and navicular may be regarded as characteristic specializations. So is the peculiar development of the fourth tarsal which separates the third from the navicular.

Evidence as to the position of the tarsal joint is inconclusive but suggestive of a developing intratarsal joint. Considerable motion, particularly rotation, was possible between tibia and astragalus. This surface, however, is flat. The rounded distal end of the navicular and ball-like proximal articulation of the fourth tarsal with the calcaneus indicate that considerable movement, especially dorsoventrally, could occur here. The displacement of the tarsus along this joint in the articulated specimen also suggests an intratarsal articulation.

The foot shows none of the characteristic developments of the therapsid line. There is no head on the astragalus, no tuber calcis. The fifth metatarsal is specialized in a characteritic fashion which is not found in any therapsid.

All archosaurs possess more specialized feet than *Trilophosaurus*, with the fifth digit vestigial and the number of ossified tarsals reduced. More generalized diapsids, the Lepidosauria, have a similar foot with a hooked fifth metatarsal, enlarged fourth distal tarsal, and generally ossified tarsal elements. The form of astragalus and calcaneus is somewhat more primitive than in these forms.

Other primitive reptiles possess similar feet. *Protorosaurus* has a similar well-ossified tarsus in which a fifth distal tarsal is lacking, the astragalus is remotely L-shaped, the navicular hemispherical. It too has the hooked fifth metatarsal. *Macrocnemus* and *Tanystrophaeus*, which appear to be specialized offshoots of the Protorosauria, likewise have hooked fifth metatarsals. The Sauropterygia, however, have feet too much modified for aquatic life to show these characters. *Mesosaurus* has an L-shaped astragalus and hook-shaped fifth metatarsal but lacks the navicular. Its feet are enlarged and apparently not very similar to *Trilophosaurus*.

In summary, the hind foot of *Trilophosaurus* shows relationship to the Protorosauria and Lepidosauria and is thus in accord with the evidence of the remainder of the skeleton.

Posture of the foot.—The toes of *Trilophosaurus* increase in length from the first to the fourth. The fifth is short and divergent. It is not, however, vestigial but well developed. The foot is in general lizard-like. Romer and Byrne have shown that this type of foot is characteristic of tetrapods which carry the proximal limb segments out horizontally from the side of the body. The foot is twisted forward on the limb, and the more lateral toes must be longer to bear their share of weight. The fifth toe, which receives little stress, is not so elongated and becomes modified or reduced. The foot is probably plantigrade, for the skeleton shows none of the specializations characteristic of digitigrade animals (such as anticlinal vertebrae, strong tuber calcis). The analogy with lizards must be very close.

RELATIONSHIPS OF *TRILOPHOSAURUS*

Case (1928–A) referred *Trilophosaurus* to the Procolophonidae, a family of diadectomorph Cotylosauria, which it resembles in its transversely widened, obscurely tricusped cheek teeth—the only portion available to him. Discovery of the fenestrated skull and advanced skeleton of this animal shows that it can not be included in the Cotylosauria, if the concept of that order as a primitive group of reptiles with solidly roofed skulls is retained. Its proper classification depends on whether it is directly derived from the diadectomorph cotylosaurs and has independently developed a fenestrated temporal region, which would necessitate the erection of a new order for it, or whether it belongs to some already known order with advanced skull structure but has teeth which are convergent in form with those of the diadectids and procolophonids.

Comparisons with Cotylosauria.—Although *Trilophosaurus* is excluded from the Cotylosauria by its fenestrated skull, its resemblances to various members of that order should not be passed over in considering its affinities. Cotylosaurs may conveniently be divided into 3 groups (as suggested by Watson, 1917, p. 171). Of these the Seymouriamorpha are extremely primitive and show no special resemblance to any later Reptilia. The Captorhinomorpha most closely resemble the hypothetical ancestors of the synapsid and diapsid reptiles, although their dentition is aberrant. The braincase of *Trilophosaurus* resembles that of *Captorhinus* (Price, 1935) in its high dorsum sellae, lizard-like sella turcica, position of the internal carotid foramina, non-ossification of the sphenethmoid region and well-developed parasphenoid rostrum. *Captorhinus* differs from *Trilophosaurus* in its small basipterygoid processes which are directed forward and laterally, small tubera, large stapes, in the low position of the inner ear at the side of the braincase, and in the absence of a bony partition between vestibule and brain cavity. These are all primitive features. The quadrate of both animals is tall and fixed at the back of the skull, but in *Captorhinus* it is completely covered at the sides by squamosal and quadratojugal, whereas in *Trilophosaurus* it is exposed. The captorhinids lack the distinctive backward curve of the upper end of the quadrate. The postcranial skeleton of *Trilophosaurus* differs in many respects from that of *Captorhinus*, but these differences are all progressive characters of the Triassic animal which have no bearing on relationships. *Trilophosaurus* resembles *Captorhinus* more closely than other cotylosaurs in the structure of its braincase. No reason is apparent why it might not bear the same relationships to the captorhinids as diapsid and synapsid reptiles do.

The Diadectomorpha includes reptiles with a peculiarly enlarged otic notch and deep quadrate. *Diadectes* and the pareiasaurs were large, the procolophonids small. All had specialized dentition. The pareiasaurs may be eliminated at once from serious consideration by a number of characters which are totally unlike *Trilophosaurus*. The brain cavity is elongate and straight, without the high dorsum sellae of *Trilophosaurus*. A sphenethmoid ossification surrounding the anterior part of the brain cavity has been described by Boonstra (1939). The fenestra ovalis is large, and situated low on the side of the braincase. The dentition is specialized by development of numerous cuspules at the edge of the tooth-crowns. The skeleton is excessively massive.

The diadectids show resemblance to *Trilophosaurus* in their transversely broadened, three-cusped teeth and in the general form of the back of the skull. The braincase is not satisfactorily known in *Diadectes*, but there appear to be important differences from *Trilophosaurus*. The tubera and basipterygoid processes do not project so far ventrally, and the braincase appears in available figures (Case, 1910, fig. 4) to be low and straight, and ossified anterior to the fenestra proötica. There is no cultiform process of the parasphenoid.

The quadrate of diadectids is covered on the lateral surface of the skull by the squamosal and quadratojugal. It is partially separated from the latter by a quadrate foramen. The upper end of the quadrate does not curve backward as in *Trilophosaurus,* but is straight to its rounded end.[1] The backward projection above the enlarged otic notch is formed by squamosal and tabular. Hence the striking superficial resemblance to *Trilophosaurus* in this region is not due to homologous structures and can not be regarded as evidence of affinity.

In *Diadectes* the posttemporal fenestrae are closed by contact of the squamosals and tabulars with the supraoccipital. If *Trilophosaurus* is derived from a diadectomorph it must be from a more primitive member of the group in which these fenestrae remained open. The presence of well-developed posttemporal fenestrae in *Procolophon* shows that such forms existed.

The transverse elongation of the teeth is indeed a strong resemblance. It is an adaptive character, however, such as might readily have arisen repeatedly under appropriate stimulus to evolution. Such teeth are also known in the Cretaceous lizard *Polyglyphanodon sternbergi* Gilmore (1940), in which they have undoubtedly evolved independently as they also have in the Triassic diadectomorph *Procolophon* (vide infra.). Moreover there appears to be an important functional difference between the dentition of *Diadectes* and *Trilophosaurus.* In the former the crowns of the teeth are flattened and served a crushing function; most specimens show them with worn surfaces. The teeth of *Trilophosaurus* always intermeshed with cutting or shearing action; their crowns are not found blunted by wear but are invariably sharp. The jaw articulations of these reptiles differ correspondingly. *Trilophosaurus* has a transverse quadrate condyle which permits only orthal motion, whereas *Diadectes* has a longitudinal groove in the quadrate and a ridge on the articular which facilitate propalinal motion. In *Trilophosaurus* the teeth were frequently replaced, whereas in *Diadectes* there is no evidence of succession.

The feet of *Diadectes* are modified for support of the heavy body of that animal. The phalanges are short and wide. Terminal claws are present, but these are wide in contrast to those of *Trilophosaurus.* The tarsus is also broadened so that the astragalus is wide and flat. A navicular is present (Romer and Byrne, 1931). The fifth metatarsal is not hook-shaped.

Diadectes is so specialized that it seems improbable that it could have given rise to *Trilophosaurus.* The resemblances between them seem more like adaptive convergence than indications of genetic affinity.

Procolophon and its allies from the Triassic of Europe and Africa are small reptiles much advanced over other cotylosaurs. Like the diadectids and *Trilophosaurus* the teeth are transversely widened. According to Seeley (1905) they bear slight cusps at the ends of a sharp, transverse blade. The Upper Permian *Nyctiphruretus* and *Nycteroleter* have conical teeth. Efremov (1940, p. 455) has shown that they connect the Procolophonidae with the Pareiasauridae. The procolophonids, therefore, acquired transverse teeth independently of the diadectids. The back of the skull is deep and concave, somewhat resembling that of *Diadectes.* A quadrate foramen is present, as in the diadectids. Watson (1914B, p. 738) says that the quadrate is small and covered laterally by quadratojugal and squamosal. The latter also covers the posterior surface of upper portion of the quadrate. A large tabular is present. Unlike the diadectids, there are large posttemporal fenestrae.

The braincase differs from that of *Trilophosaurus* in several respects. According to Watson (1914B) the inner ear is widely open into the brain cavity and occupies the entire side wall of the braincase, like that of a turtle. The stapes is fairly stout, and the fenestra ovalis large. The tubera are only moderately developed, and the basipterygoid processes do not project downward. All these are essentially primitive characters. In the postcranial skeleton *Procolophon* retains many features lost by *Trilophosaurus,* such as

[1]Prof. A. S. Romer kindly showed me a specimen of *Diadectes* in which the quadrate is clearly visible and which confirms this interpretation.

heavy neural arches which obscure the spinous processes, flat zygapophyseal articulations throughout the vertebral column, notochordal centra, well-developed metacoracoid, and large clavicles. The pelvis is peculiarly developed with a tall ilium rising above the acetabulum but no posterior spine. The femur is primitive, with a deep intertrochanteric fossa. Among the most important differences from *Trilophosaurus* are the absence of a centrale from the tarsus and straight fifth metatarsal. (Seeley, 1905, p. 228, fig. 37; Watson, 1914B, p. 745; Efremov, 1940, p. 439).

The chief resemblances of *Procolophon* to *Trilophosaurus* are its transversely widened teeth and primitive jaw with inframeckelian but no external mandibular fenestrae. The quadrate region does not have much real similarity, in spite of superficial external resemblance.

To derive *Trilophosaurus* from a primitive procolophonid would require the same changes which are necessary to derive it from a captorhinid, namely: (1) reduction of the roofing bones of the cheek to obliterate the quadrate foramen and expose the quadrate at the side of the skull; (2) formation of a superior temporal fenestra; (3) downward growth of the tubera and basipterygoid processes; (4) loss of palatal teeth; (5) development of transverse crowns on cheek teeth and edentulous beak; (6) loss of sculpture on skull bones; and (7) modernization of postcranial skeleton. The only trend in this direction shown by the Triassic procolophonids is the widening of the cheek teeth. All procolophonids are specialized in a different direction from *Trilophosaurus* in the enlargement of the orbit, part of which may have served as a temporal fenestra. Although the tooth-crowns and mode of implantation of the teeth of *Trilophosaurus* and *Procolophon* are remarkably similar, the remainder of their skeletons give little indication of relationship.

Comparisons with Chelonia. — The Chelonia possess skulls of diverse form, some with the temporal region closed, others with emargination from the posterior border, or below, or both. Their jaws are edentulous (except in *Triassochelys*) and provided with a horny beak. The distinctive character of the order is the development of the bony carapace and its intimate relationships with the ribs. *Trilophosaurus* resembles chelonians in the edentulous beak and deep curved quadrate, firmly attached to the cheek bones, but differs in almost every other part of the skeleton. The skull fenestra is unlike that of any chelonian; the basicranial region is built upon a different plan; the palate retains its interpterygoid vacuity; the inner ear is separated from the brain cavity and above the floor of the braincase; the number of presacral vertebrae exceeds 18, which is constantly found in the chelonia; and there is no trace of dermal armor.

Comparison with synapsids.—The temporal opening of *Trilophosaurus* is somewhat like that of the advanced therapsids, bounded above by the parietals, behind by the squamosal, and below and in front by the bones of the cheek region which presumably include postorbital and possibly jugal. The resemblance ceases here, however, for the therapsid temporal fenestra remains widely open at the side as well as above, whereas in *Trilophosaurus* the lower cheek region is deep and solidly enclosed by bone. A number of fundamental differences in the structure of skull and skeleton exclude the possibility of relationship between *Trilophosaurus* and the therapsids (Watson, 1921).

1. In *Trilophosaurus* the quadrate is large and forms the posterior lateral border of the temporal region of the skull. The therapsid quadrate is always small, fitting into a groove in the lower surface of the deep squamosal.

2. In advanced therapsids there is a secondary palate or at least the internal nares are large and posteriorly placed. In *Trilophosaurus* the internal nares are relatively small and at the extreme front of the palate. There is no trace of a secondary palate.

3. The ear region of therapsids is situated low on the side of the braincase and commonly extends below the bottom of the brain cavity. In *Trilophosaurus*, as in most non-therapsid reptiles, the inner ear is situated high on the side of the braincase, above the level of its floor.

4. The tubera basisphenoidales project far beneath the level of the basicranial axis. Flanges extend medially from them, closing off a deep basicranial fossa similar to that found in Saurischian dinosaurs but not in therapsids.

5. The basipterygoid processes of *Trilophosaurus* extend far below the basicranial axis; in therapsids they are short and laterally directed.

6. There is a single occipital condyle which appears to be formed entirely by basioccipital. In advanced therapsids the condyles are tripartite or double.

7. The pytergoids do not unite to form a median bar between basicranium and palate but retain the primitive separated vertical position found in pelycosaurs. Their palatal flanges are not far forward of the basicranial articulation.

8. The dentaries, although forming a small coronoid process behind the cheek teeth, show no tendency toward expansion at the expense of the posterior elements of the lower jaw.

9. There is no pineal foramen.

10. The scapula has no outwardly directed spine or acromion process.

11. The pectoral girdle has the procoracoid greatly developed posteriorly as in non-synapsid reptiles and lacks the metacoracoid.

12. The humerus lacks an entepicondylar foramen.

13. There is no reduction of the number or length of the phalanges from the primitive reptilian formula of 2–3–4–5–3, with the fourth toe longest.

14. There is no anterior spine of the ilium.

15. There is no obturator foramen.

16. The inner trochanter of the femur is more strongly developed than in therapsids, and there is less tendency to form an anterior "head" and no trace of an incipient greater trochanter.

In short, *Trilophosaurus* shows scarcely any of the evolutionary trends which characterize the therapsid reptiles and culminated in the Mammalia. In nearly every character cited it is closer to the sauropsidian type of structure. Moreover, the therapsids were mainly carnivorous forms, whereas *Trilophosaurus* was herbivorous. Of the herbivorous therapsids, the tapinocephalid dinocephalians, besides showing numerous therapsid characters which *Trilophosaurus* lacks, were so different in form and so much more massive that detailed comparison would be pointless. Their teeth were round, not transversely widened. The only resemblance is in the relatively high position of the temporal opening and moderately deep cheek region. This is no doubt related to somewhat similar habits of mastication. The Dicynodontia have edentulous beaks like *Trilophosaurus* and commonly lack cheek teeth as well, save for the canine. The differences in dentition between the two groups would be of minor importance, but in other features the skulls are very different. In particular, the dicynodonts have small quadrates at the lower end of a T-shaped squamosal which carries them well forward of the occipital region. And the numerous non-therapsid characters of *Trilophosaurus* again bar it from even general relationship to the group.

The relationship of *Trilophosaurus* to the Pelycosauria remains to be considered. In some features of skull structure (notably the form and relationships of the pterygoids) and in the primitive structure of the pelvis, there is considerable resemblance. But these features are merely primitive reptilian characters displayed by the Pelycosauria which *Trilophosaurus* retains. There is a notable difference in the temporal region and skull table. In pelycosaurs the skull roof is flat and a small fenestra occurs low on the side of the temporal region, whereas in *Trilophosaurus* there is parietal crest, upwardly opening temporal fenestra, and closed lower cheek region.

The internal ear of *Trilophosaurus* lies in the side of the braincase above the level of its floor and is shut off from the cranial cavity by bone. The stapes is slender and imperforate in contrast to the heavy pelycosaur stapes. There is no venous notch in the upper wall of the braincase behind the trigeminal foramen. In many parts of the postcranial skeleton *Trilophosaurus* is advanced over the Pelycosauria, as one would expect a Triassic reptile to be.

The differences in temporal structure and position of the ear suggest that *Trilophosaurus* arose from the cotylosaurian stock independently of the Pelycosauria, and that it is closer to the sauropsid than to the synapsid reptiles.

Comparison with Mesosaurus. — The skull structure of this form is still not satisfactorily known. Its elongated jaws and needle-like teeth, and the pachyostosis of the skeleton, seem to remove it far enough from *Trilophosaurus* to make more detailed comparison unnecessary. The evolutionary tendencies shown by the two forms seem entirely divergent, and there are no characters suggesting relationship. It has generally been thought to have a superior temporal fenestra, but Huene (1940, p. 287) suggests that it is a synapsid with a low temporal opening.

Comparison with Ichthyosauria.—The peculiar construction of the superior temporal fenestra of the ichthyosaurs, which is bordered laterally by postfrontal and tabular, and their highly developed aquatic adaptations, separate them from near relationship with other reptiles, including *Trilophosaurus.*

Comparisons with the Sauropterygia.—In these aquatic reptiles the skull has a superior fenestra, bounded laterally by squamosal and postorbital, quite as in *Trilophosaurus.* The quadrate is tall and backwardly directed, supported at the side by the squamosal. The lower end of the quadrate, in plesiosaurs, extends well below and behind the level of the palate and basicranium. *Trilophosaurus* shows this to a slight degree. Placodonts have skulls which resemble *Trilophosaurus* in many details: in the structure of cheek and temporal region, in the deep tubera basisphenoidales, and in coronoid process of the lower jaw. The anterior dentition is sometimes reduced *(Placochelys).*

Structural differences between the Sauropterygia and *Trilophosaurus* are rather numerous. They are largely related to the aquatic adaptations of the latter. Important among these are:

1. Elongation of vertebral column.
2. Articulation of ribs with centrum only.
3. Limb girdles highly specialized, scapula with low blade and large precoracoid plate, large coracoids.
4. Paddle-like modification of limbs.
5. External nares relatively far back from end of snout.
6. Palate with vacuities closed or nearly so.
7. Braincase elongate, with sphenethmoid ossification.
8. Retention of pineal foramen.

It is significant that the placodonts, which have a crushing dentition, show a greater resemblance to *Trilophosaurus* than the more primitive Nothosauria, which retain normal foot structure. This points to the convergent development of coronoid process, deep skull, and other features associated with masticating food.

The differences between the Sauropterygia and *Trilophosaurus* are profound and indicate a remote ancestry at the best. It is possible that both are specialized offshoots of a primitive stock which possessed a superior temporal fenestra, but this is by no means certain, for the temporal region may have evolved independently. On the other hand, the aquatic characters of the Sauropterygia make them appear more isolated than is actually the case, and may tend to obscure their relationships.

Comparisons with the Diapsida.—*Trilophosaurus* shows resemblance to certain diapsid reptiles. Its braincase closely resembles those of *Sphenodon* and the lizards in the high position of the inner ear and its separation from the brain cavity, in the absence of ossification anterior to the trigeminal notch, and in the primitive position of the carotid foramina. The epipterygoids and palate have similar relations. The pectoral and pelvic girdles of the recent types are advanced in being fenestrated but have the same general pattern. Resemblances of the humerus and femur with lizards have been pointed out in detail. The tarsus of *Trilophosaurus* is primitive in retaining a navicular, but the feet are otherwise similar, with the same phalangeal formula and hooked fifth metatarsal.

The Eosuchia, most primitive diapsid reptiles, are very lizard-like in palate and, so far as is known, braincase. They approach *Trilophosaurus* more closely than lizards in their two-arched skull, dorsal intercentra, and in retaining a navicular in the tarsus. *Youngina* has a straight fifth metatarsal, which is more primitive than the hooked type of other diapsids and *Trilophosaurus*. Possibly this structure has developed independently in the Protorosauria and Eosuchia.

Trilophosaurus is in about the same evolutionary stage as the Triassic rhynchosaurs (Huene, 1938). Both have lost the parietal foramen, acquired a highly specialized although different type of dentition, have similarly situated carotid and facial foramina, retain interpterygoid vacuities, have reduced suborbital fenestrae, have massive lower jaws with large primordial canals, no external mandibular fenestrae, splenials meeting in symphysis, and low coronoid processes. The divided atlas, proatlas, dorsal intercentra, form of zygapophyses, rib articulations, and long, low neural spines are common to both. The vertebral formula is nearly the same: *Stenaulorhynchus* has 25 presacral vertebrae, *Trilophosaurus* has 24; both have 7 cervicals and a gradual transition from cervical to dorsal regions. The limb and foot structure is rather similar; both have a navicular and hook-shaped fifth metatarsal.

Rhynchosaurs are less advanced than *Trilophosaurus* in the development of the tubera and basipterygoid processes, in retaining a quadrate foramen, a somewhat screw-shaped glenoid fossa, an entepicondylar foramen in the humerus, and a primitive femur. They are more advanced or specialized in the exclusion of the frontal from the orbital rim, ossification of the sidewalls of the braincase anterior to the trigeminal foramen, acromion process on the scapula, anterior spine of the ilium, and anterior process of the pubis. There are, of course, many differences of detail. The modifications for feeding are different, the jaw of *Trilophosaurus* being limited to strictly orthal movement, whereas the dominant motion in rhynchosaurs was propalinal. The skull proportions are widely different, doubtless largely to accommodate muscles suited to the peculiar jaw mechanisms, that of *Trilophosaurus* being narrow and deep, the rhynchosaurs low and broad. The beak of *Trilophosaurus* is not enamel-covered or overhanging but is more turtle-like and probably was horn-covered. The absence of a lower temporal fenestra removes *Trilophosaurus* far from the rhynchosaurs, which are typically diapsid.

The saurischian-like basicranium of *Trilophosaurus* is its only archosaurian character. It is far more primitive than any archosaur in the skull roof, unossified sphenethmoid region, absence of a mandibular foramen, presence of dorsal intercentra, expanded ventral plates of the girdles, and unreduced fifth digits. It retains a centrale in the tarsus, in contrast to all archosaurs but *Chasmatosaurus* (Broom, 1932, pl. 2). Unlike the primitive archosaurs, *Trilophosaurus* has no dermal armor.

The large array of resemblances between *Trilophosaurus* and the primitive diapsids indicates more than a similar grade of evolution. They are far more numerous and deep-seated than its resemblances to the therapsids or cotylosaurs and strongly indicate that *Trilophosaurus* is an offshoot of the stock which gave rise to the rhynchosaurs, squamata (Broom, 1925), and archosaurs. The retention of a single temporal fenestra indicates that its separation from the pre-diapsid stock occurred in Middle Permian time, or earlier, for primitive diapsids (Eosuchia) are already present in the Upper Permian.

The similarities in limb and girdle structure have developed independently but in parallel fashion from a common ancestor in which these trends already were genetically established. The dorsally placed ear chamber, slender stapes,[2] deep basisphenoid with strong tubera and basipterygoid processes are common heritage of the two groups.

On the whole *Trilophosaurus* shows more in common with the primitive diapsids than with the sauropterygians. This is due partly to the aquatic adaptations of the latter, which have modified the skeleton in a different direction from that in which these evolutionary trends are measured.

Comparisons with the Protorosauria.—Although this order may not be homo-

[2]Present in *Youngina* (Olson, 1936, p. 529).

geneous (see, for example, Watson, 1917), and though the skull structure of *Protorosaurus* itself is not satisfactorily known, there are a number of Permian and Triassic terrestrial reptiles which can not be properly referred to either the Diapsida or Synapsida and for lack of better evidence concerning their structure and affinities are grouped together in classifications. They seem to have possessed only a single fenestra on the upper portion of the temporal region, elongate cervical vertebrae, rather long limbs, and primitive girdles.

Protorosaurus (Mayer, 1856; Seeley, 1887) from the Upper Permian of Germany resembles *Trilophosaurus* in:

1. Parietals narrowing posteriorly to a sagittal crest.
2. Superior temporal opening.
3. Seven cervical vertebrae but 16 instead of 17 dorsal vertebrae.
4. Form of vertebral centra, intercentra, and neural spines.
5. Forking of neural spines of caudal vertebrae.
6. Slender cervical ribs.
7. Holocephalous posterior dorsal ribs.
8. Plate-like pelvis.
9. Similar limbs and feet; elongate compressed claws.
10. No entepicondylar foramen in humerus.
11. Centrale present in tarsus.

It differs from *Trilophosaurus* in the shape of its femur and in its pointed conical teeth. It is perhaps worthy of note that Weigelt (1930) has found seeds within skeletons of *Protorosaurus* and suggests that it may have been herbivorous. Although more detailed information about the skull of *Protorosaurus* is needed for proof of relationship, the resemblances between *Trilophosaurus* and this reptile are greater than with any other. If *Protorosaurus* was an herbivere, it is not impossible that its Triassic descendants might have acquired chopping teeth.

Araeoscelis, from the Lower Permian of North America, is likewise insufficiently known. The existence of a single upper temporal fenestra in its skull is fairly well established (Williston, 1914; Broom, 1931). The cheek region is deep like that of *Trilophosaurus*. The dentition is thecodont. *Bolosaurus*, which Broom (1913) suggested might be related to *Araeoscelis*, has teeth with slightly widened, cuspate crowns. It may, however, be more closely related to the diadectids (Case, 1911, p. 28). The vertebrae of *Araeoscelis* have heavy, primitive neural arches. Ossified intercentra are present. The rib articulation is similar to *Trilophosaurus*. The elongate limbs are similar, and the detailed agreement of the femora has already been commented upon.

Pleurosaurus, from the Upper Jurassic, has been shown by Watson (1914–A) to have a definite superior temporal fenestra and fixed quadrate. Its cheek region is not unlike *Trilophosaurus*, but the elongate body, aquatic modifications of the skull, and short vertebrae of different form do not suggest relationship. It has at times been referred to the Protorosauria, but Watson (1914–A) has shown that it is more probably closer to the Squamata.

Tanystrophaeus and *Macrocnemus* from the Alpine Middle Triassic are aberrantly specialized reptiles which have a single upper temporal fenestra, elongate cervical vertebrae, and lizard-like limbs in common with other Protorosauria. The feet of *Macrocnemus* strongly resemble those of *Protorosaurus* and *Trilophosaurus*, and many other similarities may be found between them.

Trilophosaurus differs from the animals previously grouped as Protorosauria in its transversely widened teeth and edentulous beak. These adaptive characters are no bar to relationship. Although the evidences for relationship are rather slender, due largely to imperfect knowledge of other forms, it is significant that *Trilophosaurus* agrees with *Protorosaurus* in those determinable characters in which it differs most importantly from other orders of reptiles.

It seems probable, as Broom (1931) has suggested, that the diapsid reptiles are descended from an *Araeoscelis*-like ancestor with a superior temporal fenestra. The Protorosauria show the beginnings of many evolutionary trends carried on by various diapsid orders. The parallelism between *Trilophosaurus* and the diapsids may be due to developmental tendencies inherited from common ancestors among the earlier Protorosauria. The Sauropterygia may be aquatic descendants of the same stock. Peyer (1939) has pointed out their similarities. *Trilophosaurus* can have no closer relationship with the Sauropterygia than through an early protorosaurian ancestor, because of the adaptive divergence between them. It is, like *Tanystrophaeus*, a specialized survivor of the Permian stock which gave rise to the Sauropterygia, Lepidosauria, and probably the Archosauria.

Synoptic Classification

Order PROTOROSAURIA, Seeley[3]

Permian and Triassic Reptilia having skulls with a single superior temporal fenestra, and primitive palate with interpterygoid vacuities. Inner ear situated above base of braincase, stapes slender. Basicranium deep with strong tubera in known forms. Postcranial skeleton primitive but with tendency toward elongate neck, slender cervical ribs, and moderately long, terrestrial limbs. Centrale retained in tarsus.

Families:

Araeoscelidae	Lower Permian
Protorosauridae	Middle-Upper Permian
Tanystropheidae	Middle Triassic
Trilophosauridae	Upper Triassic
?Pleurosauridae	Upper Jurassic

Family TRILOPHOSAURIDAE nov.

Reptiles with single pair superior temporal fenestrae in skull, high fixed quadrates exposed on side of skull, deep tubera and basipterygoid processes. Premaxillaries and front of dentaries edentulous, forming sharp beak, possibly covered with horn. Maxillaries and dentaries bearing a series of transversely broadened teeth which are replaced vertically. Palate with small suborbital and large interpterygoid vacuities. Vertebrae procoelous and platycoelous. Wedge-shaped intercentra throughout presacral vertebrae. Neural spines low and long. Cervical vertebrae with paired processes between postzygapophyses, covering neural canal. Elongated splint-like cervical ribs. Dorsal ribs two-headed anteriorly, holocephalous posteriorly, articulating with long transverse process of neural arch. Caudal vertebrae elongate, with chevrons. Scapula without acromion. Large coracoid with coracoid foramen. Humerus with ectepicondylar groove; no entepicondylar foramen. Manus pentadactyl, unreduced, with compressed claws. Phalangeal formula 2–3–4–5–3. Pelvis with posterior iliac spine, imperforate acetabulum, plate-like pubis and ischium. Femur elongate, with strong inner trochanter. Tarsus with navicular. Fifth metatarsal hook-shaped. Rear foot with claws similar to front foot, pentadactyl, formula 2–3–4–5–4.

Genus TRILOPHOSAURUS Case

With characters of the family. *Trilophosaurus buettneri* Case, Upper Triassic, North America.

APPEARANCE AND HABITS

Pl. 33

The skull of *Trilophosaurus* is 134 mm. long, the pre-caudal vertebral series 729 mm., plus the thicknesses of the intervertebral cartilages. The length of head and body, then, was somewhat over 863 mm., probably over 900 mm. (allowing only 1 mm. thickness for intervertebral cartilages it would be 890 mm.). In the two sections of the tail which are preserved the lengths of the centra total 826 mm. Several (perhaps 5) vertebrae near the base have been lost, and the centra at the end of the preserved portion show that the tail continued far beyond them. The tail may have been twice the length of the preserved portion, or about 1.6 meters. The lizard-like proportions of the body suggest a long tail. The total length, then, was about 2½ meters.

The slender, rather short, curved ribs, and the widths of the girdles indicate that the body was slender and lizard-like in proportions. The low neural spines and chevrons of the distal caudal verte-

[3]Professor C. L. Camp (*Prolacerta* and the protorosaurian reptiles: Amer. Jour. Sci., vol. 243, pp. 17–32, 1945) has suggested that *Protorosaurus* is a diapsid reptile belonging to the group hitherto called Eosuchia. If this proves correct, the name Araeoscelidia (Zittel, K. A. von, Textbook of Paleontology, 2nd English ed., vol. 2, 1932) may be preferable for the order under discussion. This paper by Camp appeared after the present manuscript had been set in type.

brae suggest a round tail. The limbs were slender and lizard-like.

The strong development of the ventral plates of both pectoral and pelvic girdles indicate that the limbs were held out from the sides of the body with the proximal segments nearly or quite horizontal. This position is also necessary to permit the joints to fit properly. The humerus is "twisted" and had expanded ends like a primitive reptile. It is most like that of lizards, among modern types, and these hold the upper arm horizontal. The femur is more advanced and very probably could be brought at least partly into a vertical fore-and-aft plane below the body when the animal was running rapidly. The head of the femur is slightly turned toward the anterior border, to about the same degree as that of phytosaurs, and the median region of the puboischiadic plate recedes beneath the acetabulum. The anterior border of the pubis is turned outward. All these features indicate adaptation to elevation of the body above the rear legs when running, but it is not possible to place the femur in a vertical plane without removing its head from the acetabulum. These adaptations are less advanced than the corresponding structures in the Crocodilia, however, so it is reasonable to assume that, like the crocodiles, *Trilophosaurus* habitually held its body close to the ground but could raise it and run with considerable speed when necessary.

The rear legs are slightly larger than the forelegs. The difference is not sufficient to postulate bipedalism (which would scarcely be possible unless the rear legs habitually remained in a vertical plane). The ratio of the length of the humerus to length of femur is 0.82, close to the ratio in primitive reptiles, such as the pelycosaurus (0.82–0.90 in *Ophiacodon*, 0.82–0.97 in *Dimetrodon*) and much greater than in primitive bipedal theropods such as *Saltopus* (0.65), *Ornitholestes* (0.60), or *Procompsognathus* (0.38). (Data from Romer, 1940, and Camp, 1936.) The tibia is only 4/5 the length of the femur, about the proportion found in *Ornitholestes* (0.77) and *Thecodontosaurus*. Most of the primitive bipeds have tibiae which exceed the femora in length. Other indications of quadrupedalism are the low neural spines of the dorsal vertebrae, which suggest that the back was kept nearly straight and that the animal did not raise up on on its rear legs, and the large front feet.

It is possible that *Trilophosaurus* could raise its body and forelegs from the ground and use its long tail for balancing when running rapidly just as some lizards are known to do. But its more usual pose must have been lizard-like with the body close to and parallel to the ground and its limbs extending out at the sides.

Assuming the humerus and femur to be held entirely horizontal, the height at the shoulder would be 300 mm. or about 1 foot, the height at the pelvis 250 mm. or 10 inches. The articulations of the cervical vertebrae would prevent much bending in the vertical plane, although permitting lateral motion. The short posterior cervicals and anterior dorsals, with extremely well-developed ball and socket articulations and short (anteroposteriorly) neural spines, would allow the neck as a whole to be raised to an angle with the back. This may have been a common posture. The articular surface of the occipital condyle is continued far ventrally, permitting the head to be strongly flexed on the neck. The deep tubera are like those of bipedal dinosaurs which held the head flexed on the neck in normal pose. The posterior slope of the ends of the centra of the cervical vertebrae would strengthen the neck if it were held sloping upward. All this points to a posture with the head held elevated.

The well-developed claws on both feet, and the slender toes, suggest considerable ability to go up rough surfaces. The compressed claws are unlike those of fossorial animals and are not adapted to digging. They would serve well for tearing rotten wood apart or for stripping bark from plants. Also they would have considerable value as offensive weapons. It seems most probable that they served principally to secure the animal's feet in locomotion. The flexor muscles of the arm had strong origins on the humerus. The toes could have grasped branches or held to rough surfaces in climbing. Although adult *Trilophosaurus* specimens seem large for arboreal animals, it is not impossible that they were such. Large species of *Iguana* are arboreal in habit. It seems plausible that *Trilophosaurus* may have climbed the cycads and conifers of the Triassic forest to obtain food.

Trilophosaurus lacks the sharp-pointed teeth of carnivorous animals and has a specialized chopping cheek dentition in combination with an edentulous, presumably horny beak. The jaw musculature was well developed and arranged to pull the jaws straight together. The transverse condyles permitted no grinding motion, and the unworn crowns of the teeth support the view that jaw motion was entirely orthal. The intermeshing chisel-like blades of the upper and lower teeth could cut up leaves or other soft matter very well. The food must have consisted entirely of matter which could be masticated readily, such as thick leaves, soft stems, soft fruits, or insects, for there is no grinding apparatus to crush harder structures. Accordingly a molluscivorous habit may be excluded. Nor was the diet nuts or other hard plant structure such as are used by rodents and, supposedly, by multituberculates.

The flora of the Chinle formation of Arizona has been described by Daugherty (1941). It contains ferns, lycopods, horsetails, cordaitaleans, cycads, ginkgos, and conifers, especially araucarias. As the vertebrae fauna associated with this flora is similar to that of the Dockum formation, it is likely that the flora was similar in the region inhabited by *Trilophosaurus*. Possibly it fed on the foliage of some of the ferns, cordaites, or cycads.

Trilophosaurus, then, was a moderately long, slender bodied, lizard-like reptile. At the front of its short head was a turtle-like beak. Its skin presumably was covered with scales but lacked heavy plates or spines of any sort. It was herbivorous and very possibly partly arboreal. Its only offensive weapons were sharp claws and possibly its long tail. It was probably an inhabitant of the drier portions of the Triassic flood plains, avoiding the swamps and streams in which the predatory phytosaurs lived. If it was arboreal, it may have found protection from terrestrial carnivores by climbing. Its rarity as the fossil in the Triassic deposits of the southwestern United States bespeaks a different habitat from the phytosaurs and amphibians as does also the structure of its body, which is better adapted to terrestrial life.

SUMMARY

A nearly complete articulated skeleton and supplementary skull material of *Trilophosaurus buettneri* Case is described from the Upper Triassic Dockum formation of southeastern Howard County, Texas. The more important osteological characters of this reptile are:

1. Premaxillaries and symphysis of lower jaw edentulous and beak-like.
2. Maxillaries and dentaries bearing a series of 12 to 15 transversely broadened, blade-like teeth with 3 obscure cusps.
3. Teeth thecodont, replaced vertically, in regular sequence from front of jaw toward back.
4. Palate with interpterygoid vacuities, small suborbital fenestrae, deep quadrate rami of pterygoids; no palatal teeth; no secondary palate.
5. Skull roof with large superior temporal fenestrae, but no lateral or antorbital fenestrae; temporal region solidly covered laterally. No pineal foramen.
6. Quadrates tall, exposed on side and back of skull, curved backward at top, with transverse condyle well below line of teeth.
7. Inner ear located high on side of braincase, separated from brain cavity by bone, and constricting the cranial cavity, much as in lizards.
8. Braincase with high dorsum sellae, deep sella turcica, lateral walls unossified anterior to trigeminal notch.
9. Internal carotids pierce basisphenoid from below at base of basipterygoid processes.
10. Deep tubera basisphenoidales and downward-projecting basipterygoid processes with deep pit between them similar to theropods.
11. Fenestra ovalis small; stapes slender and rod-like.
12. Cervical vertebrae procoelous, with paired processes internal to postzygapophyses, and bearing splint-like ribs.

13. Dorsal vertebrae platycoelous, with low elongate neural spines, and crescentic intercentra.
14. Caudal vertebrae procoelous, elongate.
15. Ribs two-headed anteriorly, holocephalous posteriorly. Belly ribs well developed.
16. Scapula tall, without acromion; large plate-like procoracoid, no metacoracoid.
17. Pelvis with plate-like pubis and ischium, the anterior border of the pubis turned outward.
18. Limb bones elongate and lizard-like. Humerus without entepicondylar foramen.
19. Feet large, pentadactyl, with fourth toe longest, large compressed claws.
20. Tarsus with navicular; 5th metatarsal hook-shaped.

None of the skeletal characters of *Trilophosaurus* bar it from descent from a primitive diadectomorph cotylosaur, insofar as present inadequate knowledge of that group indicates. But the only positive characters supporting this relationship are the transversely wide cheek teeth and their firm, thecodont implantation. As transverse teeth have arisen independently at least twice within the cotylosaurs, and also in the lizards, this adaptive character cannot be relied upon too heavily as an indication of relationship. The resemblance of the posterior part of the skull to the diadectids and procolophonids is illusory as the overhanging portion in *Trilophosaurus* is formed by the quadrate instead of by squamosal and tabular. The temporal region of the skull and post-cranial skeleton are widely different from the procolophonids and indicate divergence from that stock at least by early Permian time.

The similarity of the otic region and other parts of the brain case to *Sphenodon* and the lizards suggest relationship to the diapsid reptiles.

Trilophosaurus resembles the Protorosauria in: (1) skull with superior temporal fenestra, (2) form of vertebrae and rib articulations, (3) dorsal intercentra, (4) primitive girdles, (5) form and proportions of limb bones, (6) tarsus with navicular, unossified fifth distal carpal and tarsal, hooked fifth metatarsal, and (7) well-developed, lizard-like toes with compressed claws. The resemblances which it shows to the primitive diapsids and to the sauropterygians, all of which may have been derived from protorosaurian ancestors, suggest both common heritage and parallelism in development and strengthen the hypothesis that it is an offshoot of the Protorosauria.

The transversely widened cheek teeth and edentulous beak of *Trilophosaurus* are adaptive structures which are not known in other members of the Protorosauria but are no bar to its relationship to that order. As a majority of its characters indicate affinity with the Protorosauria, it is tentatively referred to that order as the only member of a new family, Trilophosauridae.

MEASUREMENTS

The tables which follow contain the chief measurements of the articulated skeleton of *Trilophosaurus*, No. 31025–140. Measurements have been made of the available limb bones to determine the mean size and extent of variation among them; these results are presented in summary and compared with those of the articulated specimen. It appears that the skeleton is slightly smaller than the mean size of the *Trilophosaurus* specimens from this quarry. Some very small bones, obviously those of young animals, have been excluded from the samples so that they represent only the normal adult population.

Many of the bones are distorted so that the measurements are not accurate. Only specimens which retained nearly normal shape were measured, but many of these were cracked or bent so that the values may differ by several millimeters from the original length of the bone. Some of the measurements may be biased by consistent distortion; for example, lengths of humeri and femora are probably more frequently increased than decreased by cracking and subsequent filling of the cracks, whereas radii and fibulae, which are slender elements, are commonly shortened by bending. No attempt was made to allow for this distortion; any bone which was too poorly preserved for reasonably accurate measurement was rejected.

All measurements are in millimeters.

Measurements of Skull

Skull measurements are taken from a model based on the incomplete skull belonging to the articulated skeleton No. 31025–140 and second incomplete skull No. 31025–143. Corrections have been made for slight size differences between these specimens, the model being the size of the skull with the articulated skeleton. The effects of distortion have been eliminated as far as possible. Measurements of the lower jaw are taken from No. 31025–5, the most complete spceimen in the collection, which is very nearly the same size as the jaw fragments associated with the skeleton.

Length skull, tip premaxillary to occipital condyle	134
Length skull, tip premaxillary to line behind quadrate condyles	120
Width skull across top quadrates	69
Width skull across quadrate condyles	78
Length lower jaw, line from tip symphysis to angle	134

Measurements of Vertebrae

Length of centrum is maximum in midline of ventral side, including ball or rounded surfaces when present. Diameter is measured transversely across posterior end of centrum. Height of neural spine is from base of centrum; length of neural spine is measured near top.

Vertebra	Length centrum	Diameter centrum	Height spine	Length spine	Width post-zygapophyses
2 Axis	24.8	9.5	34.1	20.2	28.2
3 (Cervical III)	33.0	10.5	32.6	20.7	32.5
4 (Cervical IV)	31.9	----	39.7	25.6	27.6
5 (Cervical V)	32.0	----	43.0	26.2	----
6 (Cervical VI)	27.8	16.0	49.4	24.6	25.8
7 (Cervical VII)	24.4	17 ±	55.1	19.4	25.6
8 (Thoracic I)	22.3	16.8	57 +	10.5	33.2
9 (Thoracic II)	21.5	15.4	71 (?)	15.3	21.5
10 (Thoracic III)	27.0	15.5	59.4+	10.6	----
11 (Thoracic IV)	28.1	15.2	63.3 ap.	19.4	15.0+
12 (Thoracic V)	27.3	15.5	67 +	26.9	15.6
13 (Thoracic VI)	28.6	16.5	62.8+	26.4	13.9
14 (Thoracic VII)	30.6	15.3	68.0	30.3	11.6
15 (Thoracic VIII)	31.3	16.4	70.7	32.8	----
16 (Thoracic IX)	33.5	15.9	77 ±	----	10.8
17 (Thoracic X)	34.2		64 +	29	----
18 (Thoracic XI)	31.9	16.5	66.2+	32.3	----
19 (Thoracic XII)	32.0	17.8	76	33.3	----
20 (Thoracic XIII)	31.5	18.2	66 +	30.3	18.7
21 (Thoracic XIV)	29.4	19.0	62.0+	28.4	----
22 (Thoracic XV)	29.3	20.3	70.5 ap.	29.4	25.1
23 (Thoracic XVI)	25.7	22.7	73 ±	21.4	22 ±
24 (Thoracic XVII)	25.6	21.6	70.5 ap.	23.4	24.4

Sacral Vertebrae

Vertebra	Length centrum	Diameter centrum	Height spine	Length spine	Width post-zygapophyses	Width transverse processes
25 (Sacral I)	33.7	----	----	----	?17.6	86
26 (Sacral II)	31.5	24.7	62.5	24.7	22.5	62.0

Caudal Vertebrae

Vertebra	Length centrum	Diameter centrum	Height spine	Length spine	Width post-zygapophyses
27 (Caudal I)	30.4	24.6	64.4	29.5	27.1
28 (Caudal II)	32.2	23.4	68–73 ap.	27.8	25.0
29 (Caudal III)	34.9+	21.1	63 +	35.9	29 —
30 (Caudal IV)	44 ap.	18.3	----	31.7	20.8
31 (Caudal V)	39.8	18.0	----	----	----
32 (Caudal VI)	44.4±	18.0	----	----	----
33 (Caudal VII)	44.3	17.9	57.6+	37 ±	----
34 (Caudal VIII)	48.6	17.4	42.3	40.7	----

ap. = approximate.

Second Tail Section

Number	Length centrum	Diameter centrum	Height posterior end spine	Length neural spine	Width post-zygapophyses
11	53.8	16.7	32.9	53.5	—
10	51.2	17.1	30.9	52.2	—
9	49.5	16.8	30.4	53.0	18.1
8	52.3(?)	16.9	29.9	51.5±	16.0
7	50.0	15.7	28.2	52.1	15.4
6	48.9	15 ±	25.7±	50.0	—
5	49.0	13.8	25.2	50.8	12.8
4	49.0	13.5	22.8	48.4	12.7
3	47.9	13.3	22.0	48.2	11.4
2	47.4	12.8	—	—	—
1	47.8	13.4	17.4	46.5	—

Measurements of Appendicular Skeleton

Height scapula, front glenoid to top blade	147
Dorsal process of glenoid to front scapular blade	56
Posterior lip glenoid to posterior lateral process of coracoid	54
Anteroposterior length of coracoid	130
Lower lip glenoid to medial margin coracoid	66
Interclavicle, length	106
Interclavicle, width head	24.0
Interclavicle, width stem	5.2
Interclavicle, width broadest part stem	21
Length spine ilium	87
Anteroposterior length base ilium	67
Pubis, length acetabulum to median edge along buttress	62
Humerus, length	172
Radius, length	123+
Ulna, length	140
Length manus including carpus, to end 4th toe	195
Length third digit, including metacarpal	144
Length 4th digit, including metacarpal (two phalanges from another specimen)	175
Length femur	209
Length tibia	165
Length fibula	160+
Length pes, from fibular facet astragalus	222
Length 4th digit pes, including metacarpal	193

Summary of Measurements of Length of Limb Bones

Bone	Number of specimens	Range	Mean	Standard deviation	Coefficient of variation	Skeleton No. 140
Humerus	27	149–200	174.48±2.55	13.26±1.80	7.55±1.03	172
Radius	12	106–139	125.83±2.99	10.31±2.11	8.23±1.68	122
Ulna	14	123–158	144.50±2.90	10.87±2.05	7.53±1.42	140
Femur	38	172–234	205.50±2.83	17.42±2.00	8.50±0.98	209
Tibia	21	149–190	169.60±2.65	12.16±1.88	7.18±1.11	165
Fibula	4	160–184	171.5	—	—	160+

Direct comparisons of linear measurements of skeletal elements between different animals are frequently unsatisfactory because of differences in total size of the animals. For valid comparisons of relative lengths it is necessary to reduce these to terms of a common unit which is adjusted to the bulk of each animal which is being studied. Romer (1940, p. 8) has suggested that (radius of dorsal vertebra)$^{2/3}$ is such a unit and has applied it extensively in his studies of the Pelycosauria. This unit has been calculated for the articulated skeleton of *Trilophosaurus,* using the mean of the diameters of the 11th to 20th vertebrae as a base. The value is 4.05 or approximately 4.1 mm. for this specimen. In the following table some of the skeletal measurements are reduced to this unit and compared with similar measurements of certain pelycosaurs (data from Romer, 1940, Tables 5, 6, 8.). At present data are lacking for comparisons with reptiles that are more closely related to *Trilophosaurus.*

	Trilophosaurus buettneri	*Ophiacodon retroversus*	*Sphenacodon ferox*	*Edaphosaurus boanerges*	*Casea broilii*
Unit value	4.1	5.94	4.48	5.24	3.30
Length skull to quadrate	29	79.3	61.2	26.7	23.9
Width skull at quadrates	19	25.9	29.5	17.0	20.3
Height scapula	36	29.1	29.9	31.1	23.9
Length humerus	42	23.0	30.8	30.9	25.5
Length radius	30	17.7	22.8	19.3	20.3
Length femur	51	23.2	25.4	19.1	17.6

Two rather obvious comparisons are supported by these figures. The relative size and proportions of the skull are most similar to *Edaphosaurus* and *Casea,* reptiles with durophagous dentition, and much smaller than the skulls of the carnivorous pelycosaurs. Secondly, *Trilophosaurus* has much longer limb bones than any pelycosaur, which is indicative of greater speed and agility.

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PLATE 18

FIGURES—

1. Quarry 1, Howard County, Texas, from the hill to south, shortly after beginning of excavation, January, 1940.
2. Looking west along Quarry 1 in August, 1940. The cleared shelf 2 feet above the quarry floor lies just above the fossiliferous layer.

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PLATE 19

Trilophosaurus buettneri Case, x1. Skull and three proximal cervical vertebrate of skeleton No. 31025–140.

1. Lateral view, right side.
2. Palatal view.

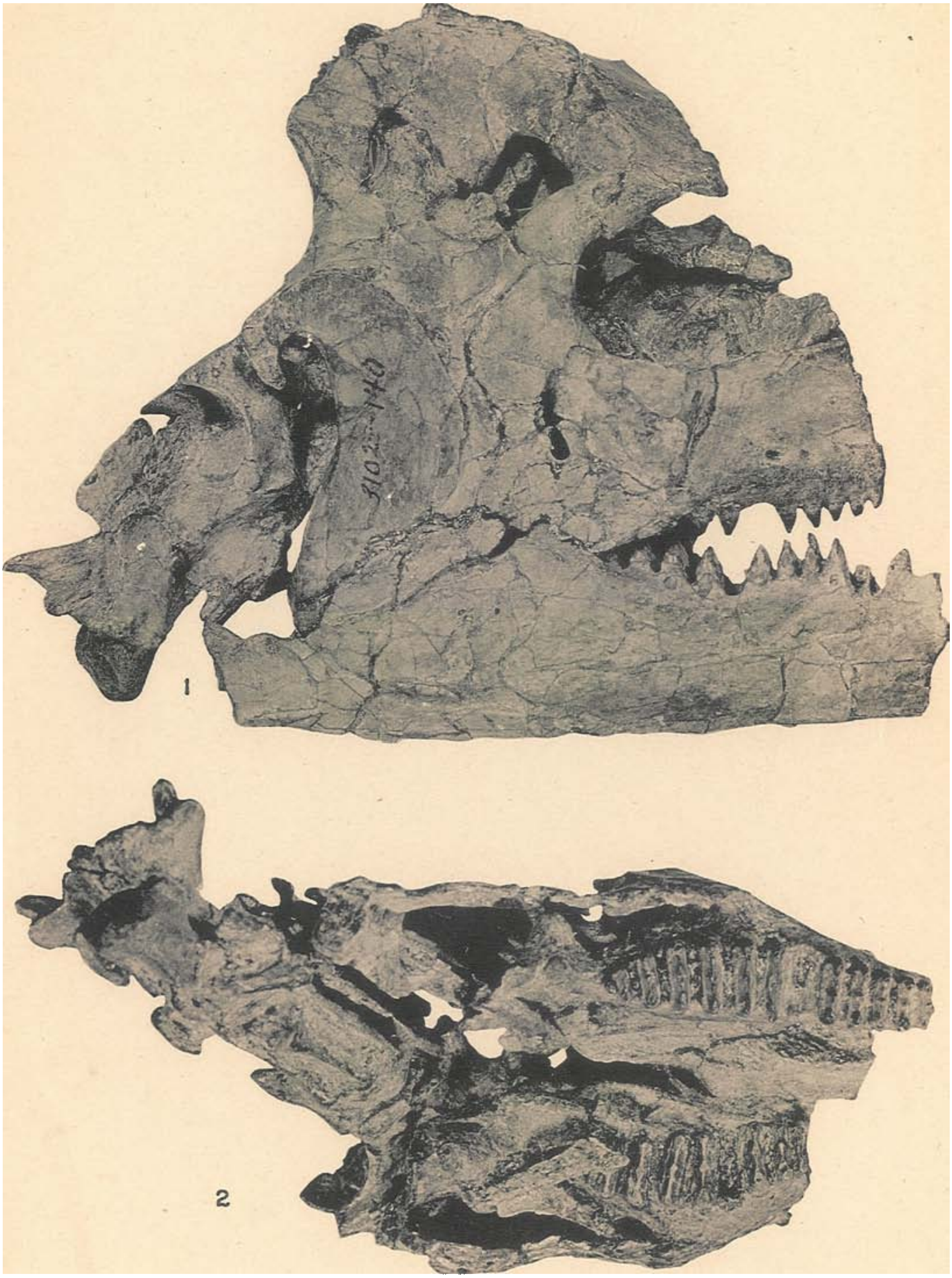
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PLATE 20

Trilophosaurus buettneri Case.

1–3. Longitudinal sections of maxillary showing tooth implantation and replacement, x1. No. 31025–143. 1, Left side. 2, Palate. 3, Right side.

4. No. 31025–127, x1.5. Anterior end toward bottom of plate. Note replacing tooth in pulp cavity of tooth to right of empty alveolus.

5. No. 31025–105, x1.5. Alveolar walls are in close contact with roots of teeth but distinct from them. Two replacing teeth show. Anterior end toward bottom of plate.

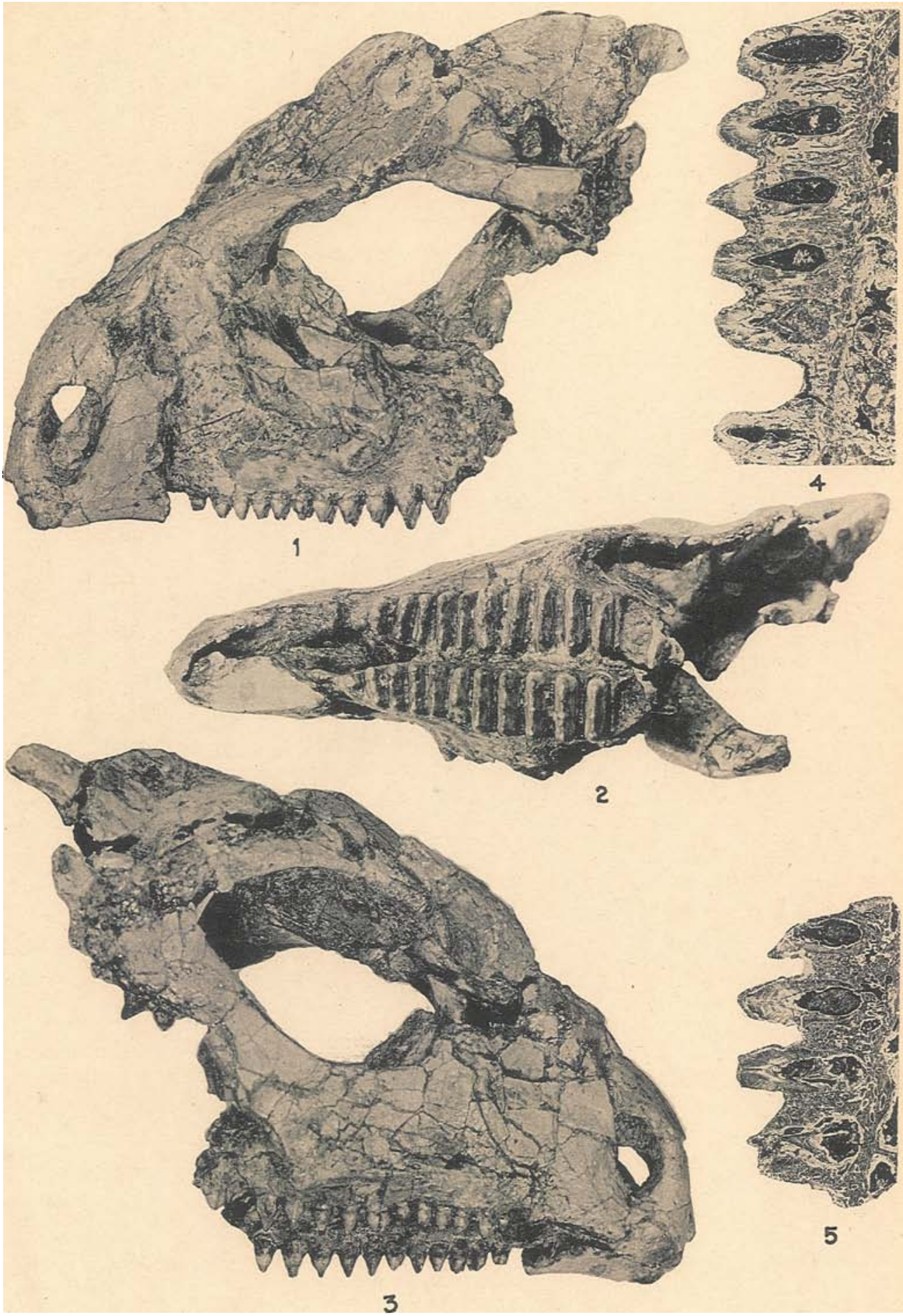
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PLATE 21

Trilophosaurus buettneri Case. Lower jaws.

1. Internal view, right mandible, No. 31025–140.
2. Occlusal view, No. 31025–5.
3. Lateral view, left side, No. 31025–5.

All figures natural size.

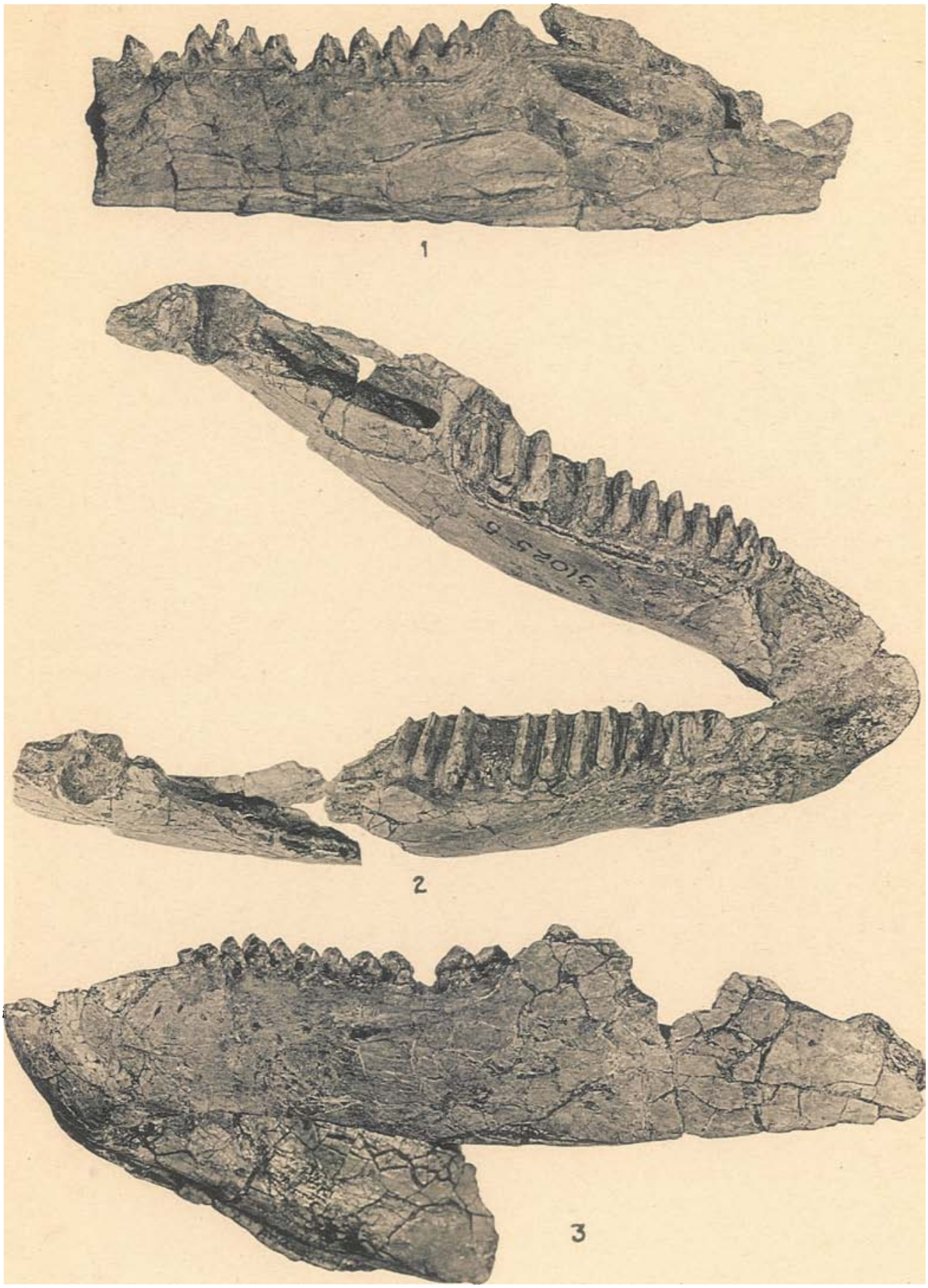
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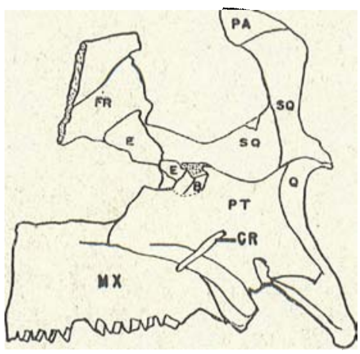
PLATE 22

Trilophosaurus buettneri Case.

1. Frontals and parietals, dorsal view, No. 31025–4.

2. Internal view of right side of skull No. 31025–140. MX, maxillary; PT, pterygoid; Q, quadrate; E, epipterygoid; B, basipterygoid process; SQ, squamosal; PA, parietal; FR, frontal; CR, cervical rib. The epipterygoid is displaced forward slightly from its proper articulation with the parietal.



3. Left lower jaw of No. 31025–140, internal view. The lower end of the quadrate has not been separated from the jaw; it is slightly forward of the articular cotylus. The posterior end of the pterygoid is seen applied to the lower end of the quadrate.

4. Lateral view of lower jaw of No. 31025–108. Replacing teeth are visible below the three teeth following the gap in the series.

All figures natural size.

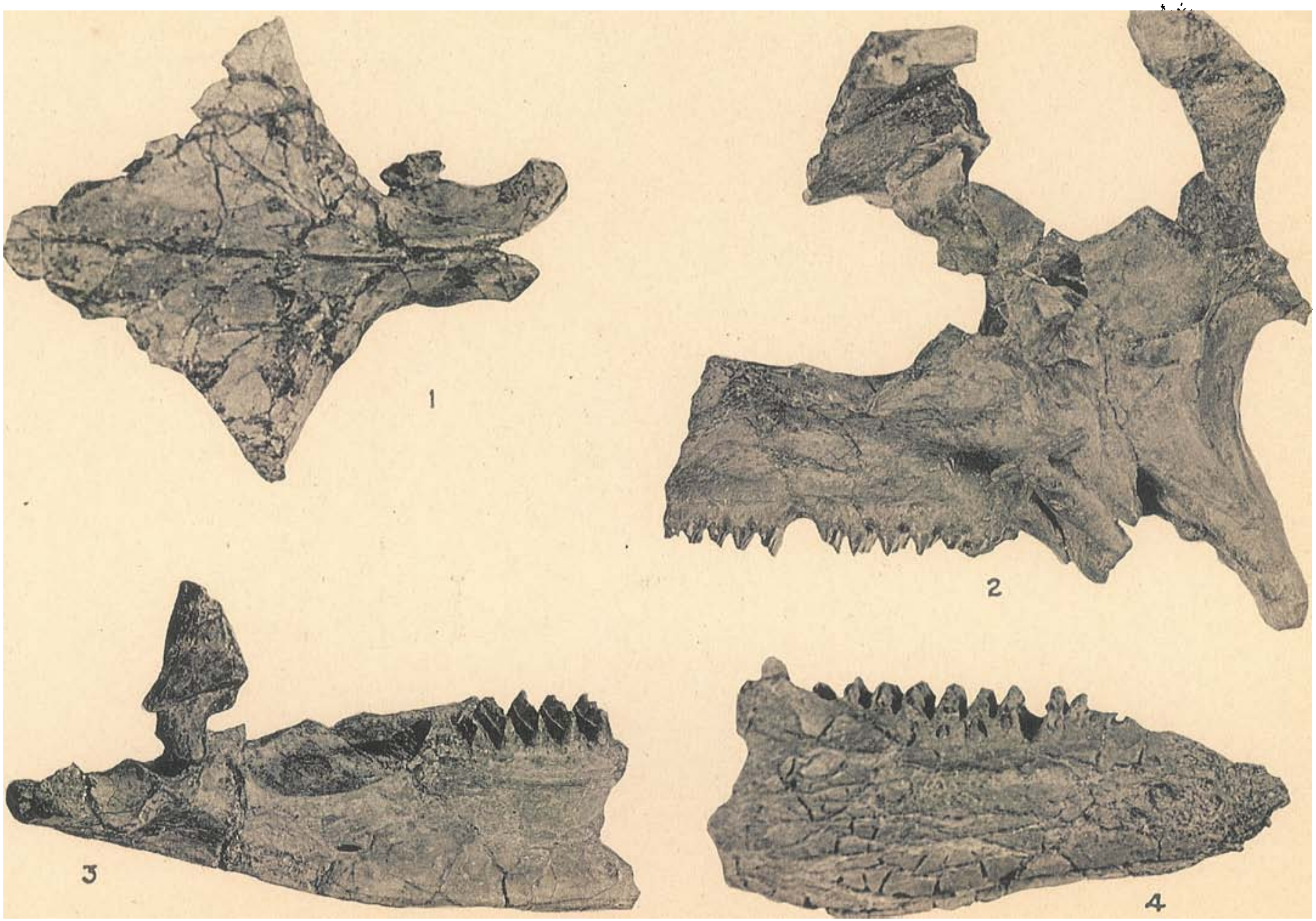


Plate 22

PLATE 23

Trilophosaurus buettneri Case. Cervical vertebrae.

Middle cervical vertebra, No. 31025–46.

1. Left side.
2. Dorsal view, showing internal shelf from posterior zygapophytes.
3. Posteroventral view, showing zygopophysial surfaces. Seventh cervical vertebra, No. 21025–140.
4. Right side.
5. Posterior end.

Fourth, fifth, and sixth cervical vertebra, No. 31025–140.

6. Left side view.

All figures natural size.

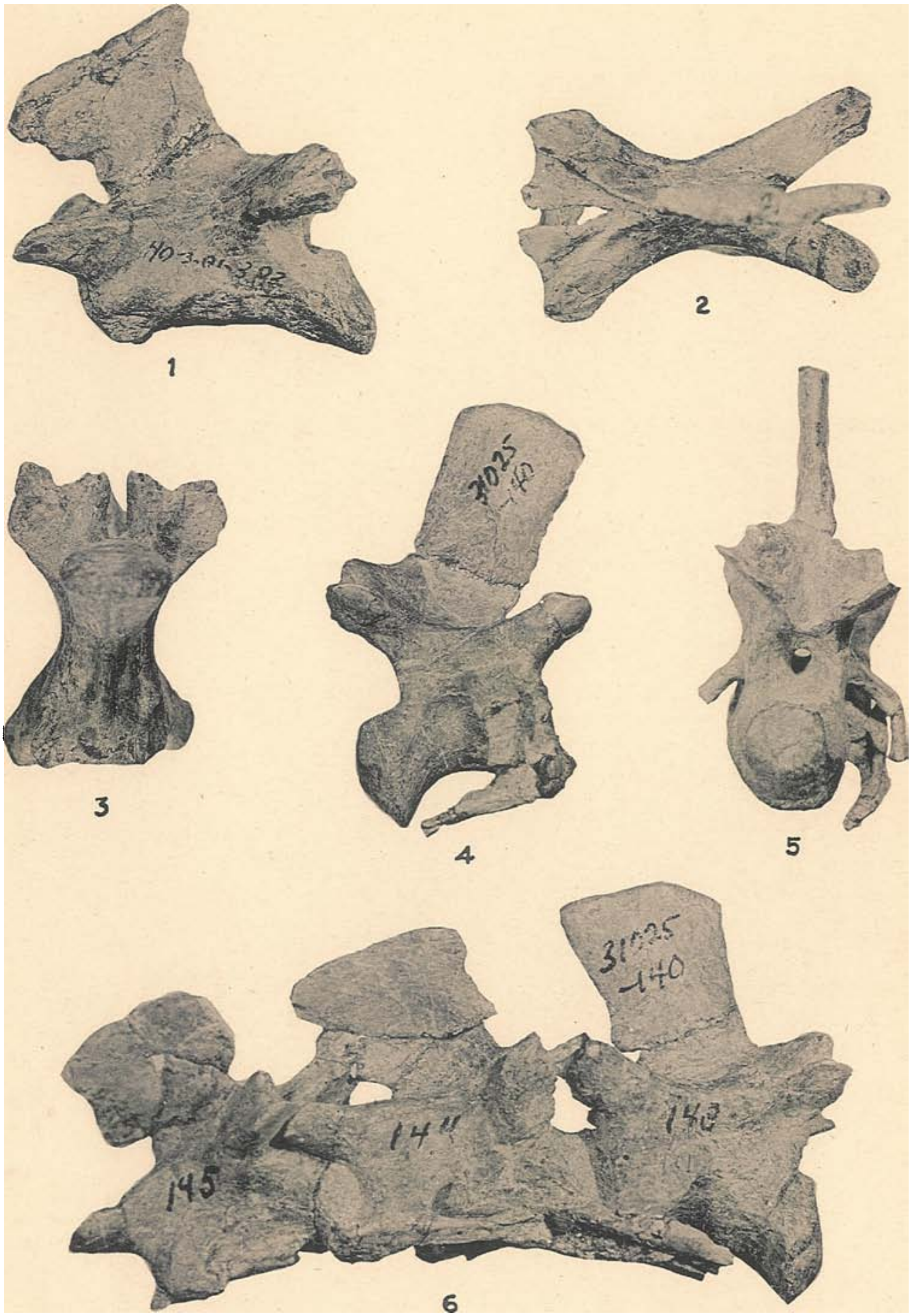

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PLATE 24

Trilophosaurus buettneri Case. Caudal vertebrae and chevron bones.

1. Eighth caudal vertebra, No. 31025–140. Left side.

2. Third and fourth caudal vertebrae from detached section found directly behind skeleton. Dorsal view.

3. Most proximal vertebrae of detached section of tail, viewed from left. These vertebrae articulate in front of the two shown in dorsal view. Shows form of distal chevrons.

4–7. Proximal caudal chevrons, all isolated specimens, No. 31025–90. 4, Left side. 5, Anterior view. 6, Posterior view. 7, Left side, chevron somewhat anterior to No. 4.

All figures natural size.

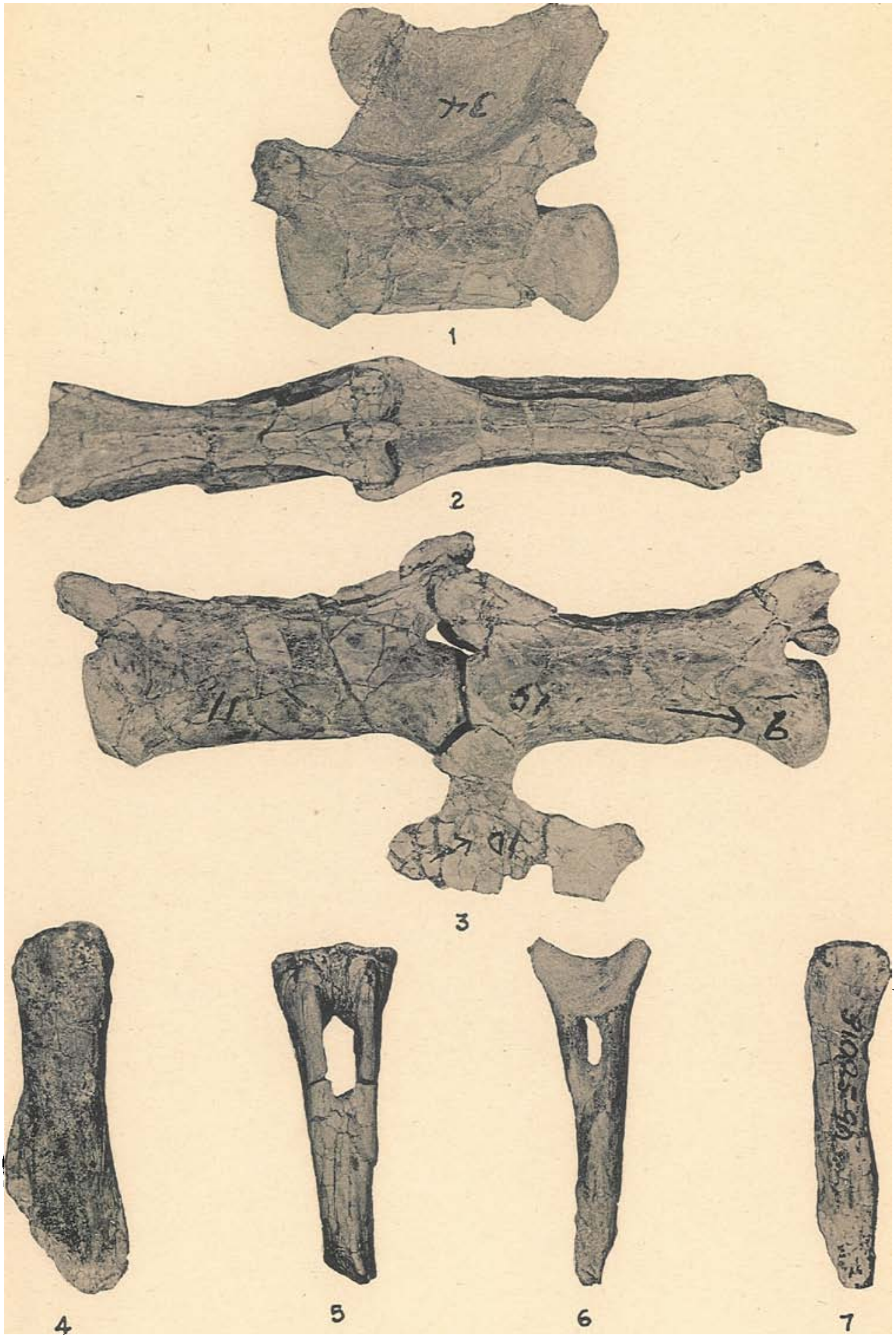
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PLATE 25

Trilosphosaurus buettneri Case. Skeleton No. 31025–140.

1. Seventh and eighth dorsal vertebrae, left side. Note intercentrum.
2. Sacral and first caudal vertebrae, ventral view. A portion of the left ilium is attached, not in proper position.
3. Anterior view of rib attached to second thoracic vertebrae.

4, 5. Posterior dorsal ribs.

6. Lumbar rib.

All figures natural size.

1 2 3 4 5 6

PLATE 26

Trilophosaurus buettneri Case. Pectoral girdle.

Interclavicle, No. 31025–144. Possibly that of *Trilophosaurus.*

1. Lateral view.
2. Dorsal view.

Right scapula, No. 31025–68R.

3. Anterior view.
4. Lateral view.

Right coracoid, No. 31025–69H.

5. Lateral view.
6. Medial view.

Pectoral girdle and anterior thoracic vertebrae of skeleton No. 31025–140. Some of the vertebrae have been inextricably crushed into the bones of the girdle.

7. Right side.
8. Dorsal view. Note shape of anterior end of interclavicle, which lies just above the lower front edge of the left scapula. The dorsal portions of the scapular blades were removed for this photograph.

All figures one-half natural size.

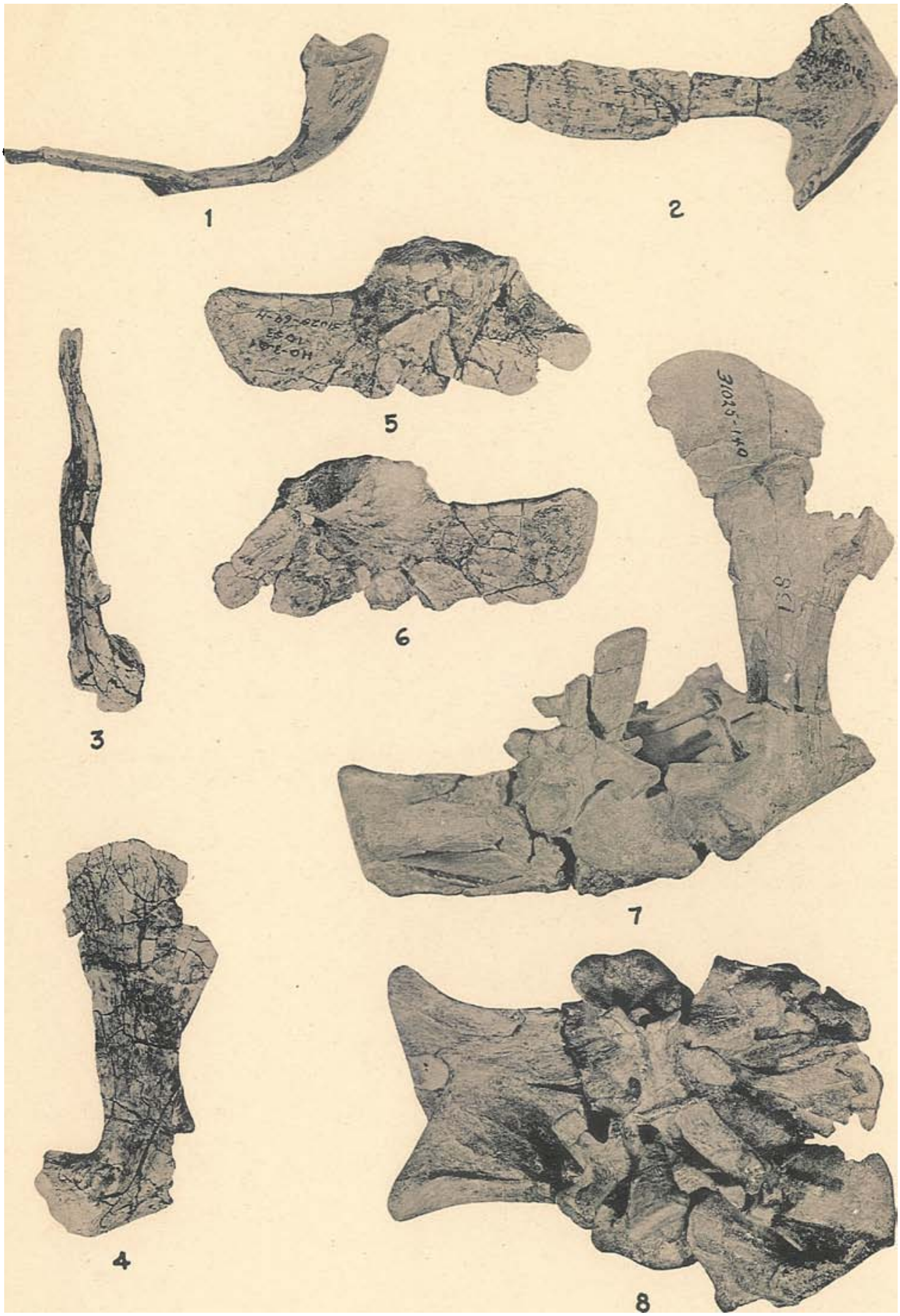
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PLATE 27

Trilophosaurus buettneri Case. Bones of forelimb.

1. Anterior view of right humerus. No. 31025–661.
2. Posteroventral view of left humerus of skeleton No. 31025–140.
3. Anterodorsal view of left humerus of skeleton No. 31025–140.
4. External side of left radius, No. 31025–82P.
5. Medial side of left radius, No. 31025–82M.
6. External side of right radius, No. 31025–82.
7. External side of right ulna, skeleton No. 31025–140.
8. Medial side of left ulna, same skeleton.
9. External side of right ulna, No. 31025–81H.
10. Medial side of same specimen as figure 9.

All figures one-half natural size.

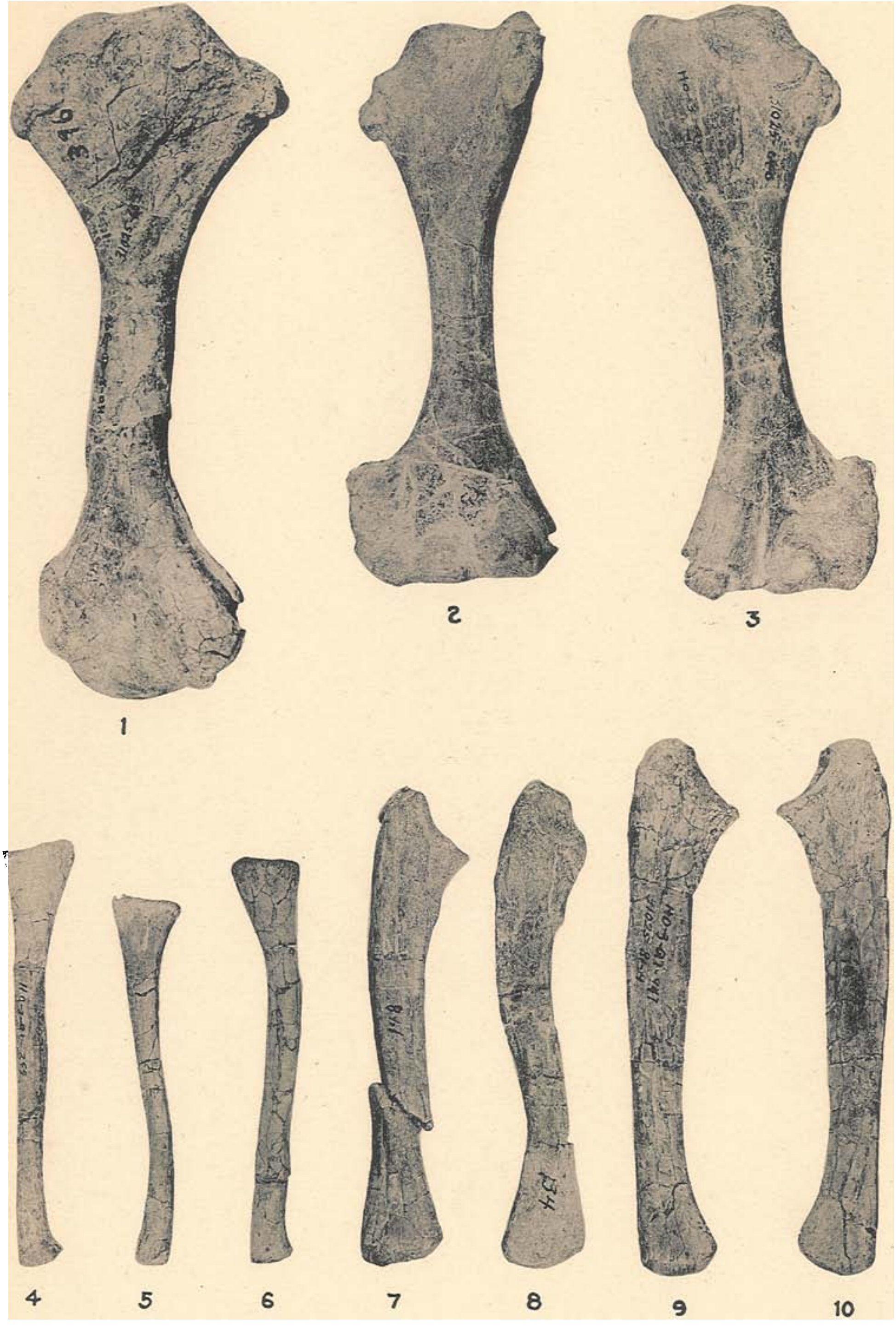
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PLATE 28

Trilophosaurus buettneri Case. Pelvic girdle.

1. External side of right ilium, No. 31025–77.
2. External side of left ilium, No. 31025–77D.
3. Internal side of left ischium, No. 31025–78.
4. External side of left ischium, No. 31025–78I.

All figures natural size.


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31025-78

PLATE 29

Trilophosaurus buettneri Case.

1. External view of pubis, No. 31025–79B, x1.
2. Anterior view of same bone, x1.
3. Left femur, lower side, skeleton No. 31025–140, x½.
4. Dorsal side of same bone, x½.
5. Ventral aspect of femur, No. 31025–67TT, x½.
6. Dorsal side of same, x½.


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31025-79B
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PLATE 30

Trilophosaurus buettneri Case.

1. Left tibia, anterior view, No. 31025–80P, x½.
2. Tibia, posterior view, No. 31025–80F, x½.
3. Fibula, external view, No. 31025–83A, x½.
4. Fibula. medial view, No. 31025–83C, x½.
5. Dorsal side of right astragalus, No. 31025–140, x1.
6. Plantar side of left astragalus, No. 31025–140, x1.
7. Dorsal side of right calcaneus, No. 31025–140, x1.
8. Medial side of right navicular, No. 31025–140, x1.
9. Plantar side of left navicular, No. 31025–140, x1.
10. Lateral view of ungual and subterminal phalanges of fourth toe, right pes, No. 31025–140, x1.
11. Lateral view of ungual and subterminal phalanges of fifth toe, right pes, No. 31025–140, x1.

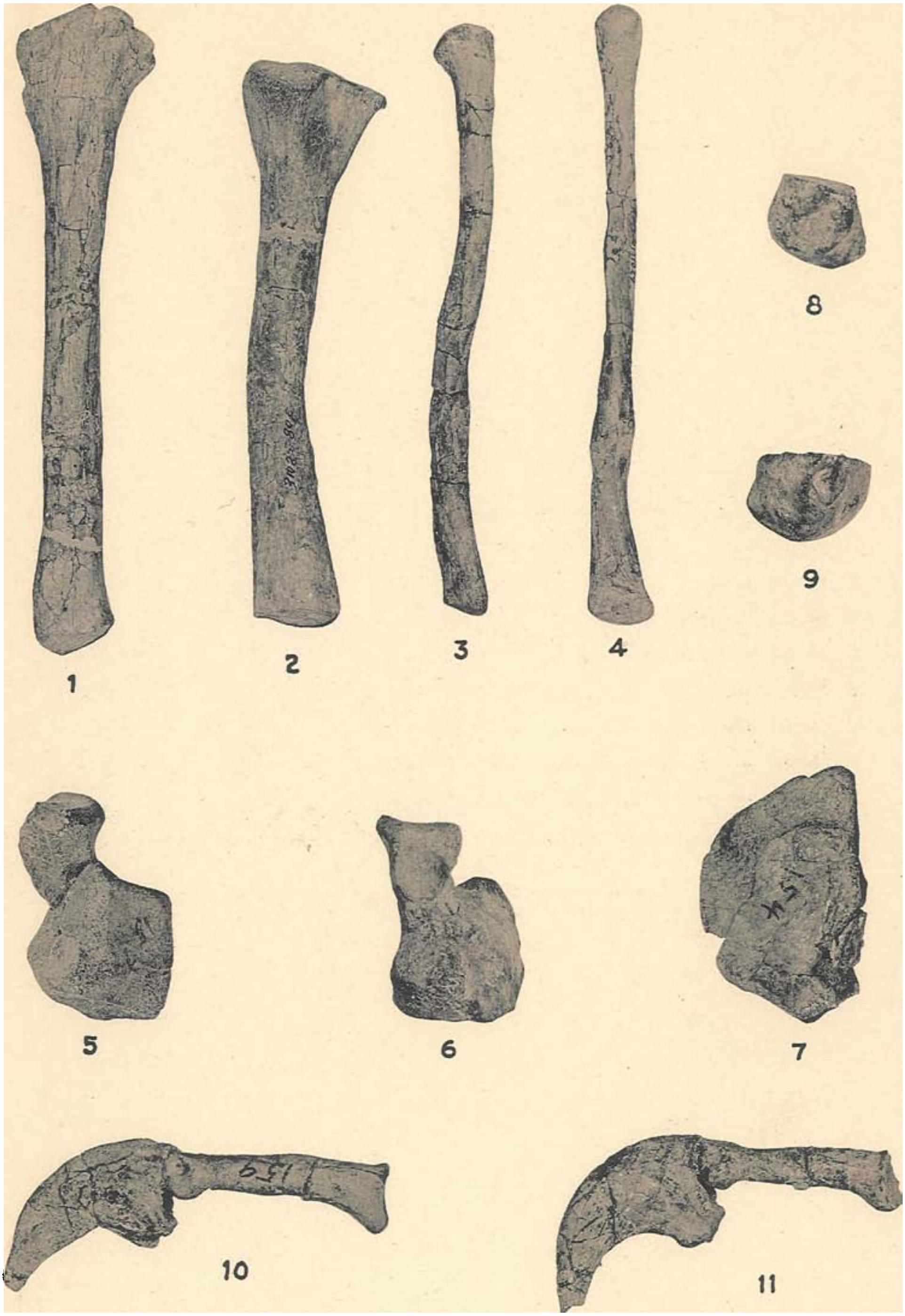
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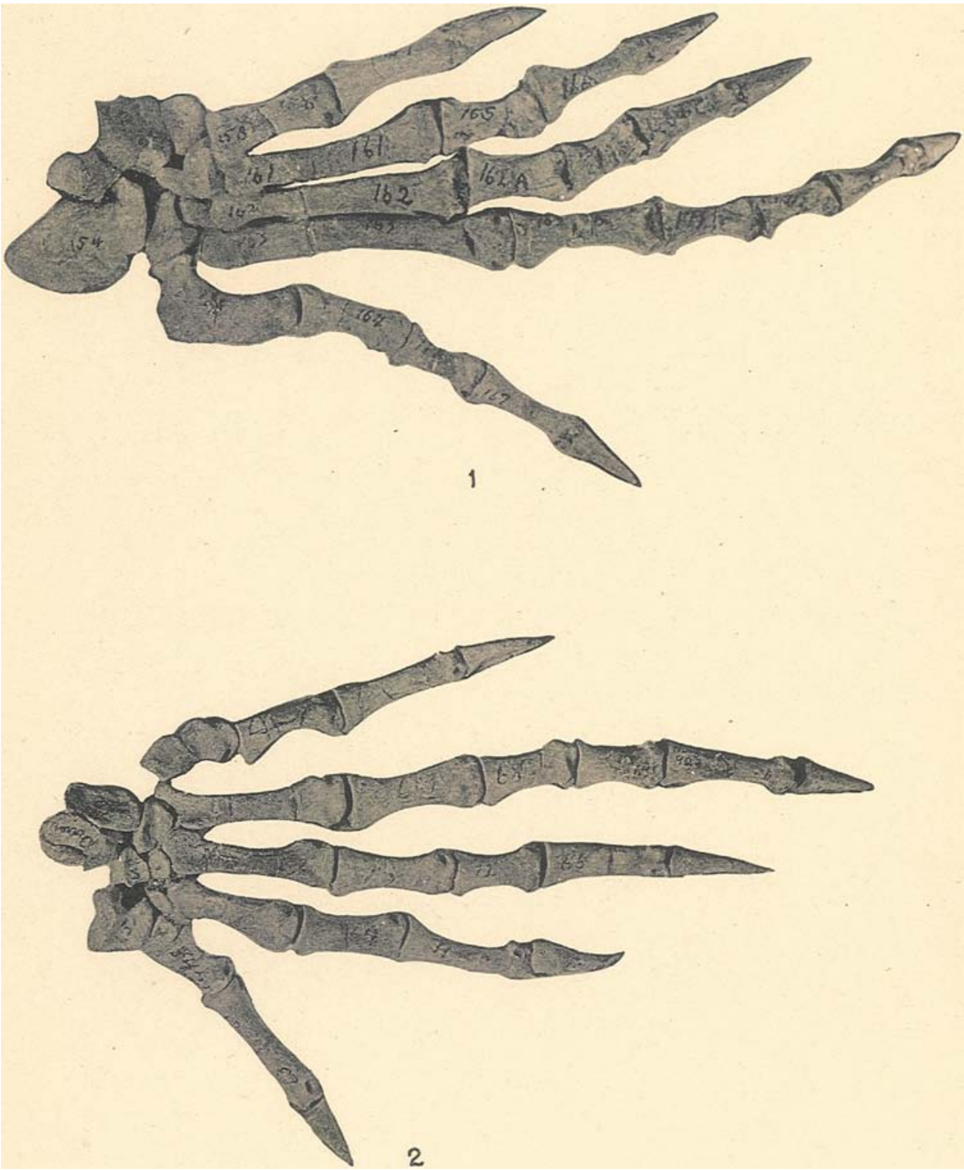
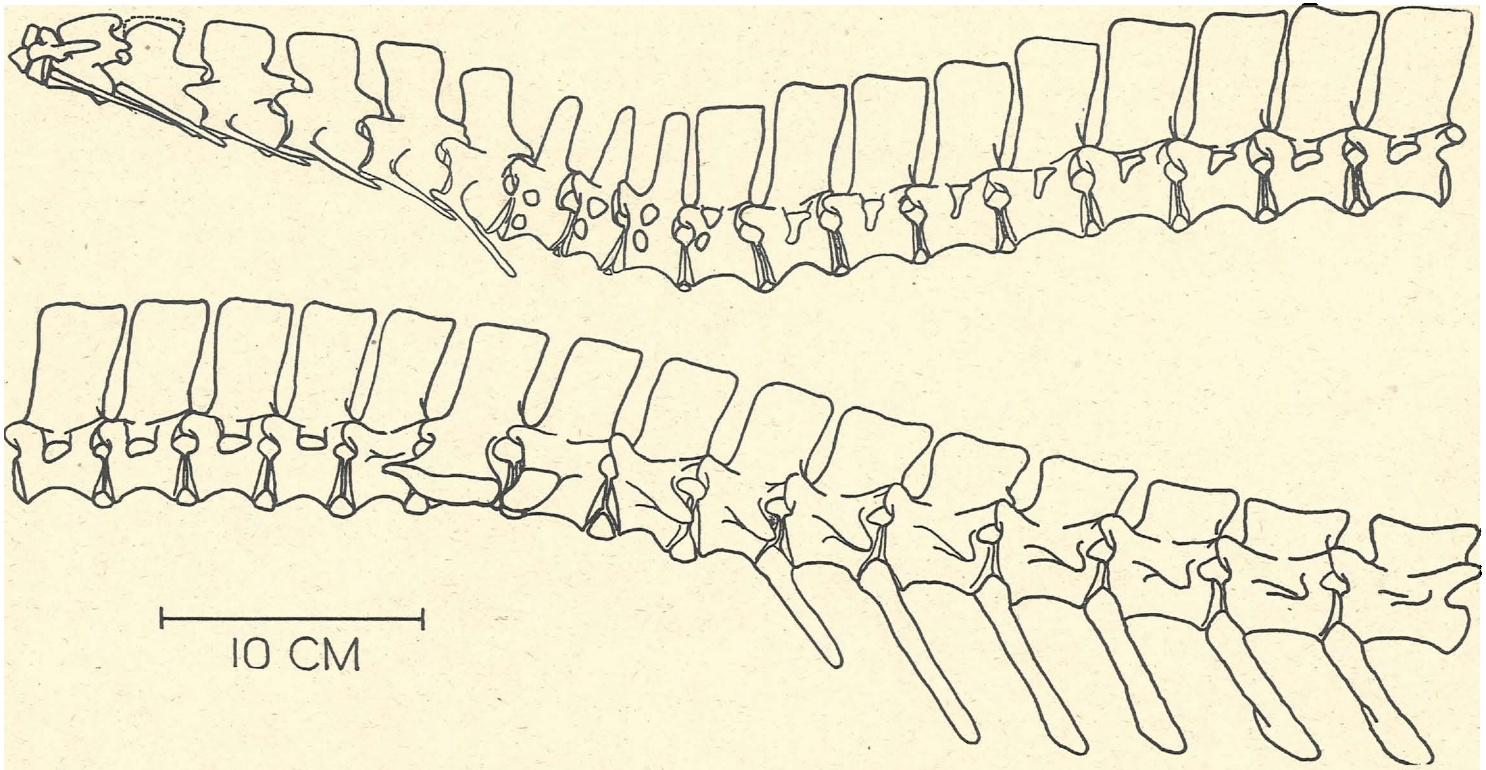
PLATE 31

Trilophosaurus buettneri Case.

1. Right pes, dorsal side, the toes straightened but otherwise as found articulated, No. 31025–140, x0.54.
2. Left manus, dorsal side, x0.54. The carpus bones articulated by their shape; not in position found. No. 31025–140.





Trilophosaurus buettneri Case, x0.35; restoration of the vertebral column of specimen No. 31025–140.

Trilophosaurus buettneri Case, x1/3; restoration of skeleton in walking pose.

AMPHIBIANS FROM THE DOCKUM TRIASSIC OF HOWARD COUNTY, TEXAS

H. J. Sawin

In the past three years (1939–1942), well-directed efforts on the part of governmental project workers have provided a wealth of fossil materials from a number of localities in the State of Texas. In connection with this work one of the most complete collections was assembled by a unit organized to collect vertebrate fossils from the Triassic beds of southwestern Howard County. Most of the sites are located on the estate of Mrs. Sarah Mina Hyman and daughters, Mrs. Otis Chalk and Mrs. Dora Roberts, 3 miles north of Otis Chalk, Texas,[1] where several hundred acres of eroded land provide a rich source for a vertebrate fauna characteristic of the Dockum formation. The many courtesies extended to the investigators by the owners of the property and their representatives are gratefully acknowledged.

Extensive quarrying operations resulted in the removal of large blocks of related skeletal elements which were for the most part prepared by project workers in a well-equipped laboratory associated with the Bureau of Economic Geology of The University of Texas. This collection includes more than a dozen skulls and much of the remainder of the skeleton of a new species of amphibian. A detailed study of this material is here reported in view of supplementing the available information on the morphology of this highly specialized group of animals.

Typical adult Dockum specimens have a body length of 6 to 7 feet and a bulk possibly 8 to 10 times that of the largest known living amphibians.

Thin sections of the teeth (fig. 1) show a complexly infolded enamel pattern which identifies these animals as members of the order Labyrinthodontia. The disk-shaped body of the vertebrae, notched above for a persisting soft structure of the embryonic skeletal system, the notochord, indicates the group Stereospondyli. The position of the eyes, somewhat forward of the center, and the low, flat skull with the characteristic pattern of canals on the upper surfaces restrict these amphibians to the family Metoposauridae. Five American genera are described for the western United States in the revision by Branson and Mehl (1929). Three of these genera, *Anaschisma*, Branson (1905), *Koskinodon*, Branson and Mehl (1929), and *Borborophagus*, Branson and Mehl (1929), are from the Popo Agie beds of the Chugwater Triassic of Wyoming. *Kalamoiketor*, Branson and Mehl (1929), is from the Chinle of Arizona, and *Buettneria*, Case (1922), is from the Dockum of Texas.

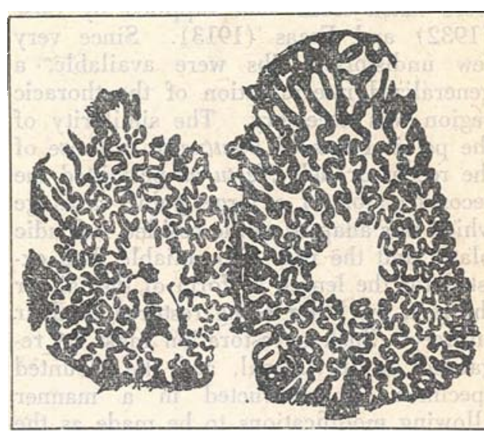


Fig. 1. Diagrammatic cross section of two mandibular teeth of *Buettneria howardensis*, n.sp., x6.

Under this system of classification the larger Dockum animals described in this study most closely approach characters known for the genus *Buettneria*. They differ from species of that genus and from other American genera in the pattern of the sensory canals and in minor variations in the form of certain regions of the skull as noted in the following descriptions.

Acknowledgment of aid in the preparation of this manuscript is made to the Research Institute of The University of Texas.

[1]For a more complete description of the fossil localities, the reader is referred to figure 1 in the preceding paper by J. T. Gregory and his geological account of the Otis Chalk locality (pp. 271–273).

Measurements and ratios are listed in Tables I–III for separate elements and the skulls, those of the latter being restricted to the least distorted and most complete individuals representative of the group as to size range. In proportional studies the length of the skull roof was used as a standard of comparison with dimensions which in part refer to regions of differential growth. The results are compared with adaptations of similar data known for related forms. In addition one skull and interclavicle collected at the head of Holmes Creek in Crosby County, Texas, were included for the purpose of comparison. Field data are included with the tables.

The abundance of material justified a restoration of the skeleton as indicated in figure 2. The assembled skeleton shown in this figure is based on a skull, clavicles, and interclavicle together with other skeletal parts from the same deposits and mostly from the same pit.

The position of the skull relative to the pectoral girdle and the vertebral count were taken from data supplied by Case (1932) and Fraas (1913). Since very few undistorted ribs were available, a generalized interpretation of the thoracic region was necessary. The similarity of the pelvic bones of *Buettneria* to those of the recent urodele *Necturus* permitted the reconstruction of a large pubic cartilage which was adapted to the ossified ischiadic plates and the ilia. No reliable data existed for the length or form of the tail or the feet, the latter being restored in their entirety. Such a restoration must be regarded as provisional, and the mounted specimen is constructed in a manner allowing modifications to be made as the knowledge of the appendages and other missing elements becomes supplemented by the discovery of more complete specimens.

An historical survey shows that the first element described from the western Triassic deposits was an interclavicle designated as *Metoposaurus fraasi* by Lucas (1904). This was followed by Branson's description of the genus *Anaschisma* based on a skull. Case (1920, 1922) described a shoulder girdle *(Metoposaurus jonesi)* and a complete skull and interclavicles of a new genus, *Buettneria.* In 1927 Branson and Mehl analysed the auditory region of an undescribed form. Later (1929) these authors proposed the genera *Koskinodon, Borborophagus,* and *Kalamoiketor;* the first mentioned is identified as the form studied in the previous work. Other American genera were reviewed, and the classification now commonly accepted was proposed. Case (1931) described a small species, *Buettneria bakeri,* and later (1932) a series of this species which were compared with the genotype, *B. perfecta.* Wilson (1941) completed a precise study on the skull of the latter species.

The writer is indebted to Dr. E. H. Sellards, Director of the Bureau of Economic Geology of The University of Texas, for the use of several drawings and for many stimulating suggestions. Mr. Glen L. Evans, Mr. Grayson Meade, Dr. J. T. Gregory, and Mr. William N. McAnulty are thanked for their coöperation in the field and laboratory, and the assistance given by the many government project workers who conscientiously prepared the bulk of the material under the supervision of Mr. Thomas White is acknowledged. Mr. Chester Wallace ably prepared the illustrations, and Mr. Powell Goodwin assisted in the restoration of the mounted specimen.

OSTEOLOGY OF BUETTNERIA HOWARDENSIS

General Features of the Skeleton

Skull

The skull of *Buettneria howardensis* is longer than broad (Table I), the length-width ratio varying from 1:0.89 to 1:0.95. Specimen No. 31100–30, on which most of the description is based, has a ratio of 1:0.92 which approaches the mean for the skulls selected for the dimensional data. Width-height ratios are 1:0.25+, an expected proportion for flat-skulled stereospondyls.

A dorsal view (fig. 3) shows the form of the margin which extends out and back from the blunt muzzle to expand to the greatest width at the anterior third of the border of the quadratojugal. The posterior portion of this bone curves upward forming with the squamosal that

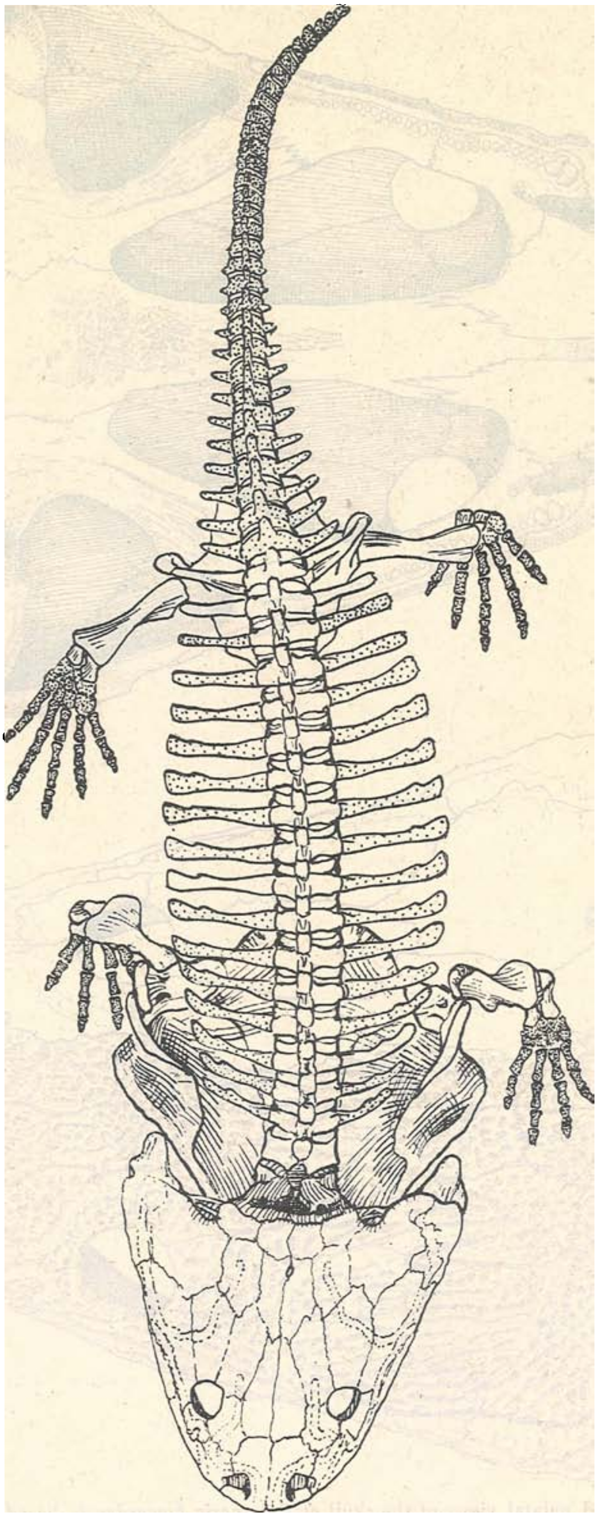


Fig. 2. Restoration of skeleton of *Buettneria howardensis*, x1/10. Feet, tail, and majority of ribs unknown.

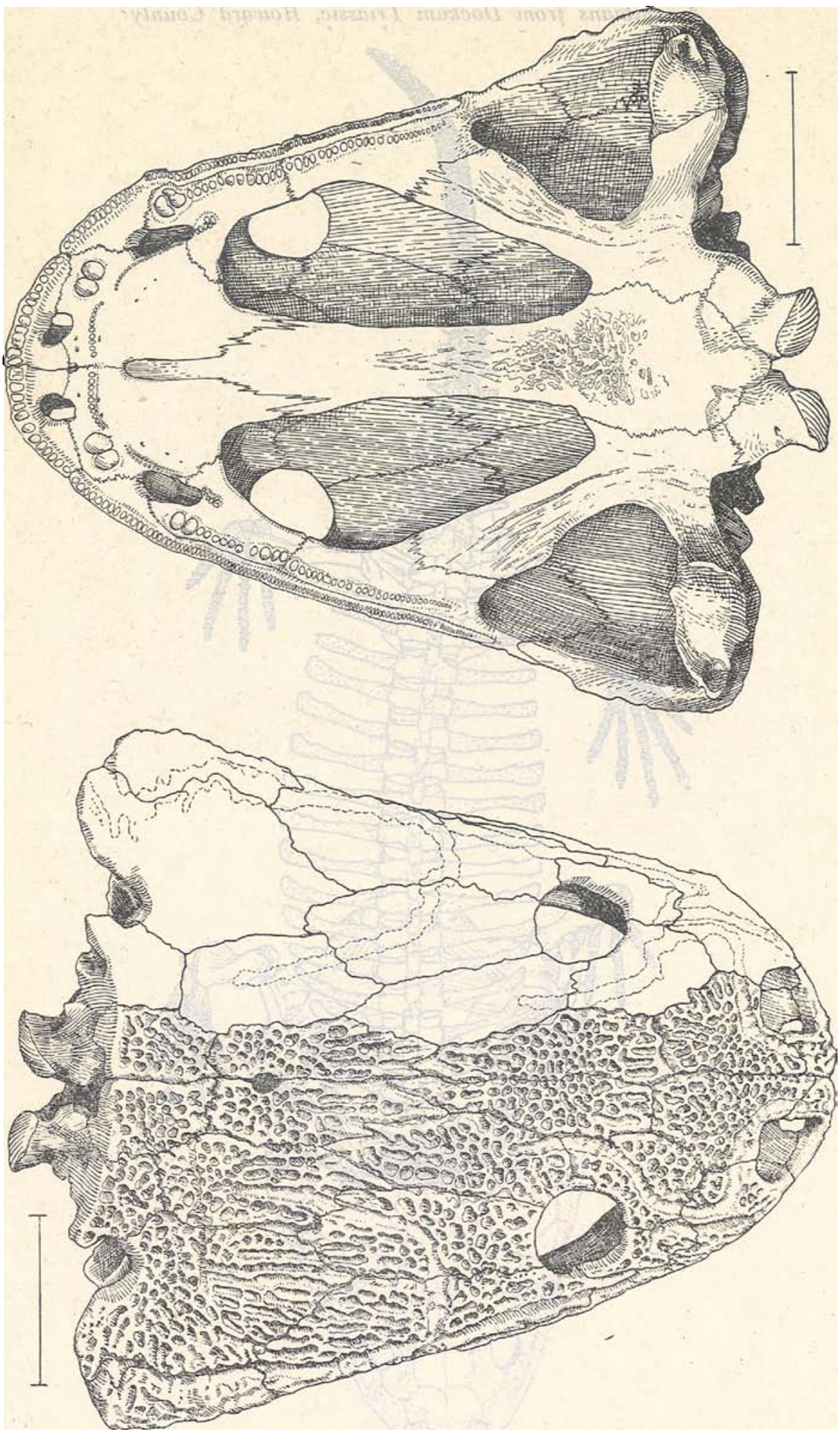


Fig. 3. Dorsal and palatal views of the skull of *Buettneria howardensis* based on specimens No. 31100–122 and 31220–1. x¼.

part of the posterior margin of the skull lateral to the otic notch. The squamosal is sharply indented to form the anterior and lateral rim of the notch, the tabular curving slightly outward to border the notch medially. Posteriorly the back rim of the table is very nearly transverse with a gentle inward curvature from the tips of the tabulars.

Surfaces of the skull roof curve gradually toward the margin with an upward slope from front to back and a pronounced slope to the lateral borders from the central and posterior portions of the table. The central region is very nearly flat between lines extending from the anterior rims of the otic notches to the lateral rims of the orbits, this horizontal surface extending anteriorly to the abruptly downcurving marginal elements. Lateral to the above designated lines the roof slopes gently down to an abruptly downcurving margin along the maxillary. Behind the latter bone the roof curves evenly to the margins of the jugal and quadratojugal.

Dorsal apertures include the orbits, nares, and the median parietal foramen. There is no small median opening between the nares as described for *Buettneria perfecta* by Wilson (1941). The parietal foramen is circular in shape with a diameter of 1.3 cm. Irregularly shaped orbital openings face upward from their position on the front half of the deck near the margins, their borders making little or no interruption on the contour of the roof. The narial rims are elevated medially and posteriorly but are low anteriorly forming a transverse floor rostrally; the premaxillary, which forms a portion of the narial floor, slopes abruptly down to the margin. In most specimens the medial narial rims curve at slightly more than a right angle from the posterior rim.

Ornamentation consists of polygonal, usually hexagonal, pits, the borders of which are elongated into ridges in the regions of the skull subject to the most intensive growth. These pits are rarely more than 3 mm. deep and in areas of uniform pitting average about 5 mm. in diameter. The elongated pits are situated centrally in an irregularly crescentic area of intensive growth behind the orbits and in front of the parietal foramen, the horns of the crescent extending posterolaterally over the jugal and squamosal. Anteriorly a few pits are longitudinally distorted in the region of the transverse naso-frontal suture to indicate a rostral growth zone. The two regions of intensive growth are equal in length in the largest specimens.

Slime canals varying in width from 7 to 13 mm. and in depth from 3 to 5 mm. form a bilateral system on the roof. The borders of these canals vary in outline with the margins of the adjacent pits; the sculpture is weakly carried into the depressed surfaces and the pits within the canals are structurally related to those on the surface of the deck. The pattern of this system is similar to that described for *Anaschisma* by Branson and Mehl and consequently differs with that described for *Buettneria perfecta* by Case in the absence of a connection between the supraorbital and temporal canals. Other departures from the systems as described for *Buettneria perfecta* and *Anaschisma* include separate channels for the supraorbital and infraorbital canals in the preorbital region and a lack of a connection between the jugal and temporal canals in the mid-jugal region, the jugal canal here curving down to the margin and closely approaching the upcurving temporal canal.

Posterior

An occipital view (fig. 4) shows the general skull shape, the relations of the foramen magnum with its associated structures and the position of the paraquadrate and posttemporal fenestrae. The stapes is figured on the left side, the data for its relation with the rest of the skull having been obtained from specimen No. 31100–430 where it was found in position. Several specimens were used in an attempt to present an accurate posterior view of an undistorted braincase, since in most cases dorsoventral crushing obscured important details of the central region.

The portion of the foramen magnum occupied by the nerve cord and associated structures is triangular in shape and

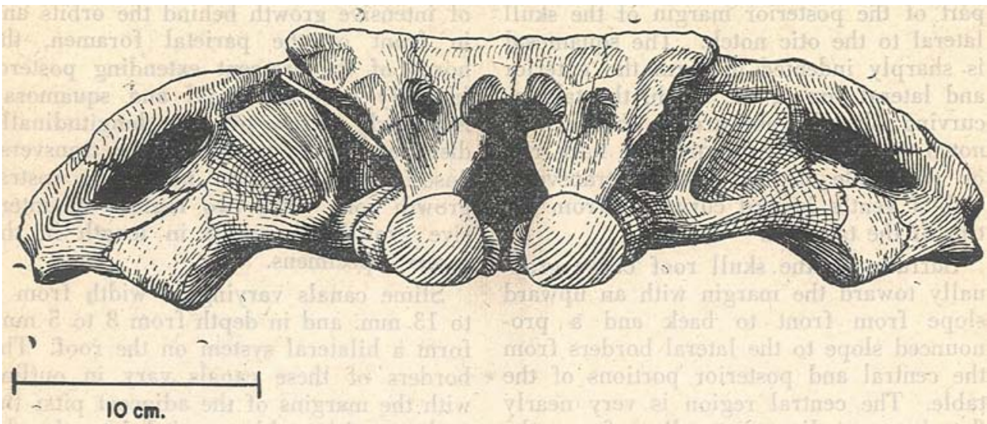


Fig. 4. Occipital view of the skull of *Buettneria howardensis* based on specimens No. 31100–122 and 31100–47. x¼.

delineated by the exoccipitals. These bones form an incomplete arch which is open above to a transversely oval space presumably occupied by cartilage of the supraoccipital element. The base of the triangular opening was probably floored by the cartilaginous basioccipital. This group of confluent openings is keyhole-shaped, and in most specimens the mesially extending portions of the exoccipitals were considerably distorted.

Posttemporal fenestrae, oval in outline with a length of about 1 cm., open internally to a "supraotic fossa."[2] These openings extend to the inside of the skull in *Anaschisma* and *Koskinodon* Branson and Mehl (1929) but were described as closed in *Buettneria perfecta* by Case (1922). Wilson (1941), however, describes this fenestra as being . . . "open dorsally to the opisthotic."

The large elongately oval paraquadrate fenestra are bounded dorso- and ventromesially by the squamosal; the lower rim is also limited by the dorsal portion of the quadrate ramus of the pterygoid. The latter elements vary considerably in the different specimens as to overlap and are shown in their most constant relation on the left side of figure 4. The quadratojugal forms the ventrolateral border of the fenestra with its lower process extending up over the quadrate to meet the pterygoid, or pterygoid-squamosal complex. These fenestrae average 6 cm. in length, 1.5 cm. in width above the ventral rims, and are considerably larger and of different proportions than the opening figured by Case for *Buettneria perfecta.*

Other noteworthy features seen in this view include the depressions for muscular attachments on the occiput, the upward slope of the back rims of the articular surfaces of the quadrates, and the position of the occipital condyles. The latter are convex, face downward and inward, and extend well back of the dorsal border of the skull, the pillars of the exoccipitals sloping upward to the skull roof.

Palate

Ventral surface.—Modifications of the contours of the palatal elements in relation to the interpterygoid vacuities and other openings are evident as shown in figure 3. The horizontal plane of the palate is modified by a slight ventral convexity of the broad central portion of the parasphenoid underlying the braincase and also by the curvature of the quadrate rami of the pterygoid and the descending processes of the palatal rami.

A groove may be traced over the surface of the pterygoid from an origin posteriorly at the angle between the body of the bone with the quadrate ramus. There it leads anteriorly and a little mesially to bifurcate into a mesial branch leading

[2]This term is proposed instead of *fossa bridgeii* which applies to a similar but probably non-homologous structure in fishes.

to the posterior margin of the interpterygoid vacuity and a lateral branch which courses on the under surface of the inner third of the palatal ramus. The mesial groove was possibly related to the suborbital artery which branched from a maxillary artery occupying the lateral groove. A slight depression in the lateral limiting ridge which borders the lateral groove is present in specimen No. 31100–122. This may mark the point of departure of the mandibular artery from the maxillary.

An unbroken marginal row of teeth and an irregular submarginal series occupy the peripheral portions of the palate in front of a line across the anterior borders of the adductor fenestrae. The marginal row consists of over 100 teeth borne on the premaxillary and maxillary, these diminishing regularly in size posteriorly. Internal to, and roughly parallel to, this series is a submarginal line which is broken anteriorly but is continuous behind a point lateral to the internal narial openings. The unbroken line begins anteriorly with a large tooth and pit emplacement followed by smaller teeth which diminish in size posteriorly. Anteromesial to this line four groups of teeth complete the anterior portion of the submarginal series. Four to six small teeth form an irregular group behind the internal naris. Twenty-one or more very small teeth form a row along the mesial border of the naris extending anteriorly and curving inward behind the third group which consists of a tooth and pit combination, the largest teeth of the skull. A row of 11 or 12 medium-sized teeth curves gently anteriorly from a point posteromesial to the latter to join the corresponding row of the other side.

Paired openings of the palate include the prenarial apertures, interpterygoid vacuities, and adductor fenestrae. A single median opening for the intermaxillary gland (cf. Wilson, 1941) is present at the tip of the parasphenoid.

The rims of the prenarial apertures are bordered by the premaxillae anteriorly and the vomers posteriorly; these oval openings measure 1.5 cm. anteroposteriorly and 2.3 cm. transversely and are placed 2.2 cm. apart. They are situated between the marginal and submarginal tooth rows.

Large interpterygoid vacuities shaped like flat footprints in outline are separated by the cultriform process of the parasphenoid which forms their mesial borders. Each is limited by the vomer anteromesially, the palatine and transpalatine anterolaterally, and the palatine ramus of the petrygoid posterolaterally.

Each adductor fenestra is bordered laterally by the jugal and quadratojugal, posteriorly by a process of the latter and the quadrate, mesially by the deeply incurved pterygoid. Anteromesially the narrow portion of the fenestra is limited by the heavy downturned descending process of the pterygoid with the anteriormost curvature formed by the posterior end of the transpalatine.

The general pattern and proportions of the mandibles do not vary significantly from that shown from the other species. Seven symphysial teeth are present on either side as in *Buettneria bakeri.*

Postcranial Skeleton

Additional information regarding the appendages and descriptions of the ischium, cleithrum, and scapulo-coracoid is added to the data concerned with the principal appendicular elements given by Case (1932) for *Buettneria bakeri.* No bones were found which could be definitely associated with the manus or pes. It is probable that the carpus and tarsus were formed of cartilage. Only two or three terminally unossified metapodial or phalangeal elements were found which could not be definitely identified.

Separate Skull Elements

Skull Roof

Premaxilla.—This bone forms the anterior rim of the external naris dorsally and all but the posterior third of the border of the prenarial aperture at its palatal exposure. A short portion of the slime canal system occupies the surface that curves upward to meet the nasal close to the narial rim. Anteriorly this rim is horizontal above the tooth row where it grades into the thin floor of the naris. The downcurving margin of the skull in this region is free of pits back to a point a little posterior to the suture with the maxilla. Thirteen or fourteen teeth are borne on the ventral margin which is depressed ventrally at the midline. A sharply incised groove occurs near the margin on the ventral surface of that part of the premaxilla which forms the mesial rim of the external naris and probably exists as an abutment for an exceedingly thin septomaxilla. The latter is not present in any of the specimens examined and may have become chondrified as in recent amphibians.

Maxilla.—Dorsally the maxilla borders the posterolateral portion of the naris and extends back to the prefrontal and lacrimal for a distance approximately equal to the length of the naris. It meets the nasal mesially and extends beneath the tip of the lacrimal to underlie the jugal. There it forms the margin of the skull to a point about 1 cm. in front of the expanded downcurving posterolateral border.

Two slime canals are closely parallel on the dorsally exposed area, one passing in from the margin of the skull lateral to the posterior rim of the naris, and the other curving posteriorly from the nasal at the middle of the maxillary-nasal suture. Medium-sized irregular pits occupy this dorsal surface around the slime canals and small pits and ridges are placed irregularly on the marginal surface.

On its palatal exposure the maxilla limits the internal naris anterolaterally and joins the premaxilla at a short sutural interval in front of a stout union with the vomer lateral to the large paired tooth battery of that bone. Its junction anteriorly with the palatine about 1 cm. in front of the submarginal tooth row is equally strong. The mesial border of the maxilla extends back between the marginal and submarginal tooth rows of the palatine and transpalatine to taper to a point under the jugal 1 cm. in front of the jugal-quadratojugal suture. Each maxilla bears alveoli for 90–95 teeth which diminish regularly in size posteriorly.

Jugal.—The jugal forms the anterior portion of the lower rim of the orbit anteriorly and joins the postorbital on its mesial boundary for over three-fourths of the length of that bone. Posteromesially it meets the squamosal and posteriorly the quadratojugal, the suture with the latter reaching the skull margin just behind and a little above the tooth row of the maxilla. Most of the narrower posterior portion of the maxilla is overlain by the jugal which anteriorly tapers between the lacrimal and maxilla, there extending a short distance anterior to the front rim of the orbit.

This bone curves from the horizontal plane of the skull deck to the margin over the anterior two-thirds of its length, this curvature becoming more gradual posteriorly where it conforms to the slope of the squamosal. Small pits and heavy ridges are present on the marginal surface beneath the longitudinally directed slime canals; the pitting in front of the transversely placed section of the temporal canal is small and regular while the sculpture behind this canal is larger and longitudinally elongate. The suborbital canal slopes gently down to reach the margin at about the mid-length of the bone, in most cases merging to a greater or lesser degree with the temporal and jugal canals at their point of junction. Pitting extensively invades the temporal section of the canal from the point where it crosses the central portion of the postorbital to its point of junction with the jugal canal.

Quadratojugal.—As seen in dorsal view, this bone curves down marginally to form the posterolateral border of the skull, extending slightly laterally and ventrally from a line projected back from the margin along the maxillary. It joins the jugal anteriorly with an irregular suture and is overlapped slightly above by the squamosal, the suture coursing along a wide sigmoid curvature of the slime canal and terminating posteriorly at a slight indentation in the posterior margin. Large pits occupy the posterodorsal surface, these becoming elongate anteriorly and posteriorly.

At the posterior margin of the skull the quadratojugal is exposed to show in part its complex relations with the quadrate and pterygoid (fig. 3). It forms the lower half of the dorsolateral and more than half of the ventral borders of the paraquadrate foramen. That portion of the bone which is produced to embrace the quadrate turns sharply mesially and sheaths the lateral region of that bone. It extends above the central portion to meet the quadrate ramus of the pterygoid below the paraquadrate foramen as well as sending sharply-ending processes in front and back of the articular surface of the quadrate.

Ventrally the quadratojugal has a considerable exposure, forming a curved, pillar-like lateral limiting surface to the articular area of the quadrate and very nearly or completely excompassing the ventral margin of this bone to its junction with the pterygoid. There is a deep funnel-shaped pit between the quadrate and quadratojugal at the articular surface probably occupied in life by cartilage.

Squamosal.—Structural relations of this element as a buttress for the palate are complex and the bone is heavier than the others of the lateral marginal series, its considerable thickness being evident in posterior view. The upper surface slopes gently from back to front and curves abruptly down toward the lateral margin. Evenly spaced pits extend about 4 cm. around the rim of the otic notch, the ornamentation becoming more elongate anteriorly and laterally. A crook-shaped section of the slime canal follows the course of the suture with the quadratojugal. Posteromesially the margin is incurved to form the anterior border of the otic notch where the bone is 1.8 cm. thick at its junction with the tabular. Lateral to this region the outer portion of the notch is completed with a thinner semicircular border extending back from the thick part of the bone to become prominent at a point on a line projected anteriorly from the tip of the tabular. Here it curves down laterally to a level with the uppermost rim of the paraquadrate foramen. The total thickness of the bone is 2.5 cm. in this region which is produced anteroventrally and downward to form a buttress for the rising processes of the quadrate ramus of the pterygoid. Laterally the bone overhangs the paraquadrate foramen with the posterior margin about 2 cm. posterior to the border of the foramen. The margin is modified by a small notch which marks the suture with the quadratojugal.

A descending process extends under the posteromesial half of the bone as a vertical plate. This extends transversely and diagonally from its mesial limits at a point beneath and slightly in front of the innermost part of the otic notch to its lateral limits at the inner border of the paraquadrate foramen. This process overlaps the anterior rising process with a strong, finely interdigitating suture as seen in an anterior view. The lateral portion is stoutly joined to the upper part of the quadrate ramus of the pterygoid at the point of junction of the anterior and posterior rising processes close to the uppermost curvature of the paraquadrate foramen. In well-preserved specimens a thin spur of bone from this process extends to the quadrate over the anterodorsal surface of the quadrate ramus of the pterygoid. This region is confusing in poorly preserved specimens due to incomplete ossification in the quadrate region and the broken laminae of the bone of the above described process.

On the under surface of the squamosal the more horizontal area in front of the descending process is marked by a concave rugosity which is most prominent at the proximal end of the process. This narrow rugose area is directed anteromesially to extend for a short distance on to the supratemporal and a ridge passes downward from this rugosity on the descending process toward the quadrate. These structures probably in part mark the upper boundary of a thin extension of the anterior rising process of the pterygoid noted by Case (1921), and it is also possible that they show the upper extent of a portion of the otic process of the palatoquadrate cartilage.

Circumorbital Series

Lacrimal.—The lacrimal is the smallest dermal bone of the skull. It forms the anterolateral rim of the orbit occupying about one-sixth of the perimeter. Anteriorly it extends over the dorsally exposed portion of the maxillary, reaching approximately half of the distance between the orbital and narial rims. Mesially it joins the prefrontal and posterolaterally the anteriormost tip of the jugal. The narrow (0.8 cm.) infraorbital slime canal occupies the anterior portion of the bone with the upper section of its sigmoid curve. That section of the bone bordering the orbit forms a nearly vertical rim which is 1.5 cm. thick, sloping anteroventrally toward the prefrontal. The ventral surface overlies the palatine with an irregular space of several millimeters separating these bones. Several small foramina occupy the under surface in front of the orbital rim near the junction with the maxillary and palatine.

Prefrontal.—The posterolateral section of the prefrontal forms the front and inner rim of the orbit. It extends as an overlapping wedge between the maxillary and nasal anteriorly. Posterolaterally it joins the frontal and posteriorly the postfrontal with an irregular diagonal suture between the latter two bones. The supraorbital slime canal curves mesially across the central surface and recurves posteriorly at about half the length of the suture with the frontal. There the mesial border of the canal closely approaches or follows the sutural line. Posteriorly this canal is 1.5 cm. in breadth and 3–4 mm. deep. Anteriorly, on or near the suture with the lacrimal a small ridge is present which incompletely separates this canal from the infraorbital canal. Uniformly shaped pits occupy the areas of the bone on either side of the canal, those of the anterior section being noticeably larger than the pits around the orbital rim. The rim slopes inward and curves regularly on to the under surface of the bone, several nutrient foramina being present on this surface near the ventral orbital border. Thickness of this bone varies from 1.5 cm. at the orbital rim to 1.3 cm. anteriorly.

Postfrontal. — Anteriorly this element meets the prefrontal and forms the posteromesial rim of the orbit. Posteriorly it extends between the postorbital and frontal to taper between the parietal and supratemporal, the overlapping sutural junction with the former being twice the length of that with the latter as seen dorsally. Pitting is uniform over the anterior two-thirds of the surface but becomes elongate posteriorly. The supraorbital slime canal crosses the junction of sutures between the three frontal elements and terminates at a point close to the center of ossification of this bone. Contours of the under surface show a slight upward concavity and the entire bone has a very slight upward tilt laterally. The curvature is regular up to the rim of the orbit.

Postorbital.—This is a long bone somewhat wider than the postfrontal. It extends from the posterior rim of the orbit between the postfrontal and jugal and tapers between the squamosal and supratemporal. More than the posterior third is sculptured with elongate pits, those anteriorly being medium sized and regularly disposed. A section of the temporal canal curves from its outwardly diagonal course at the middle of the posteromesial suture with the supratemporal down to the jugal, reaching the latter at the middle of the postorbital-jugal suture. The ventral surface is smooth with a slightly concave region latero-centrally. Curvature of the rim of the orbit to the ventral surface is more gradual than in the other bones of this series, the rim being about 1 cm. thick; at the center of ossification, about a third of the length of the bone in back of the orbit, the greatest thickness is 1.3 cm.

Bones of the Central Region

Nasal.—The nasal meets its fellow over its greatest length at the midline and extends back from the premaxilla to a nearly transverse suture with the frontal about 2 cm. in front of a line across the anterior rims of the orbits. It meets the prefrontal posterolaterally and the maxilla anterolaterally. A section of the preorbital slime canal follows the curvature of the bone close to the thin (3–5 mm.) posteromesial rim of the naris. Two-thirds of the surface is covered by small to medium-sized pits, those posteriorly showing some elongation. On the under surface of the narial rim and extending forward on to the premaxilla a ledge is inset about 2 mm., possibly serving as an abutment for a cartilaginous septomaxillary. Posteriorly the ventral surface is nearly plane grading anteriorly into a gentle concavity at the approach to the ventral rim of the naris. There are no distinctive structures present to conform to the shape of a cartilage nasal capsule as is the case in *Eryops*.

Frontal.—The frontals are of a uniform width from their anterior borders with the nasals to a line across the posterior rims of the orbits, this roughly coinciding with the junction of the prefrontal-postfrontal sutures at the anterior third of their lateral borders. Posteriorly the lateral suture extends diagonally inward along the postfrontal to taper irregularly to a point at an overlap over the parietal. Sculpture consists of small to medium-sized pits radiating from the central area with elongated borders appearing anteriorly in front of a line across the middle of the orbits and posteriorly on the tapered portion of the bones. The mesialmost curvature of the supraorbital canal reaches the lateral border of the bone a little ahead of the intersection of the sutures of the frontal elements and curves on to the surface of the postfrontal just behind this intersection.

On the ventral surface the apposed frontals produce a median ridge which is continuous structurally with the parietals. This ridge slopes toward the general plane of the roof anteriorly and bifurcates at a point a little in front of a line across the posterior rims of the orbits, the two low subordinate ridges extending outward at an angle of 22° to merge with the general level of the ventral surface of the frontal 3–4 cm. from their point of separation.

Parietal.—The length of this bone is 3.5 times the width and the region of intensive growth anteriorly is especially prominent. There is an extensive overlap of the postfrontal and frontal anteriorly and a less marked extension of the parietal over the postparietal posteriorly. Each element meets its fellow at the midline for three-quarters of its length; the parietal foramen is 1.3 cm. in diameter and interrupts this line about a third of its length from the postparietal suture. Anteriorly the greater part of the elongated portion of the bone extends irregularly to a point between the frontal and postfrontal, the sutural junction with the latter being twice the length of that with the former. Posterolaterally the parietals meet the supratemporals at a suture which extends slightly diagonally outwards, and posteriorly they join the postparietals at an irregular, nearly transversely-placed border. Small pits, becoming medium-sized peripherally, surround the parietal foramen over the posterior half of the surface; anteriorly these become progressively more elongate to the ends of the bones.

Ventrally almost the entire surface consists of finished bone. A ridge about 2.5 cm. in width and 1 cm. high is formed along the midline, this becoming lower posteriorly to conform to the curvature up to the anterior region of the parietal foramen. Here this structure bifurcates, each member becoming narrower and extended downward to form a descending process about 1.5 cm. below the level of the bone on either side of the posterior portion of the foramen. These processes are about 1 cm. from the outer rim of the opening and placed about 3 cm. apart. The posterior portion of the surface of the parietals is on a level with that portion of the ridge anterior to the foramen, the lateral extremes of this thicker region of the bone being limited on either side along a line between the descending process and the mesial rim of the posttemporal fenestra. These lateral borders are inconspicuously marked by a slight elevation extending back from the base of the process toward the thick posteroventrally extending portions of the postparietals.

The inner opening of the parietal foramen is pear-shaped in outline, the greatest width at the posterior being 1.6 cm. and the length 2.3 cm. Anteriorly the bone is only slightly depressed for a distance equal to the diameter of the dorsal opening of the foramen but posteriorly and laterally the slope upwards and inwards is abrupt. There is no depression posteriorly for a parapineal organ as noted for *Buettneria perfecta* by Wilson (1941).

Postparietal.—As seen dorsally this element has but slightly more area than the tabular. It meets its fellow on the midline at its greatest length and is overlapped in front by the parietal at an irregular transversely placed suture. Anterolaterally the suture with the supratemporal extends diagonally inward, and posterolaterally a longitudinally directed border marks the union with the tabular. The surface of the bone slopes downward toward the parietal from the occipital margin, and regularly spaced small pits form the sculpture.

In occipital view (fig. 4) the postparietals are seen to border the space above the foramen magnum presumably occupied by the supraoccipital and to produce pillars which join the exoccipitals beneath the mesial border of the posttemporal fenestrae. These bones have excavated unfinished surfaces above the foramen magnum which were doubtless completed in cartilage of the supraoccipital. Above the posttemporal fenestra there is a rugosity extending on to the tabular which is probably a part of the surface of insertion of the *spinalis* and *rectus capitus posterior* muscles. This entire face formed from these elements is directed sharply downward and a little posterior from the plane of the deck.

On the ventral surface the conjoined postparietals form a thick arch above the foramen magnum and are produced posteroventrally as pillars to join the exoccipitals. Anteriorly the central region is depressed dorsally, the upward curvature of the pillars and the upward slope from the thick posterior border above the foramen magnum delineating the depression. Laterally the surfaces of the pillar slope upwards to the supraotic fossa which is depressed dorsally above the posttemporal fenestra. Several irregularly placed nutrient foramina are to be found on the gently sloping surface at the base of the pillars.

It is possible that the depressed area was in part occupied by the supraoccipital cartilage which conformed to the contours of the cerebellar region of the brain. The nutrient foramina may have existed in relation to the underlying otic cartilage.

Supratemporal. — The supratemporal forms the principal lateral portion of the skull table with a length equal to the parietal and a somewhat greater width than that bone. Anteriorly it tapers between the postfrontal and postorbital, the suture with the former being twice the length of that with the latter. In back of this taper the width is uniform between the parietal and squamosal, the borders with these bones being almost equal in length. Posteromesially the short suture with the postparietal extends diagonally inward and the union with the tabular posteriorly is nearly transverse. The supratemporal laterally overlaps the squamosal and is overlapped anteriorly to a small extent by the postorbital and postfrontal. Small pitting is confined to less than the posterior half of its area, elongate sculpture extending anteriorly from a horizontal line across the back rim of the parietal foramen to the end of the bone. The supratemporal slime canal passes on to this element from the central portion of the postorbital. It extends back and slightly inward to end near the center of ossification slightly behind a horizontal line across the parietal foramen, the canal becoming narrower and more extensively invaded by the sulpture posteriorly.

Ventrally the surface is nearly plane with a slight slope downward toward the lateral margin. On the posterior surface elevated rugosities occur presumably in relation to the cartilaginous continuation of the otic. A small anteromesially directed depression interrupts this rough surface on a line between the tip of the tabular and the anterior border of the parietal foramen probably showing the presence of a venous channel similar to that described for *Eryops* (Sawin, 1941, Plate 9A "V"). The presence of a large nutrient foramen on the anterolateral margin of this depression strengthens this interpretation of its function, and the position directly in front of the supraotic chamber and a little lateral to the posttemporal fenestra is directly comparable to the position of the opening of the ossified otic in *Eryops*. In that form the venus foramen is placed more ventrally, and a deficiency in ossification of the otic above this opening is in the position of the rugosities in *Buettneria.*

Tabular.—Dorsally this bone has the form of an irregular pentagon, the free slightly downcurving "horn" extending posteriorly and a little laterally. The lateral border of the horn is unsculptured, the sharp ventral border forming the mesial rim of the otic notch back to within 1 cm. of the end. Anterolaterally there is a stout union (2 cm. thick) with the squamosal; anteriorly the supratemporal is joined and overlapped along an irregular transverse suture. Mesially the tabular meets the postparietal. At this junction the greatest thickness of the dermal elements of the roof is to be found. Small pits are irregularly dispersed on the anterior and central surface, becoming deeper and more irregular toward the tip of the horn.

The exposure of the tabular on the occiput is about equal in area to the dorsal surface. The union with the lateral pillar of the exoccipital is marked by an irregular finely interdigitate suture extending ventrolaterally from the posttemporal fenestra. A rugose concavity on the lateral margin beneath the horn is a continuation of the surface for the muscular attachments noted above for the postparietal. This rugosity is above the posttemporal fenestra and overhangs its lateral border. There is a pronounced curvature of the bone to the border of the posttemporal fenestra.

The under surface of the tabular is extensively modified in relation to the underlying structures of the braincase and the otic notch. Centrally a sharply delineated unfinished surface is elevated from the level of the posttemporal and squamosal and slopes downward posteriorly to merge with that part of the tabular lateral to the mid-diameter of the posttemporal fenestra. The mesial border of this structure is curved toward the horn with a downward regular curvature of finished bone from the most dorsal portion of the supraotic fossa. Four or five foramina occupy this curved surface. Laterally the border is nearly at right angles to the projecting horn, this elevated border and the posterolateral edge of the bone bracing the relatively thin lateral and distal portion of the horn. There is but little doubt that the centrally elevated unfinished region is the surface of an abutment for the posterodorsal portion of the otic since its position lateral to the supraotic fossa is comparable to that region in better ossified rhachitomous forms.

Palatal Elements

Vomer.—This bone joins the palatine posterolaterally at a diagonal suture which extends inwards from behind the tooth row of the mesial rim of the internal naris to the anterior rim of the interpterygoid vacuity. Most of the mesial and half of the anterior rim of the internal naris are formed by this element. Anteriorly it meets the maxilla and premaxilla at stout junctions between the two large tusks and the marginal tooth row, the suture with the former extending anteriorly from the anterior rim of the naris to the marginal junction of the maxilla-premaxilla sutures. Here the suture with the premaxilla turns abruptly mesially, coursing between the vomerine tusks and the marginal teeth to the lateral border of the prenarial aperture. On the mesial border of this opening the suture continues posteromesially to the midline. The vomers meet at the midline anteriorly along a quarter of their length, a large nutrient foramen marking the intersection anteriorly with the premaxillae and an unossified interval at the tip of the parasphenoidal rostrum forming the posterior limit. There a duct leads forward and over the ends of the prevomers to the interior. Sutures with the parasphenoid extend to the anteromesial border of the interpterygoid vacuities; the anterior half of the sutural length is posteriorly directed and the posterior half coarsely and irregularly interdigitate to its limits at the vacuity. Posterolaterally the vomers form the anteromesial curvature of the interpterygoid vacuities.

Paired phthanar tusks 1 to 1.2 cm. in diameter, the largest teeth of the skull, are situated posterolateral to the prenarial apertures. A row of 18 to 22 small (1 to 2 mm.) teeth follow the line of the mesial rim of the naris curving mesially to a ridge which extends from the forward member of this row toward a transverse row of larger teeth (3 mm.). The latter, composed of 11–12 teeth on either side, reaches nearly to the midline behind the intersection of sutures. Other features of the almost horizontal ventral surface of these bones include several nutrient foramina in front of the above described transverse row of teeth. The largest of these is on the midline at the intersection of sutures with the premaxilla, extends into the bone, but fails to perforate it. In *Buettneria perfecta* (Wilson, 1941) it penetrates the bone as the anteroventral foramen for the intermaxillary gland.

On the dorsal surface each bone gently slopes centrally to form a shallow basin centered a little posterior to the tip of the parasphenoid. In front of the tip a groove extends to the opening of the foramen described by Wilson as the posterior foramen for the intermaxillary gland. There are no foramina in this region dispersed in the abundance described for *Buettneria perfecta*.

Palatine.—Anteriorly this bone forms more than the rear half of the internal narial rim and posterolaterally the free margin curves outward as the border of the interpterygoid vacuity. The irregular suture with the vomer extends diagonally inward from the posterior third of the inner narial rim. A junction with the maxilla at the anterolateral border of the naris extends back between the marginal and submarginal tooth rows. Posteriorly the palatine-transpalatine suture runs posteromesially to the rim of the palatal vacuity on a line across the midorbital region. The surface slopes ventromesially and laterally bears 13 or 14 teeth constituting the anterior members of the submarginal row. The two anterior teeth are large (1 to 1.3 cm. in diameter at the base), the remainder averaging half that size. In addition, 6 to 8 very small teeth are irregularly grouped behind the narial rim.

Dorsally the surface slopes down from the thick region (1.5 cm.) at the junction with the vomer to the thin lateral margin. A small groove in back of the narial rim may be related to surfaces of origin for the oblique eye muscles.

Transpalatine.—This element has a curved surface which slopes gently to the marginal area and descends posteromesially toward the palatine ramus of the pterygoid. Anteromesially it forms the lateralmost curvature of the interpterygoid vacuity and posteriorly the bone is incised as the thick anterior border of the adductor fenestra. The posterior section of the submarginal tooth row of about 30 small teeth extends over most the length of the lateral surface just mesial to the suture with the maxilla.

The bone is the thickness of the palatine for half the length of its margin along the palatal vacuity. There it becomes increasingly stouter (2.2 cm.) toward its overlapping junction with the palatine ramus of the pterygoid. The dorsal surface slopes up to the marginal junction with the maxilla. A shallow central concavity is in continuity with a depression of the dorsal surface of the pterygoid and probably marks the distal limits of the cartilage palatal process.

Parasphenoid.—As the longest skull element, the parasphenoid extends from a point between the occipital condyles to taper rostrally between the vomers anterior to a line across the front rims of the internal nares. This well-ossified median bone underlies the major portion of the braincase as the central stem of the skull. A rigid basipterygoid union of the broad massive posterior region of the bone with the pterygoid is formed with irregular finely interdigitate sutures on lines projected anteriorly from the lateral borders of the condyles to the inner margins of the interpterygoid vacuities. Posteriorly the parasphenoid joins the exoccipitals with sutures similar in form to those with the pterygoid. These are directed posteromesially on either side back to the blunt end of the bone which separates the exoccipitals ventrally and forms the anterior border of an intercondylar notch. Anterior to the broad region the cultriform process extends forward, its slightly inbowed lateral margins forming the mesial borders of the interpterygoid vacuities. The rostral end overlaps the vomers strongly. Irregular and coarsely interdigitate sutures extend anteromesially from a point even with a line across the mid-orbital region to become altered to parallel, anteriorly directed sutures on a line across the front rims of the interpterygoid vacuities. These border a narrow (1.5 cm.) rostral tip which ends at the duct for the intermaxillary gland.

In typical specimens the palatal surface of this bone is horizontal with this plane modified anteriorly by a slight upward curvature of the rostrum. Posteriorly a chevron-shaped region of the bone extends ventral to the surfaces of the exoccipitals. The surface is rugose and on either side indented on a line with the junction of sutures with the pterygoid and basioccipital; these probably were the regions of attachment of the rectus capitus muscles. Shallow irregular sculpture occupies the broad central portion, fading out anteriorly.

Dorsally the parasphenoid bears several structural features related to the overlying regions of the braincase. On the cultriform process two prominent ridges extend dorsomesially from the margin to enclose a central shallow U-shaped trough. This tapers proximally, the limiting ridges becoming indistinct where they slightly diverge again in front of the cranial openings for the internal carotid artery. This trough is narrowest (1.2 cm.) on a line 2 cm. in front of the posterior rims of the interpterygoid vacuities and is four times that width where the ridges become indistinct anteriorly on a line across the front margins of the vacuities. The height of the ridges is greatest (1.1 cm.) at the mid-length of the process; the slope toward the margin anteriorly is somewhat more gentle than that posteriorly.

The central broader portion of the cranial surface is modified by semicylindrical prominences which extend inward from the widest part of the bone. These enclose channels 5 mm. in diameter which presumably were occupied by the internal carotid arteries. The anterior openings are 2 cm. apart immediately in back of the ridges of the cultriform process; a very shallow depression between and in front of these probably reflects the presence of an overlying sella turcica which may have been formed by a thin cartilage basisphenoid. The upper posterior foramina open dorsolaterally above the dermal basipterygoid processes, the suture on either side with the pterygoid passing over the distal end of the openings. The parasphenoid here has its greatest thickness of 2.8 cm., the bone curving down to the floor of the braincase and the suture with the pterygoid passing diagonally anteromesially from the distal internal carotid opening to the inner posterior margin of the interpterygoid vacuity. Posteriorly the finely interdigitate suture extends slightly outwards on the floor of the braincase about 1 cm. internal to the high rim formed by the pterygoid to reach the exoccipital 3 cm. in back of the outer carotid foramen. The widely interdigitate suture with the exoccipital extends mesially to the posterior limit of the bone. The posterior end forms the ventral border of the space below the foramen magnum and in some cases is covered with poorly ossified bone which may be the remnants of a basioccipital. Thickness of the bone along the border with the pterygoid is 7 mm. in front of the lateral carotid foramen, nearly 3 cm. at the dorsal border of this opening, and varying from 1.5 cm. immediately behind the semicylindrical prominence containing the artery to 5 mm. at the posterior end. The latter represents the thickness along the median line up to the area between the mesial internal carotid openings where the bone is slightly thinner (3 to 4 mm.) in the region below the assumed position of the pituitary gland. Both pterygoids and exoccipitals overlap the bone on either side.

Four cartilage bone elements overlie the upper surface of the parasphenoid. Anteriorly the mesial side of the triangular base of the epipterygoid extends on to the region between the carotid prominence and the inner border of the posterior margin of the palatal vacuity, the space between the bases of the epipterygoids possibly being occupied by a thin basisphenoid cartilage. The anteroventral process of the stapes rests against the otic above the rim of the outer carotid opening, the base of the ossified part of the otic extending inward over two-thirds of the length of the semicylindrical prominence. Posteriorly, as noted above, remnants of the basioccipital occupy the central posterior region.

Pterygoid.—For convenience of description this complex bone is divided into three regions: These include first the proximal portion, or *base,* which forms the basipterygoid connection with the parasphenoid and presumably a cartilage basisphenoid and underlies the epipterygoid and the anterior portion of the braincase; second, the *palatine ramus* which joins the *base* with the margin of the palate; and third, the *quadrate ramus* extending laterally from the *base* to the quadrate and quadratojugal. The latter produces an anterior rising process which joins the squamosal and skull roof, and a free posterior rising process.

Base.—The sutures of the proximal region have been described above with the parasphenoid and are represented in figure 3. Posteriorly the pterygoid meets the exoccipital. On the outer surface of the bone the suture passes posterolaterally from the widest part of the parasphenoid around the lateral border to extend upward and inward to the rim of the braincase. The palatal surface of the base is convex from front to back and slopes dorsally toward the palatal and quadrate rami. A groove extends anteriorly on each side from the indentation between the base and the quadrate ramus to bifurcate on the central surface, one member passing anteromesially to the posterior margin of the palatal vacuity and the other coursing anterolaterally between well-defined ridges on the palatal ramus.

The bone is thin in front of a line paralleling the carotid prominences and slopes down to a sharp edge at the margin of the palatal vacuity. Most of this area is covered by the base of the epipterygoid and, in life, with its attendant cartilages. Anterolateral to the distal carotid opening and continuous with its lower border a spur of bone from the base of the anterior rising process extends anteromesially to support the base of the epipterygoid. This spur contains a large nutrient foramen 4 mm. in diameter which probably conducted blood vessels related to the cartilage palatoquadrate and the basipterygoid process. This foramen opens ventrally into a cavity which is a point of junction for other foramina in the quadrate and palatal rami. This space is formed beneath the overhanging spur and the lateral continuation of the carotid prominence. It is enclosed anteriorly and dorsally by the base of the epipterygoid.

Posterior to the region associated with the epipterygoid the dorsal surface of the base is at a level with the lower rim of the lateral internal carotid opening. A sharp rim of bone with a broken surface extends back from the lateral border of the opening to the exoccipital as the lateral margin of that part of the braincase underlying the otic region. Cranially this rim slightly overhangs the floor of the otic region of the braincase forming a slight concavity laterally as it slopes to the floor to meet the parasphenoid. Dorsally at the suture with the exoccipital this rim is a little above the level of the upper border of the lateral carotid opening at its highest point 1.6 cm. above the floor of the braincase. Laterally the bone slopes down from the rim to the curving margin at a 45° angle in the region posterior to the carotid foramen; 1.5 cm. lateral to the mouth of this opening the surface curves down to a depression between the anterior and posterior rising processes.

Thickness of the base of the pterygoid varies from 7 mm. at the anterior portion underlying the epipterygoid to a maximum of 3.3 cm. at the suture with the exoccipital. The bone is 1.5 cm. thick in the depression between the rising processes, which is the average for a section through the base of the quadrate and palatal rami at their junction with the base.

Palatine ramus.—As seen ventrally this palatine ramus extends from the *base* anterolaterally to the transpalatine to overlap that bone at an irregular suture. The surface slopes dorsomesially from its border at the adductor fenestra to the margin along the palatal vacuity and expands anterolaterally where a stout downcurving descending process forms the region of attachment for adductor muscles of the jaw. The ventralmost tip of this process marks the posterior of the constricted region of the adductor fenestra. Low parallel ridges extend longitudinally over the surface of the bone; those on the descending process are irregular muscle scars but the two mesialmost extend on to the base with a groove between them which was probably occupied by a blood vessel.

In cross sectional view the dorsal surface of this ramus is curved upward with a depression mesially which marks the course of a longitudinal furrow. This structure has a well-defined lateral border for a distance of 2–3 cm. from the lateral third of the base of the epipterygoid but more distally the margins become indistinct and the furrow exists as a depression which continues on to the surface of the transpalatine. The furrow and the depression probably formed the base for a cartilage palatal process of the primary palatoquadrate complex.

Quadrate ramus.—As seen ventrally the ramus extends outward and backward from the base to abut against the ventromesial surface of the quadrate. The surface slopes upward from the plane of the base of the pterygoid then curves downward to the quadrate. There is also a gentle upward slope from front to back. The distal and ventralmost portion is 1.5 cm. beneath the level of the proximal region. Anteriorly the acute angle with the anterior rising process produces a sharp margin bordering the posteromesial limit of the adductor fenestra. Posteriorly the margin is curved and a portion of the posterior rising process is in view below the otic notch.

In anterior view the anterior rising process of the quadrate ramus appears as a transversely placed vertical plate joined and overlapped on all but the inner portion of the dorsal third of its area by the descending process of the squamosal. The mesial edge of the bone extends on a line from the buttress at the middle of the base of the epipterygoid dorso-postero-mesially to approach or meet the ventral surface of the posterolateral portion of the supratemporal. Dorsomesially it forms a knob which fits into the cupped surface of the proötic ossification. The quadrate overlaps the anterolateral surface with a region of unfinished bone extending dorsomesially. This portion of the quadrate was evidently completed in cartilage over the face of the pterygoid to join cartilage otic and palatal processes from the base of the epipterygoid. Ventrolaterally the quadrate ramus overlies the spongy surface of the quadrate and meets the anterior process of the quadratojugal. The mesialmost section of the anterior rising process is very thin and usually unpreserved, but in some specimens it is evident that it extended mesial to the descending process of the squamosal up to the supratemporal. The width of the rugosities on the ventral surface of the latter element is sufficient to accommodate both this portion of the pterygoid and an anterior facing of the palatoquadrate cartilage.

Most of the specimens are cracked along the squamosal pterygoid suture, thereby showing in section the relative position of the associated elements. Structurally most of the support for the deck in this region was centered on the squamosal-pterygoid union at the lateral portion of the anterior rising process. As seen in dorsal view the quadrate ramus extends ventrolaterally from the anterior rising process to form the dorsal and posterior abutment for the quadrate and to meet a dorsal process of the quadratojugal laterally at the paraquadrate foramen. A curvature of the lateralmost rim of the anterior rising process turns posterolaterally to merge with the lateral free rim of the posterior rising process. The latter curves laterodorsally on a line produced diagonally upward and outward from the base of the postero-proximal region of the ramus.

The dorsal sharp border of the posterior rising process curves (figs. 3, 4) posteroventral to the otic notch, there continuing ventrally along the curvature of the lower border of the notch very nearly to complete a circular rim at the inner lower margin. Here at this deficiency in the rim the mesial portion of the process descends abruptly to the body of the quadrate ramus. The stapes extends over the gap in the more complete specimens to rest on the mesialmost portion of the dorsal margin. The interval between the anterior and posterior rising processes appears as a U-shaped "trough" in section. This structure leads forward and downward at a 45° angle to the depression in the base of the pterygoid, 1.5 cm. lateral to the outer opening for the internal carotid artery. The posterior surface of the posterior rising process is concave centrally and curves abruptly to the concavity lateral to the junction of the base of the process with the quadrate ramus. A large nutrient foramen leads into the bone at this point.

Cartilage Bones and Cartilages of the Braincase

Occipital Series

Supraoccipital.—No ossified supraoccipital is present. A space dorsal to the mesially directed processes of the exoccipital above the foramen magnum (fig. 4) was probably occupied by cartilage which extended anteriorly as a roof to the braincase and joined the cartilage proötic region posterolaterally. Since the ventral surface of the overlying postparietal shows contours adapted to the cerebellar region and also grooves possibly associated with the cranial endolymphatic system, the cartilage roof was probably quite thin and the greatest thickness of this element was in the posterior region above the foramen magnum.

Exoccipital.—As seen posteriorly (fig. 4) the nearly hemispherically convex condyles face inward and slightly downward. Below and centrally the exoccipitals are separated by an interval of 8 mm. by the posterior end of the parasphenoid and in some specimens by spongy bone which probably represents an ossified portion of the basioccipital. Each bone underlies a small part of the braincase ventrolaterally and produces a dorsally expanded pillar which rises from the region 5 mm. in front of the upper condylar rim and slopes anteriorly toward the deck to form the lower rim of the posttemporal fenestra. Mesial to the fenestra it joins the ventral process of the postparietal and laterally the tabular. Each pillar sends a stout flange posteromesially which together form an incomplete arch above the foramen magnum. The posterior surface of the pillar faces slightly inward and is depressed centrally beneath the rim of the posttemporal fenestra with one or two nutrient foramina on the depressed surface. A foramen possibly for one of the branches of the hypoglossal nerve is situated posterolaterally at the junction of the pillar with the body of the bone. Two cm. below and slightly in front of this opening is another foramen presumably for the same nerve. The outlines of the bases of the exoccipitals are indented with the constricted regions on a line connecting the last mentioned foramina, this marking the anterior limits of the condylar region. Anteriorly these bones expand to their lateralmost point at the pterygoid suture.

The dorsal surface in front of the base of the pillar forms a low ledge with a poorly finished surface. It is continued centrally as a region of unfinished bone with the mesial margin elevated 1 cm. above the floor of the braincase. This margin curves posteriorly to the lower rim of the foramen magnum 1.5 cm. mesial to the inner base of the pillar. In front the border curves laterally, then anteriorly, with a sharp rim ascending to the level of that sharp border of the pterygoid which delineates the cranial cavity. The exoccipitals are but slightly exposed on the unfinished central part of the floor of the braincase due to the overlap by the parasphenoid, the greatest area of about 2 sq. cm. underlying each side of the posterior part of the otic region. Posterolaterally that part of the floor of the braincase presumably occupied by the medulla is formed by the above described ledge anterior and mesial to the pillar. The two "hypoglossal" foramina open cranially at the inner base of the pillar and in addition a small foramen is present posterior to these in most specimens. It is assumed that the vagal group of nerves left the braincase in front of the pillar and the best-preserved specimen shows grooves which are probably remnants of the vagal foramen, most of which may have been enclosed in the cartilage of the opisthotic region. A nutrient foramen also perforates the pillar anteroposteriorly at the base of the expanded region in some specimens.

Basioccipital.—Fragments of spongy bone between the exoccipitals were removed in the course of preparation in several of the larger specimens. These formed an incomplete floor with an unfinished surface for a distance of about 2 cm. from the posterior rim of the foramen magnum. It is suspected that most of the basioccipital existed as a cartilage floor to the braincase extending from the level of the ventral rim of the foramen magnum anteriorly to join cartilage of the basisphenoid 3 to 4 mm. above the level of the cranial openings of the internal carotid arteries and somewhat posterior to them. Posterolaterally the cartilage was probably situated slightly below the level of the inner openings of the hypoglossal foramina to complete the floor in the region of the medulla. Anterolaterally the basioccipital probably met cartilages of the otic region.

Basisphenoid.—In the course of preparation of skull No. 31100–30 a small irregular piece of cancellous bone was found loose in the matrix mesial to the base of the epipterygoid and this is doubtfully referred to this element. Otherwise chondrification was complete, the basisphenoid region extending from a line across the mid-basal portion of the epipterygoids back to the cartilage basioccipital and overlying the carotid eminences. Laterally it probably joined the ventral cartilaginous part of the proötic region and anteriorly formed a shallow sella turcica in front of a line across the cranial openings of the internal carotid arteries and directly above a depression in the parasphenoid in this region. Anterior to this it was possibly continuous with cartilage of the sphenethmoid.

Otic.—Preserved portions of this bone include an irregular mass about 5 cu. cm. in size occupying the dorsal proötic region, and a button-shaped fragment found between the heads of the under surfaces of both stapes. The former has finished surfaces dorsally and anteriorly but the ventral, mesial, and posterior faces are spongy and irregular and were doubtless finished in cartilage. Laterally a cup-like excavation was closely apposed to a protuberance on the dorsomesial face of the anterior rising process of the quadrate ramus of the pterygoid. The dorsal surface forms the floor of the anterior portion of the supraotic fossa with a concave antero-posterior depression modified centrally by a transverse elevation. There is no groove present at the junction of this ossification and the rising process as described for *Buettneria perfecta.* Ventrally two concavities are present; the anteriormost is shallow and opens anteriorly to a notch apparently in part occupied by the proötic process of the stapes. Posteriorly there is a deeper excavation which may be related to the dorsalmost portion of the vestibular region of the inner ear.

The above described mass overlies the double head of the stapes and a small button-like fragment between the heads of that bone may be a remnant of the ossification between chambers of the vestibule. Otherwise the remainder of the otic was composed of cartilage with the exception of very small fragments of spongy bone adhering to the rugosity on the ventral surface of the tabular. Nothing was found in any of the specimens in the position of the opisthotic remnant described by Wilson for *Buettneria perfecta.* The notch in the dermal skull roof below the anterior opening of the supraotic fossa is directly above the proötic and it seems more likely that it is related to a vascular channel than to the endolymphatic system since the latter is usually confined to the cranial cavity or bone intimately related to it. (Cf. Wilson, 1941.)

Sphenethmoid and Laterosphenoid Regions

This complex was probably almost entirely chondrified and extended from the otics and basisphenoid anteriorly to the nasal capsule, and from the rugosities and ridges of the ventral dermal roofing elements to the margins of the trough of the parasphenoid. An arbitrary boundary between the laterosphenoid and the sphenethmoid may be marked by the descending processes of the parietal postero-lateral to the pineal foramen. The lateral ridges leading posteriorly to the otic rugosities show the position of the dorsal attachment of this cartilage, and the diverging postero-lateral borders of the trough of the parasphenoid form the ventral limits. The sphenethmoid was probably continuous ventrally with the latter cartilage but the finished surface of the anterior and posterior borders of the descending processes of the parietals indicates that the dorsal region was possibly in part membranous. The longitudinal median ridge formed by the parietals and frontals has a ventrally unfinished surface with fragments of spongy bone present in some specimens which may be remnants of the dorsal portion of the sphenethmoid. This region has been restored by Wilson

(1941), and the reader is referred to his figures which accurately show the relations of these cartilages and the probable positions of the cranial foramina.

Ossifications of the Primary Palatoquadrate and Hyoid Arches

Epipterygoid

The distorted three-sided pyramidal base of this element rests behind the posterior rim of the interpterygoid vacuity on the surface of the pterygoid at the junction of the palatal ramus with the body of the bone. A club-shaped rod is produced from the base to extend antero-dorso-mesially toward the laterosphenoid region. The free end of the rod has an unfinished surface which was probably continued dorsally as cartilage to reach the descending process of the parietal. Dorsoposteriorly the rod merges with the base at a vertically placed upcurving flange with a poorly finished proximal surface; the latter was probably continuous dorsally with the otic as a proötic process. In specimen No. 31100–47 this proximal portion is closely applied to the lateral surface of the anteriorly directed portion of the anterior rising process, the latter also supporting the base of the epipterygoid by interlocking with the posterior face of the pyramid near its lateral border. The outwardly directed face of the base slopes downward with an unfinished surface conforming to the channel of the palatal ramus described above in relation to the cartilage palatal process. It is probable that the base was continuous with the latter and also that a cartilage connection between the quadrate and the posteromesial face was present in the complete skull. The anteromesial face has an irregular, poorly ossified surface and, as noted above, was probably extended mesially by cartilage of the basisphenoid. A spongy textured surface underlies a shallow cavity beneath the base of the epipterygoid and is continuous with a more expanded cavity which underlies the anteriorly directed portion of the anterior rising process. This cavity is limited posteriorly by the carotid eminence. Since this region was probably occupied by the distal portion of the primary basipterygoid process, it is apparent that the path of the carotid artery as interpreted by Watson (1920) and Wilson (1941) is in the proper morphological position.

The exposed surface of the dorsomesial face of the epipterygoid curves abruptly upward from a ledge above the excavated portion to the posterior flange at the back corner of the pyramid. This ledge is a little below the level of the distal opening of the internal carotid artery and its surface is modified by an angular depression where it meets the anterior rising process of the pterygoid.

Quadrate

This bone is embraced mesially and dorsally by the quadrate ramus of the pterygoid; laterally, posterolaterally, and anteriorly by the quadratojugal. The articular surface is concave transversely and slightly convex anteroposteriorly, the entire surface sloping down and forward from the mesial border. A deep (8 mm.) irregularly conical pit is shared between the lateralmost portion of the quadrate and the quadratojugal on the outer surface of the articular area. The latter element curves down as a flange-like rim anterolaterally and forms a veneer-like surface over the lower part of the anterior face.

Posteriorly the quadrate is exposed as a triangular area modified by a prominent irregular convexity protruding above the mesial half of the rim of the articular surface. The quadrate ramus of the pterygoid limits the mesial side and the quadratojugal the lateral portion. The latter also is produced as a thin spur around the posterior margin of the articular surface to approach or meet the quadrate ramus mesially.

Anteriorly only a small irregular section of cancellous bone is preserved in most specimens, this projecting 1.5 to 2 cm. above the lower process of the quadratojugal. There is no doubt that an ossified portion was continued nearly across the anterior face of the anterior rising process and the lower surface of this face of the descending process of the squamosal. Here the quadrate probably was extended as cartilage which joined the otic process and the cartilage at the posterolateral edge of the base of the epipterygoid, thereby being continuous with the remainder of the primary palatoquadrate.

Stapes

The following description is based on four stapes (fig. 5) which were found in position in skulls of *Buettneria howardensis*. The bone has a double proximal head which is horizontally oriented beneath the ossified portion of the proötic region. A small proötic spur extends dorsomesially from the front and proximal portion of the anterior head to overlie a groove on the anterolateral surface of the otic. This structure was badly distorted in the specimens but probably had the relations to the head as shown by Wilson (1941).

The ventral proximal surface of the anterior head occupies a position slightly above the outer opening of the internal carotid artery, the proötic spur pointing anteromesially on a line with the parietal opening. The proximal ventral surface is of unfinished bone, and in specimen No. 31100–431 there is an uncertain indication that this region was structurally related to the parasphenoid, a condition known for the head of this element in *Eryops*. This ventral surface is almost horizontal but dorsally the head is convex as seen in section, and fractured thin edges of the bone show that it was more extensive than represented in the figures.

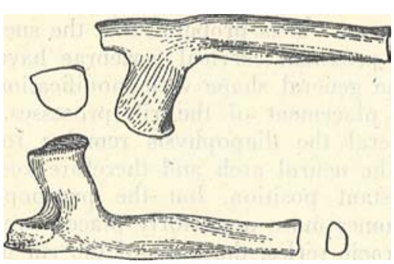


Fig. 5. Left stapes of *Buettneria howardensis* from specimen No. 31100–431, x½. Top, Dorsal view. Bottom, Ventral view.

The posterior head is much stouter and terminates squarely with a constricted oval end which was apposed to the region of the fenestra ovalis; the latter opening, if present, was formed in a cartilaginous portion of the otic. A section through this head has an oval outline, regular dorsally but depressed anteroventrally. A small button-shaped fragment noted in the description of the otic was found between the two heads on both sides of specimen No. 31100–431.

Dorsally a pronounced semicircular depression modifies the surface of the region between the heads, the anterior quadrant of the semicircle extending on to the anterior head. Distal to this, the neck between the rod and heads is horizontal with a slight curvature to the margins. The rod is produced dorsoposteriorly at 120° angle to the head, the distal end terminating in a cupped surface which was evidently completed in cartilage to the tympanic structure. The anteroventral portion of the rod probably rested on the mesial border of the posterior rising process. The shaft is compressed dorsoventrally for two-thirds of its length, but the distal end is oval in section in contrast to the spatulate shape described for *Buettneria perfecta* by Wilson (1941). The anterior edge of the rod is thin proximally. This thin border is modified distally into a very small thin ridge which extends toward the dorsal surface. The posterior edge is rounded proximally to become very thin at the distal third of the length and angularly rounded distally. A groove on the ventral surface extends longitudinally from the thin edge at the distal third of the length to the neck. The dorsal surface is generally convex as seen in section, the more elevated region extending from the anterior border of the distal end toward the posterior border proximally where it fades out at the neck.

The stapes described for *Buettneria perfecta* has a thin spatulate structure with a blade-like end to the rod and a rather definite spine on the dorsal surface, but otherwise the general shape is similar to the element described above.

Mandibles

The jaws are thick and high in the articular and coronoid regions and diminish regularly in size anteriorly. A well-developed retroarticular process is present with most of its lateral surface devoid of sculpture. Coarse and irregular pitting radiates from centers on the lower surfaces on the dentary, splenial, postsplenial, and angular, and very coarse pits occupy the postero-dorso-lateral surface of the surangular behind the slime canal. The borders of the pits extend peripherally into ridges which are especially prominent over the anterior half of the angular; this region of intensive growth is to be correlated with that between the pineal and orbits on the overlying region of the skull roof.

Sixty or more conical teeth with oval bases are borne on the upper margin of the dentary and 7 small teeth are directed posteriorly from a ridge near the symphysis in back of the regular row. The first three teeth of the regular series are small and are followed by the two largest of the jaw. There is a regular increase in size from the small teeth behind these to a maximum at Nos. 24 and 25; posteriorly the remainder diminish regularly in size.

The following foramina are present on all well-preserved specimens: (1) a mental foramen at the junction of the procoronoid-splenial sutures; (2) the mandibular foramen on the lower central surface of the postsplenial; (3) the inframeckelian beneath the prearticular and coronoid and above the angular and postsplenial; (4) the dental foramen posteriorly on the prearticular; and (5) two openings on the dorsal surface of the surangular postero-lateral to the meckelian fossa.

Comparative measurements are given in Table I–C. The specimens here examined do not differ in any important detail from those described for *Buettneria perfecta* or *Anaschisma* except for the symphysial row of teeth.

Postcranial Skeleton

Vertebrae

Over a hundred vertebrae were associated with the specimens (fig. 6, 7). The atlas and axis were found together in two cases and several "strings" of from 2 to 9 dorsal and caudal vertebrae are present in the collection, but no complete column has been found in the materials thus far prepared. In most cases the neural arch is absent except in the atlas where it is fused to the intercentrum. Several complete ribs permit but little more than a conjectural interpretation of the thoracic basket, the specimens showing little if any variation from those described by Fraas for *Metoposaurus*.

No data exist for the number of presacral vertebrae; a fairly complete but dissociated column is known for *Buettneria bakeri* which probably has 18 in this series and it is assumed that *Buettneria howardensis* had the same number. Several specimens (fig. 7g, h) which have stoutly developed rib facets are suspected of being sacral vertebrae or to have been situated in the sacral region. Two stout short ribs are known which may be from the sacral region, but there are no associated specimens.

Regional differentiation is marked by changes in shape and form of the intercentrum and in variation in the position of the rib articular surfaces. In the anterior cervical region the atlas is transversely oval in outline with a fused neural arch, and the shape of the axis is conformable to this but modified by a pair of articular surfaces for a two-headed rib, the diapophysis formed by the neural arch and the parapophysis being placed directly below on the ventrolateral surface of the intercentrum. It is probable that the succeeding proximal cervical vertebrae have the same general shape with modifications in the placement of the rib processes. In general the diapophysis remains related to the neural arch and therefore keeps a constant position, but the parapophysis becomes more posteriorly placed over the thoracic series, the head of the rib in the posterior thoracic region possibly articulating to a slight extent with the intervertebral cartilage. The thoracic vertebrae

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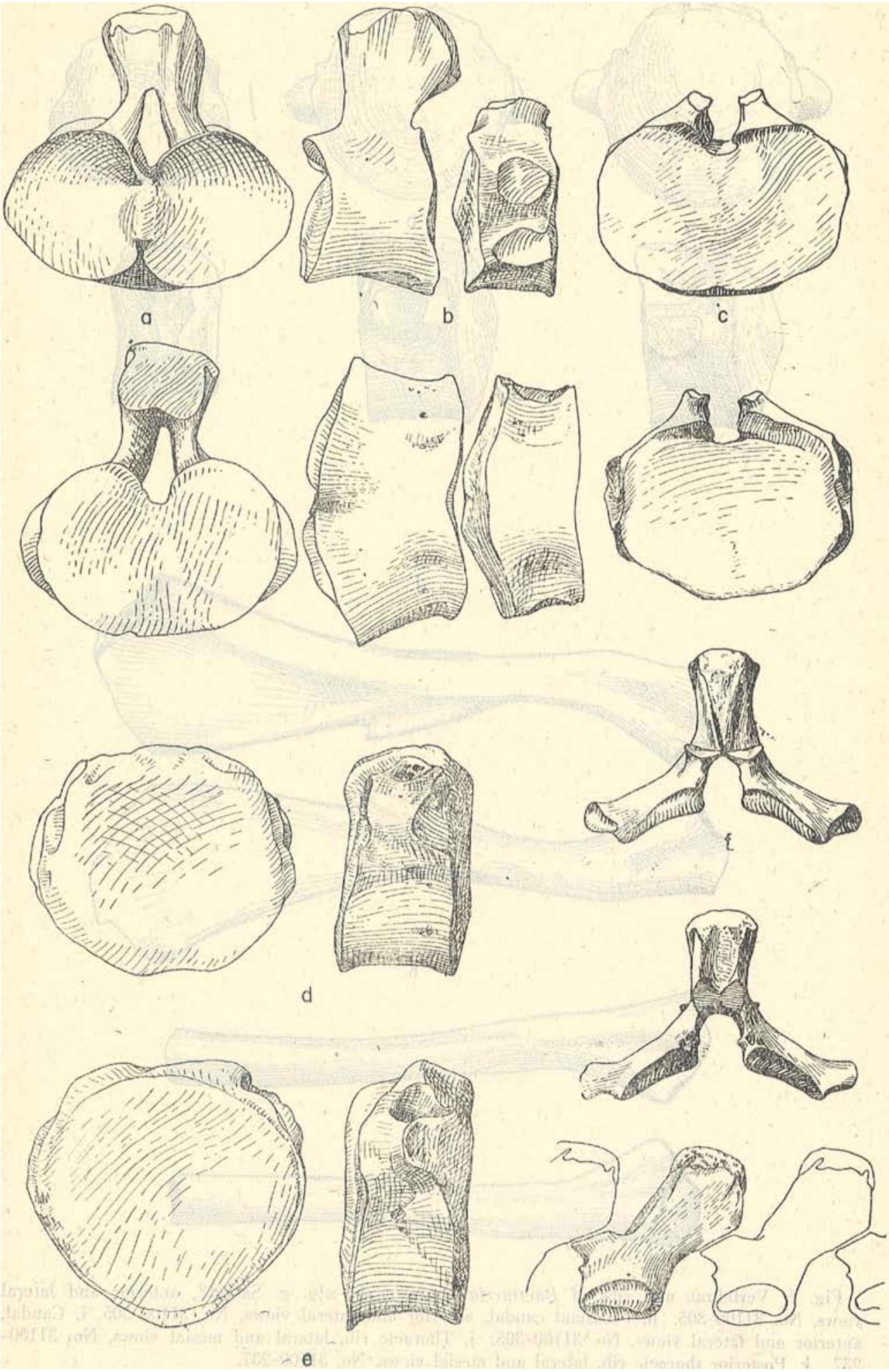
Fig. 6. Vertebrae of *Buettneria howardensis* and *Buettneria* sp., x½. a, Atlas, anterior and posterior views, *Buettneria* sp. No. 31185–25. b, Atlas and axis, lateral and ventral views. c, Axis, anterior and posterior views, No. 31185–25. d, Anterior thoracic? of *B. howardensis*, No. 31100–305, e, Posterior thoracic?, No. 31100–305. f, Anterior, posterior, and lateral views of neural arch of *B. howardensis*, No. 31100–237.


a
b
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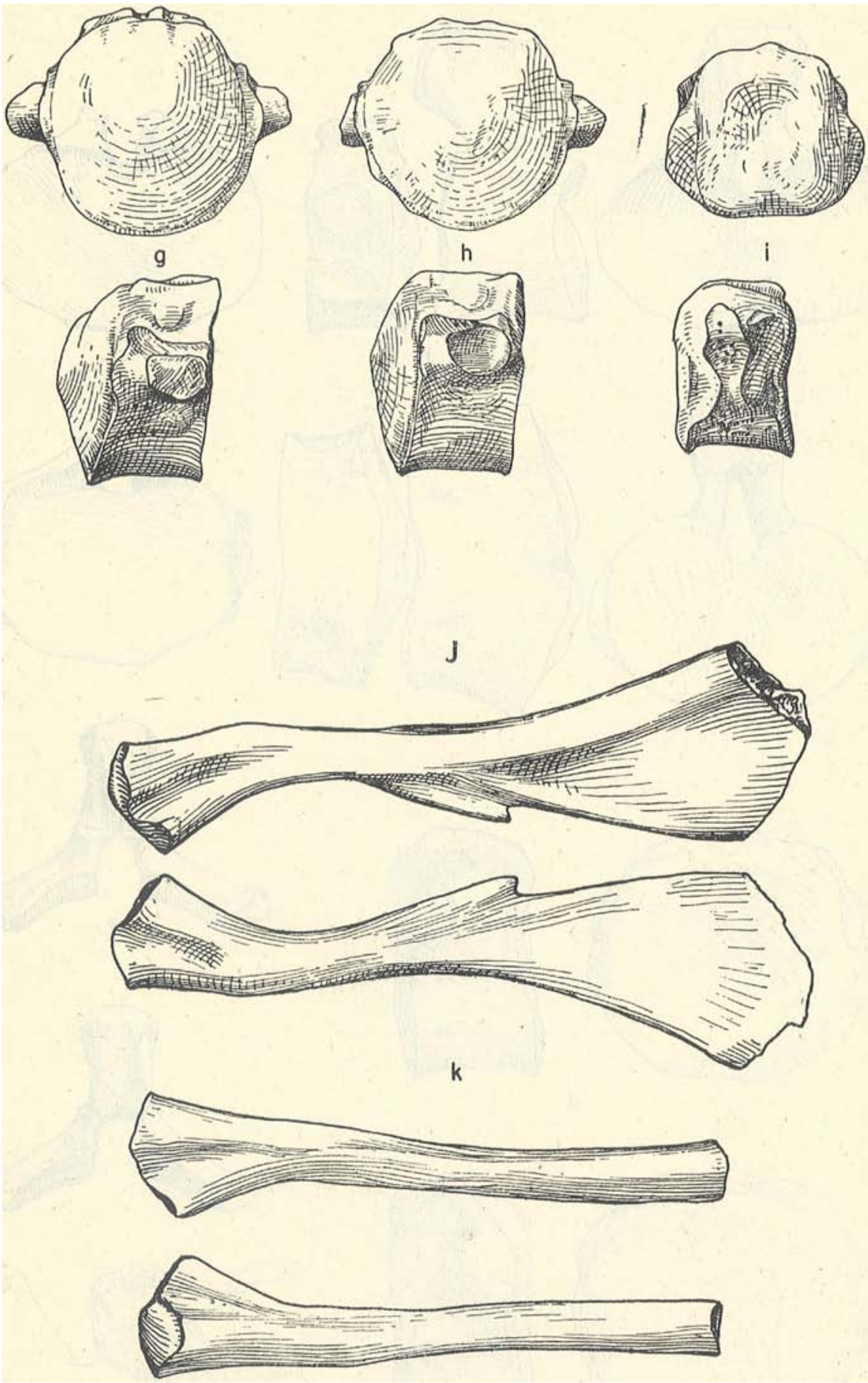


Fig. 7. Vertebrae and ribs of *Buettneria howardensis*, x½. g, Sacral?, anterior and lateral views, No. 31100–305. h, Proximal caudal, anterior and lateral views, No. 31100–305. i, Caudal, anterior and lateral views, No. 31100–305. j, Thoracic rib, lateral and mesial views, No. 31100–237. k, Posterior thoracic rib, lateral and mesial views, No. 31100–237.

are rarely preserved with the neural arch in association and are to be recognized mainly by the slightly compressed circular outline of the intercentrum and nutrient foramina which are anterodorsal to the parapophysis. Anteriorly the intercentra are definitely opisthocoelous but in vertebrae interpreted as posterior thoracic the ends of the intercentra are nearly flat or slightly amphicoelous. No sacral vertebra is known but various centra in association with ilia are opisthocoelous and have well-developed lower rib articulations. The specimens supposed to be proximal caudals are opisthocoelous with the outline of the intercentrum changing from a bilaterally compressed circle to a roughly rectangular form as seen in outline.

Several of the isolated neural arches show the position of the zygapophyses (fig. 6f) which closely approach the midline, the median edges of the anterior articular facets overlying the neural canal. The postzygapophyses are higher and only slightly wider than the neural spine. The neural canal was probably enclosed completely in life by the arch, a thin cartilage or connective tissue layer separating the nerve cord from the underlying notochord. The latter was apparently persistent in the average-sized specimens, the corresponding notches on some of the intercentra showing its largest diameter to be about 1 cm.

Ribs

Only a few ribs (fig. 7j, k) were preserved, and the information regarding their form and position is scanty. Several from the thoracic region have incomplete double heads which were probably completed in cartilage. A constricted portion of the bone is characteristic of the proximal quarter of the length and distally the rib is expanded with a small uncinate process on the posterior border more than half the length of the bone from the head. The anterior border is sharp proximally but becomes rounded from the neck to the distal end. Here this rounded portion terminates in a cupped surface which probably was connected to a cartilage sternum. The posterior edge is rounded for the proximal third of the length to become produced to a thin edge at the uncinate process, this edge having but slightly more thickness at the distal end. Laterally there is a concavity between the heads; the remainder of the surface is convex with a slight concavity modifying the contour at the uncinate process and the surface between the front and back borders of the expanded portion.

Ribs possibly from the posterior thoracic region vary from 1/4 to 3/4 the length of the averaged-sized thoracic, have a more robust head (fig. 7), and lack the expanded region. The distal end is cupped for attachment to the cartilage of the sternum, both the anterior and posterior portions are rounded, and concave surfaces are present above and below between the heads.

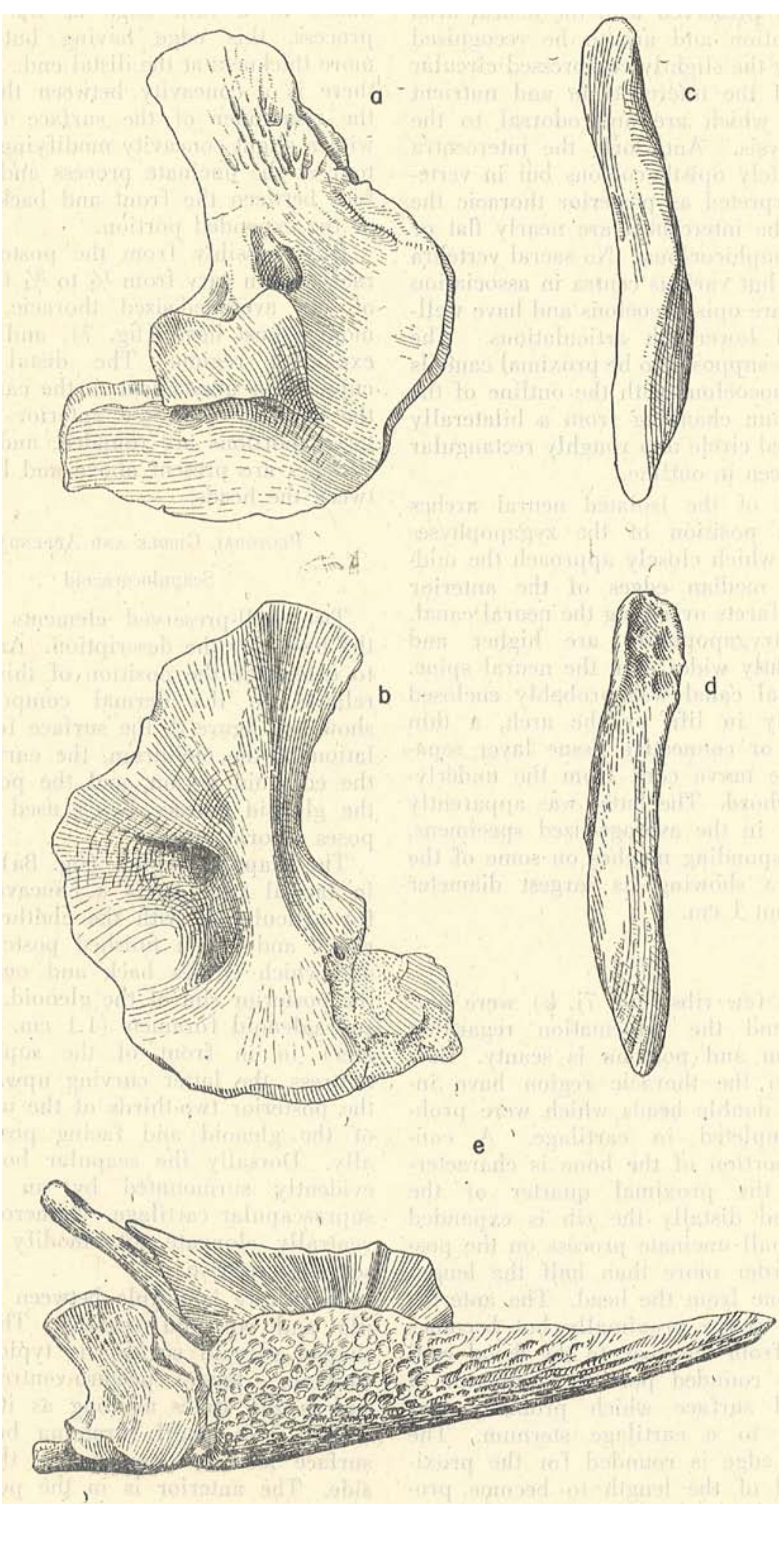
Pectoral Girdle and Appendage

Scapulocoracoid

Two well-preserved elements serve as the basis for the description. An attempt to determine the position of this element relative to the dermal components is shown in figure 8, the surface for articulation of the cleithrum, the curvature of the coracoid region, and the position of the glenoid surface being used for purposes of orientation.

The scapular region (fig. 8a) as seen in lateral view bears a concave surface for articulation with the cleithrum anteriorly and has a finished posterior border which curves back and outward to the posterior rim of the glenoid. A large supraglenoid foramen (1.1 cm. in diameter) in in front of the supraglenoid buttress, the latter curving upward from the posterior two-thirds of the upper rim of the glenoid and facing posterolaterally. Dorsally the scapular border was evidently surmounted by an extensive suprascapular cartilage. Numerous dorsoventrally elongate pits modify the dorsolateral surface.

No suture is visible between the scapula and coracoid regions. The screw-shaped glenoid surface is typically amphibian, faces postero-ventro-laterally and is 2½ times as long as its central width. Two small foramina below this surface lead to openings on the mesial side. The anterior is in the position of


a
c
b
d
e

the coracoid foramen and the posterior may be a nutrient opening.

The entire lower margin of the scapulocoracoid from the ventral border of the cleithral articular surface to the posterior border of the glenoid bears an unfinished surface which was probably extended in cartilage. From this margin the surface slopes centrally to the protruding anterior and ventral borders of the glenoid. The posteriormost region is almost vertically placed, curving outward so that the surface is lateral to the posterior border of the glenoid.

A mesial view (fig. 8b) shows the extent of the subscapular fossa. This concavity is limited posteriorly by a prominent ridge of bone which is interpreted as the mesocoracoid arch. Internal openings for the supraglenoid and infracoracoid foramina are within the central area of the fossa and noticeably modify the contours of the bone. The nutrient foramen opens above a poorly ossified region ventral and posterior to the arch. Above the foramen the bone is finished with a slightly concave surface which faces posteromesially and is limited anteriorly by a sharp ridge of the posterior border of the mesocoracoid arch.

Cleithrum

Several cleithra were found in association with the dermal shoulder girdle but never in articulation. The characteristic form of the element, however, leaves but little doubt as to its position relative to the cleithral process of the clavicle.

In lateral view (fig. 8c) a prominent spine is seen to extend centrally and longitudinally over the upper half of the element. Anterior to the spine the bone curves inward and forward with a concave surface conforming to the corresponding contours of the mesial surface of the cleithral process of the clavicle: that portion of the cleithrum beneath the spine forms the major surface for this articulation. The posterolateral surface behind the spine has a gently recurving outline, the dorsal tip bending anteriorly and the tapering proximal end sloping posteriorly. A nutrient foramen opens near the posterior border of the upper third of this face.

Beneath the spine the cleithrum is triangular as seen in section, the anterior apex forming the front border of the articular surface. Distally this anterior edge is distinctly produced as a short flange. The free distal end is rugose and concave on its posteromesial face (fig. 8d) where it may have been attached to the suprascapular cartilage. This area grades into a convex surface over the remainder of this face of the bone. Longitudinal ridges on the proximal third may have been surfaces of attachment for ligaments attaching this bone to corresponding ridges on the posteromesial surface of the base of the cleithral process of the clavicle.

Clavicle

As seen ventrally (fig. 9b) the clavicle is triangular with the length twice the width and the surface modified by sculpture radiating from the thick posterolateral portion of the bone. Here large to medium-sized hexagonal pits occupy an area which extends dorsally over the curvature of the bone to the elevated lateral margin. Mesially and anteriorly the borders of these pits are extended into ridges which radiate peripherally, the best-preserved specimens showing a continuous shallow pitting between the ridges to the margins of the bone. A line on the greatest length of the clavicle divides the perimeter so that the mesial portion of the bone has the irregular outline which coincides with the margin of the interclavicle. The border lateral to the line bears a finished surface with very small nutrient foramina on the rim, these probably occurring in relation to thick connective tissue at the junction of the bone with the skin of the body.

As seen laterally (fig. 8e) the anterior margin is but slightly elevated above the

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Fig. 8. Scapulocoracoid, cleithrum, and diagram of shoulder girdle of *Buettneria howardensis*, x1½. a, Scapulocoracoid, lateral view, No. 31100-47. b, Scapulocoracoid, mesial view. c, Cleithrum, lateral view, No. 31100-430. d, Cleithrum, mesial view.

thickness of the bone. The height increases gradually over the anterior third above the pitted area.

The thickness of the cleithral process and blade are apparent in a dorsal view (fig. 9a), as is also a considerable depression between the outer base of the latter and the sculptured rim. The mesial portion of the blade overhangs the base. In the best-preserved specimens (31100–37) the dorsal edge is thin and sharp with an undulating outline and fluted vertical ridges which radiate anteriorly and posteriorly from the central portion of the base. Continuous with the base of the blade, the cleithral process extends postero-dorso-laterally above the thickest portion of the bone to terminate in an anteroposteriorly flattened point. The lateral surface of this process extends over the border and has a small spine anteroventrally with fine parallel ridges continuous with the somewhat coarser ridges of the blade. The central region of the mesial surface is also produced into a spine for the distal quarter of its height, this merging into a general convexity proximally. Posteromesially the surface is screw-shaped, with a gentle concavity on the distal third of the spine facing posteriorly and slightly laterally. Below this, another concavity on the middle third of this surface faces posteromesially. Both of these concavities and the interval between are marked by ridges. This screw-shaped arch is the portion of the cleithral process which probably forms the articular surface for the cleithrum. The lower third of the base of the spine slopes ventrolaterally to overhang the basal curvature of the anterolateral portion of the clavicle.

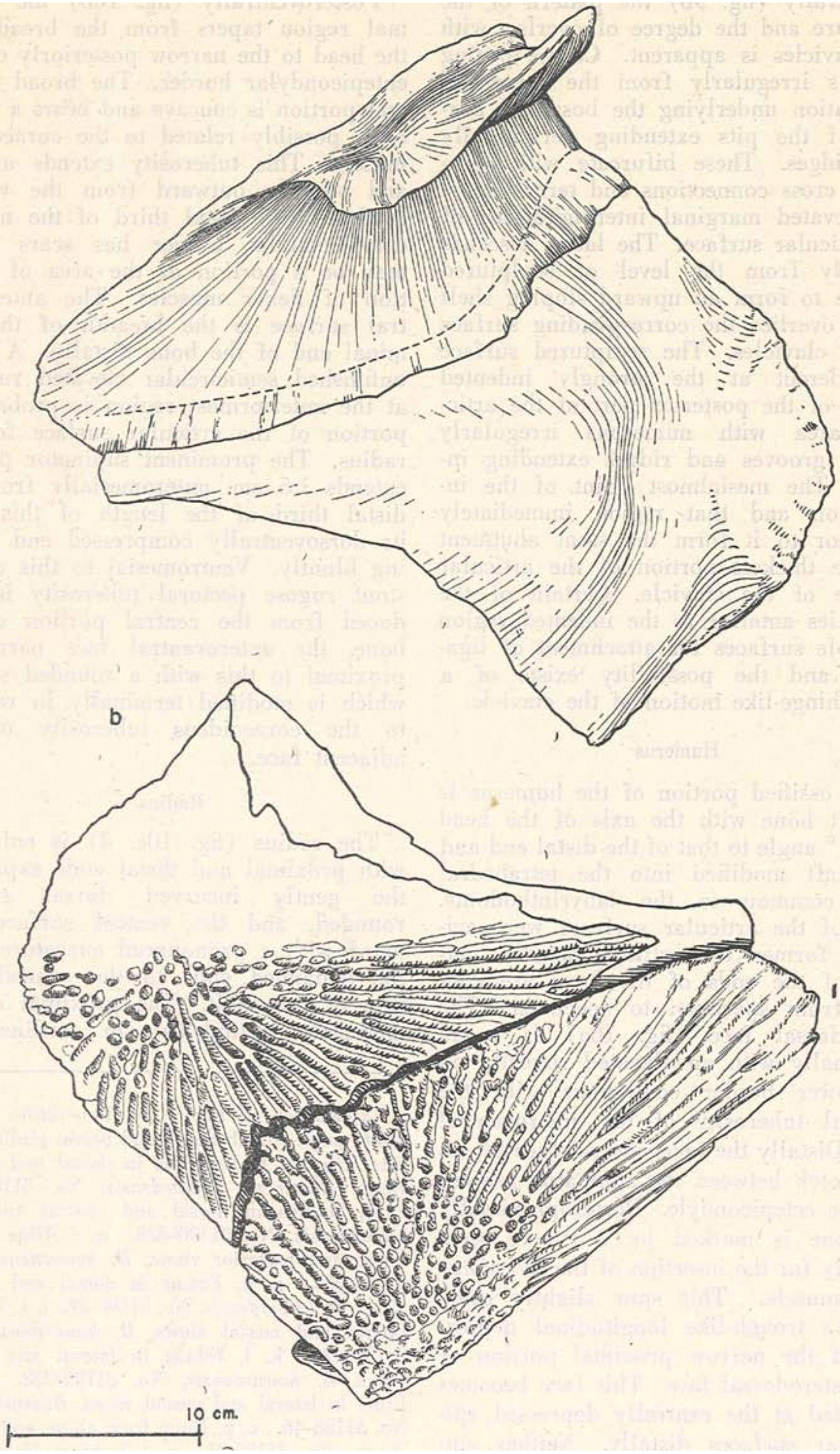
The dorsal surface of the base mesial to the cleithral process and blade is concave and horizontal with a broad elevated surface extending mesially and a little posteriorly from the base of the spine to the border. The lateralmost extent of the overlapping interclavicle extends laterally to the region shown by the dotted line in figure 9a. The broad elevated surface corresponding to the surface of the interclavicle in front of the widest portion of that bone extends laterally to separate the undercut region at the base of the spine from an anterior concavity beneath the base of the blade. Anterolateral to the base of the blade the surface curves upward to the elevated margin, this upward curvature persisting nearly to the anterior end of the bone.

Considerable variation in the form of the lateral margin was found in one specimen (31100–37), a hump-like elevation occurring opposite the middle of the blade. Only three specimens were complete and these showed a considerable variation in the angle and elevation of the blade.

Interclavicle

The dorsal surface of this massive bone (fig. 9a) is in general smoothly finished and modified by a centrally situated boss. This structure is at the intersection of elevations extending anterolaterally to the greatest width of the bone and posterolaterally to emarginations on either side of the apex of the posterior border. The contours of this region are shown in sagittal section (fig. 11b, c.) The curvature at the border is abrupt along the posterolateral faces and the surface is marked by irregularities at the emarginate regions. The margins above the articular surfaces are irregular in outline and are incomplete in all of the specimens; a dotted line in figure 9a shows the probable extent of this thin-edged border. Anterocentrally the curvature of the surface toward the boss and its attendant elevated regions produce a concavity which is accentuated by a slight upward curvature of the anterior "tongue" of the bone. When placed in position this basin of the interclavicle appears to underlie the cardiac region and in conjunction with the clavicles furnishes a stout shield for anterior thoracic organs.

Fig. 9. Clavicle and interclavicle of *Buettneria howardensis.* Specimens No. 31100–37 and 31100–21. a, Dorsal view. The position of the clavicular blade has been corrected. Dotted line shows probable extent of overlap of interclavicle. b, Ventral view.


b
10 cm.

Ventrally (fig. 9b) the pattern of the sculpture and the degree of overlap with the clavicles is apparent. Coarse pitting radiates irregularly from the center of ossification underlying the boss, the borders of the pits extending peripherally into ridges. These bifurcate with occasional cross connections and terminate at the elevated marginal interdigitations of the articular surface. The latter descends abruptly from the level of sculptured surface to form an upward sloping shelf which overlies the corresponding surface of the clavicles. The sculptured surface is undercut at the strongly indented region of the posterior part of the articular area with numerous irregularly curved grooves and ridges extending inward. The mesialmost point of the indentation and that region immediately posterior to it form the stout abutment for the thickest portion of the articular surface of the clavicle. Certain of the rugosities anterior to the indented region resemble surfaces for attachment of ligaments and the possibility exists of a slight hinge-like motion of the clavicle.

Humerus

The ossified portion of the humerus is a short bone with the axis of the head at a 45° angle to that of the distal end and the shaft modified into the tetrahedral form common to the labyrinthodonts. Most of the articular surfaces were evidently formed of cartilage but the outlines of the ends of the bone are constant from specimen to specimen. The anterodorsal face (fig. 10a) is broad proximally with an elevated rugosity on the lower border continuous with the pectoral tuberosity of the anteroventral face. Distally the anterodorsal face tapers to a notch between the supinator process and the ectepicondyle. Posteroproximally the bone is marked by a rugose spur possibly for the insertion of the *latissimus dorsi* muscle. This spur slightly overhangs a trough-like longitudinal depression of the narrow proximal portion of the posterodorsal face. This face becomes expanded at the centrally depressed epicondylar surfaces distally. Neither ent- nor ectepicondylar foramina are present.

Posteroventrally (fig. 10b) the proximal region tapers from the breadth of the head to the narrow posteriorly curved entepicondylar border. The broad proximal portion is concave and bears a tuberosity possibly related to the coracoideus muscle. This tuberosity extends upward and slightly outward from the ventral border. The distal third of the narrow entepicondylar border has scars which may be a portion of the area of insertion of flexor muscles. The anteroventral surface is the breadth of the terminal end of the bone distally. A small unfinished semicircular elevated rugosity at the anteriormost region is probably a portion of the articular surface for the radius. The prominent supinator process extends 1.5 cm. anteromesially from the distal third of the length of this face, its dorsoventrally compressed end tapering bluntly. Ventromesial to this a very stout rugose pectoral tuberosity is produced from the central portion of the bone, the anteroventral face narrowing proximal to this with a rounded surface which is modified terminally in relation to the coracoideus tuberosity of the adjacent face.

Radius

The radius (fig. 10c, d) is columnar with proximal and distal ends expanded, the gently incurved dorsal surface rounded, and the ventral surface flattened with a pronounced curvature from the expanded ends to the central portion of the shaft. The proximal end is angularly cylindrical in outline and

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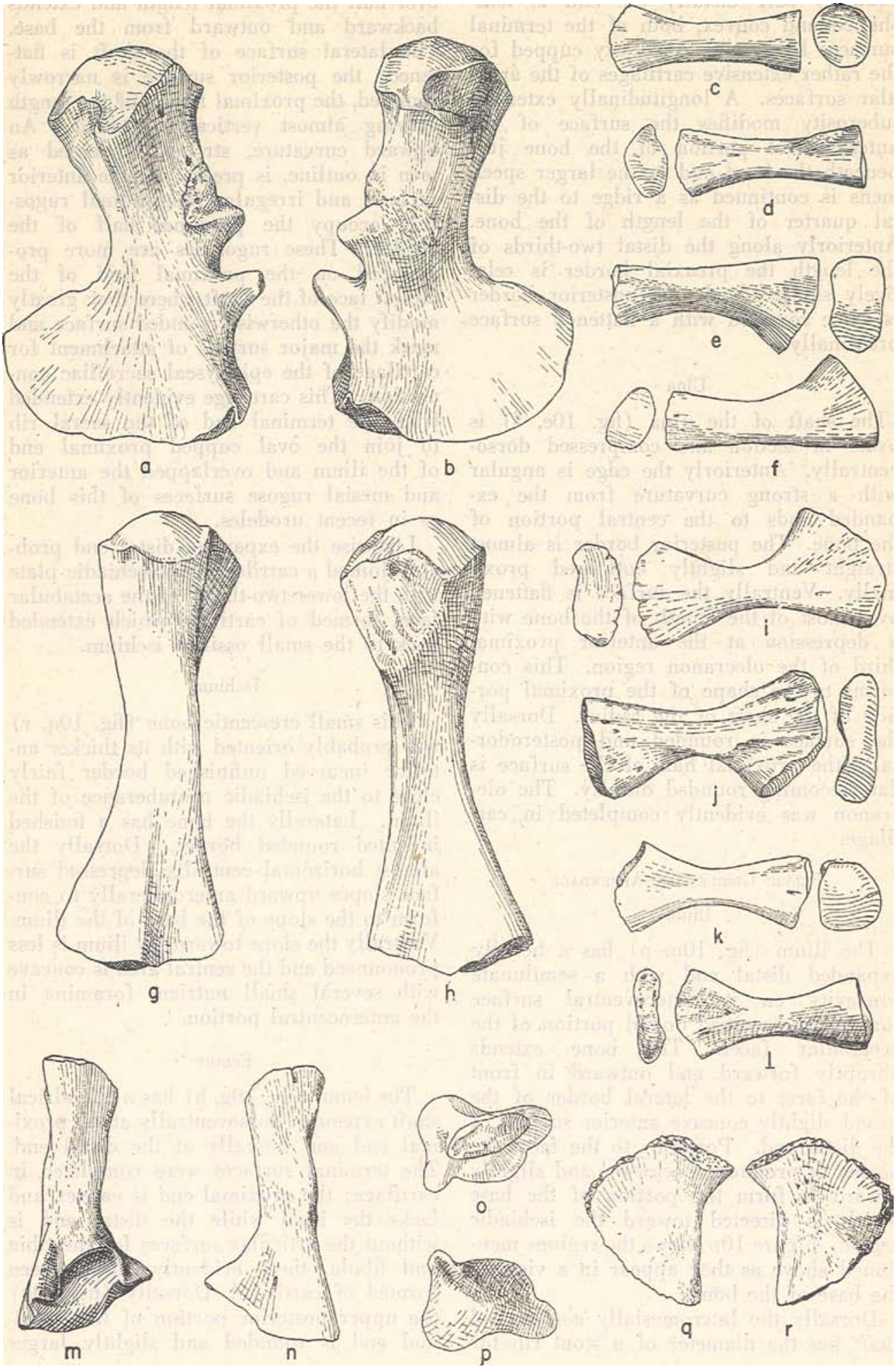
Explanation of Figure 10, illustration on opposite page.—Limb bones and pelvic girdle, right side, x½. a, b, Humerus in dorsal and ventral views, *Buettneria howardensis*, No. 31100–304. c, d, Radius in dorsal and ventral views, *B. howardensis*, No. 31100–338. e, f, Ulna in anterior and posterior views, *B. howardensis*, No. 31100–338. g, h, Femur in dorsal and ventral views, *B. howardensis*, No. 31100–28. i, j, Tibia in lateral and mesial views, *B. howardensis*, No. 31100–429. k, l, Fibula in lateral and mesial views, *B. howardensis*, No. 31100–338. m, n, Ilium in lateral and mesial views, *Buettneria* sp. No. 31185–46. o, p, Ilium from above and below, *B.* sp., No. 31185–46. q, r, Ischium from above and below, *B.* sp., No. 31100–428.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squarely cut; distally the end is lens-shaped and convex, both of the terminal surfaces being very shallowly cupped for the rather extensive cartilages of the articular surfaces. A longitudinally extended tuberosity modifies the surface of the anteroventral portion of the bone just beneath the head and in the larger specimens is continued as a ridge to the distal quarter of the length of the bone. Anteriorly along the distal two-thirds of the length the preaxial border is relatively sharp edged; the posterior border is more rounded with a flattened surface proximally.

Ulna

The shaft of the ulna (fig. 10e, f) is ovate in section and compressed dorsoventrally. Anteriorly the edge is angular with a strong curvature from the expanded ends to the central portion of the bone. The posterior border is almost straight and slightly outbowed proximally. Ventrally the surface is flattened over most of the length of the bone with a depression at the anterior proximal third of the olecranon region. This conforms to the shape of the proximal portion of the shaft of the radius. Dorsally the surface is rounded and posterodorsally the proximal half of the surface is flat, becoming rounded distally. The olecranon was evidently completed in cartilage.

Pelvic Girdle and Appendage

Ilium

The ilium (fig. 10m–p) has a heavily expanded distal end with a semilunate concavity on its lateroventral surface forming the ossified dorsal portion of the acetabular facet. The bone extends abruptly forward and outward in front of the facet to the lateral border of the broad slightly concave anterior surface of the distal end. Posterior to the facet the border is produced backward and slightly inward to form the portion of the base which is directed toward the ischiadic region. Figure 10o shows the regions mentioned above as they appear in a view of the base of the bone.

Dorsally the lateromesially compressed shaft has the diameter of a stout rib for over half the proximal length and extends backward and outward from the base. The lateral surface of the shaft is flattened; the posterior surface is narrowly rounded, the proximal fourth of the length curving almost vertically upward. An upward curvature, strongly indented as seen in outline, is present on the anterior surface, and irregular longitudinal rugosities occupy the proximal half of the border. These rugosities are more pronounced on the proximal half of the mesial face of the shaft where they greatly modify the otherwise rounded surface and mark the major surface of attachment for cartilage of the epiphyseal sacroiliac connection. This cartilage evidently extended from the terminal end of the sacral rib to join the oval cupped proximal end of the ilium and overlapped the anterior and mesial rugose surfaces of this bone as in recent urodeles.

Likewise the expanded distal end probably joined a cartilage puboischiadic plate with the lower two-thirds of the acetabular facet formed of cartilage which extended back to the small ossified ischium.

Ischium

This small crescentic bone (fig. 10q, r) was probably oriented with its thicker anterior incurved unfinished border fairly close to the ischiadic protuberance of the ilium. Laterally the bone has a finished indented rounded border. Dorsally the almost horizontal centrally depressed surface slopes upward anterolaterally to conform to the slope of the base of the ilium. Ventrally the slope toward the ilium is less pronounced and the central area is concave with several small nutrient foramina in the anterocentral portion.

Femur

The femur (fig. 10g, h) has a cylindrical shaft expanded dorsoventrally at the proximal end and laterally at the distal end. The terminal surfaces were completed in cartilage; the proximal end is convex and lacks the head while the distal end is without the articular surfaces for the tibia and fibula, these evidently having been formed of cartilage. Dorsally (fig. 10g) the upper posterior portion of the proximal end is rounded and slightly larger than the central region of the shaft. Rugosities on the posterior surface probably exist in relation to a part of the area of insertion of the pubo-ischio-femoralis-internus muscle mass. The intertrochanteric fossa forms a shallow depression anteroproximally. Dorsolaterally the intercondylar fossa is distinguishable for the distal third of the length of the bone.

Ventrally the large trochanter for the insertion of the caudifemoralis muscle is prominent as a rugose surface on the anteroproximal quarter of the length. The proximal portion of this rugosity is slightly concave with a fairly well finished surface. It is possible that an internal trochanter was present more proximally on the terminal cartilage. An adductor ridge extends to the distal quarter of the length from the apex of the rugosity and fades out in the gently concave popliteal area which modifies the downcurved expanded distal third of the end of the bone.

Tibia

The tibia (fig. 10i, j) is narrow waisted with an oval shaft and flattened ends, the proximal expansion being greater than the distal. The outer surface is convex and very slightly inbowed. The preaxial curvature of the bone is moderate and the anterior face is rounded on the distal half of the length and flattened proximally. Posteriorly the curvature is pronounced and the bone is rounded.

The inner surface is flattened and inbowed with a slight concavity extending longitudinally. The posteroproximal third of the expanded head curves inward, the inner portion of the curved surface modified by several nutrient foramina.

Fibula

The fibula (fig. 10k, l) is expanded to a greater degree distally than proximally and the curvature is more pronounced anteriorly than posteriorly. The head is robust and roughly triangular in outline. the slightly outward tapering apex modified by scars which persist along the proximal third of the narrowly rounded posterior border. Laterally the flattened surface of the bone has a shallowly concave area above the expanded distal end. Anteriorly the surface is fully rounded from the head to the central portion of the shaft; distally the bone is narrow at the compressed terminal region but has a more rounded curvature at the incurved antero-distal end.

The inner face is rounded over the proximal half of the length of bone. A low ridge on the central third of the proximal length becomes more prominent distally where it divides the concave surface of the distal end as it extends to the border about a third of the width of the head of the bone from the posterior margin.

The terminal ends were evidently completed in cartilage and show few details. Distally the end is bluntly wedge-shaped as seen in lateral view with anterior and posteroventral faces oriented in a manner which suggests that articular faces were present for an intermedium and fibulare.

NOTES ON SMALL SPECIMENS OF BUETTNERIA BAKERI?

One block received from a quarry situated at a lower level about a mile north-northeast of the principal sites of excavation in the Otis Chalk, Texas, region contained incomplete skeletons of two very small individuals which in all recognizable features compare closely with the descriptions of Case (1932) for *Buettneria bakeri.* The smallest skull is complete and measures 15.3 cm. in deck length. It is the smallest skull known from the Dockum. Certain proportional differences (Table I–A) existing between this specimen and Case's series (1932) are assumed to be due to growth factors. Other remains include poorly ossified vertebrae, limb bones, and dermal elements of the shoulder girdle. An outline and sectional view of the interclavicle (fig. 12) are comparable with other specimens in the size range of adults of *Buettneria howardensis.*

TABLES OF DIMENSIONS

The following three tables are designed to present numerical values as a supplement to the descriptions.

Numbers of the series 31100 refer to specimens from the major quarry (Quarry 3) situated in the northwest corner of section 87, block 29, near Magnolia No. 1 well, R. Scott lease, near Otis Chalk, Howard County, Texas. Numbers of the series 31025 refer to specimens from Quarry 1, about 1 mile north-northeast of Quarry 3 and at a lower level; series 31099 refers to specimens from Quarry 2, 100 yards east-northeast of Quarry 1; series 31220 refers to specimens from Quarry 4, 1 mile southwest of Quarry 3; series 31172 refers to specimens from the head of Holmes Creek on the A. J. Swenson ranch, Crosby County, Texas; and series 31173 refers to specimens from near Cedar Mountain, 6 miles southeast of Crosbyton, Crosby County, Texas.

In the tables an asterisk (☆) indicates that the specimens were used in making the restoration of the skeleton. All measurements are in centimeters.

DISCUSSION

Skull Roof

In spite of the many dissimilar morphological features, the skulls of the several American genera of the family Metoposauridae have much in common, particularly in the growth patterns of the skull roof. Every adequately figured dorsal view shows extensions of the sculpture in the antorbital and the postorbital-pineal regions. These two regions, by intensive growth (cf. Bystrow, 1935), affect proportions of the skull in various ways. Figure 11 is designed to show graphically these two principal variables for the better known genera, measurements being adapted from dimensional data of Branson (1905), Branson and Mehl (1929), and Case (1932).

The most obvious deviations are noticeable between the Wyoming Chugwater genera and the Dockum forms. The

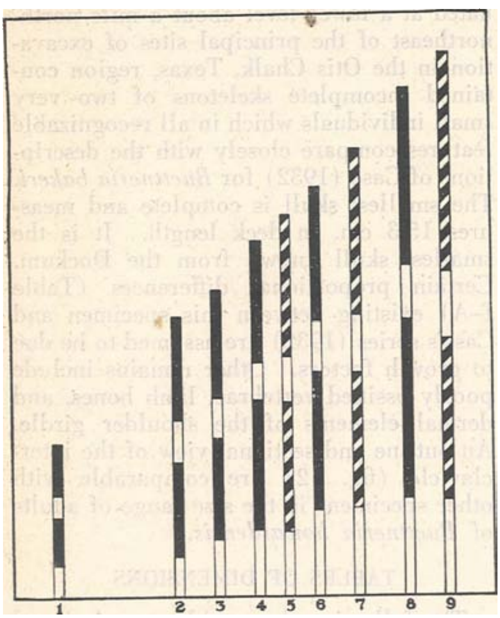

Fig. 11. Regional growth zones in skulls of American metoposaurids.

Total length of bars equal skull lengths of specimens. The upper segment represents the antorbital length, the second, the orbital length. The third segment represents the postorbital-pineal length and the fourth the distance from the front rim of the pineal to the posterior end of the skull. Method of measure indicated in Table I.

Solid lines are used to distinguish the Dockum forms and broken lines the Chugwater forms.

		$\frac{\text{Length}}{\text{Width}}$ in cm.
(1)	Buettneria bakeri, U. T.[a] No. 31099–12	$\frac{15.3}{11.8} = 1{:}0.78$
(2)	B. bakeri, M. C. Z.[b] No. 1054	$\frac{27.95}{21.8} = 1{:}0.74$
(3)	B. bakeri, U. M.[c] No. 13820	$\frac{30.55}{23.8} = 1{:}0.78$
(4)	B. howardensis, U. T. No. 31100–124	$\frac{35.3}{32.1} = 1{:}0.91$
(5)	Borborophagus wyomingensis, U. Mo.[d] No. 517	$\frac{38.0}{30.5} = 1{:}0.80$
(6)	Buettneria howardensis, U.T. No. 31100–42	$\frac{40.9}{39.8} = 1{:}0.97$
(7)	Anaschisma browni, U. Chicago No. 447	$\frac{44.5}{40.5} = 1{:}0.91$
(8)	Buettneria howardensis, U.T. No. 31098–17	$\frac{50.4}{\quad}$
(9)	Koskinodon princeps, U. Mo. No. 537	$\frac{54.0}{44.0} = 1{:}0.81$

[a]The University of Texas, Austin, Texas.

[b]Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts.

[c]University of Michigan, Ann Arbor, Michigan.

[d]University of Missouri, Columbia, Missouri.

TABLE I–A COMPARATIVE MEASUREMENTS AND RATIOS OF THE SKULL.

	a B. howardensis 31100–124	b B. howardensis 31220–1	c B. howardensis 31100–42	d B. howardensis 31100–30	e B. howardensis 31100–161★	f B. howardensis 31100–122	g B. howardensis? 31098–17	h B. bakeri? 31099–12 b.	i B. perfecta (Crosby (County) 31172–11
1. Length of skull roof	35.3 cm.	38.4 cm.	40.9 cm.	42.7 cm.	43.1 cm.	43.2 cm.	50.4 cm. est.	15.3 cm.	41.0 cm.
2. (1) / Antorbital length (line across anterior rims of orbits to anterior)	$\frac{35.3}{12.0}=1:0.34$	$\frac{38.4}{12.0}=1:0.31$	$\frac{40.9}{13.6}=1:0.33$	$\frac{42.7}{14.0}=1:0.33$	$\frac{43.1}{14.3}=1:0.33$	$\frac{43.2}{13.4}=1:0.31$	$\frac{50.4}{17.6}=1:0.35$ (est.)	$\frac{15.3}{5.1}=1:0.33$	$\frac{41.0}{13.3}=1:0.32$
(1) / 3. Average length of orbits	$\frac{35.3}{3.75}=1:0.11$	$\frac{38.4}{5.25}=1:0.14$	$\frac{40.9}{5.27}=1:0.13$	$\frac{42.7}{4.78}=1:0.11$	$\frac{43.1}{5.4}=1:0.125$	$\frac{43.2}{5.6}=1:0.13$	$\frac{50.4}{5.6}=1:0.11$	$\frac{15.3}{2.2}=1:0.14$	$\frac{41.0}{4.68}=1:0.11$
4. (1) / Length, postorbital from line across back rims of orbits to line across front rim of pineal	$\frac{35.3}{12.8}=1:0.36$	$\frac{38.4}{12.6}=1:0.33$	$\frac{40.9}{13.55}=1:0.33$	$\frac{42.7}{16.15}=1:0.38$	$\frac{43.1}{15.1}=1:0.35$	$\frac{43.2}{14.7}=1:0.34$	$\frac{50.4}{17.6}=1:0.35$	$\frac{15.3}{4.83}=1:0.31$	$\frac{41.0}{15.1}=1:0.37$
5. Length of pineal foramen	1.1	1.7?	1.6	1.3	1.25	1.4	1.6	0.46	1.6
6. (1) / Postpineal length (posterior rim of pineal to posterior)	$\frac{35.3}{5.8}=1:0.16$	$\frac{38.4}{7.1}=1:0.185$	$\frac{40.9}{6.95}=1:0.17$	$\frac{42.7}{6.75}=1:0.16$	$\frac{43.1}{7.6}=1:0.165$	$\frac{43.2}{8.13}=1:0.19$	$\frac{50.4}{8.0}=1:0.16$	$\frac{15.3}{2.73}=1:0.18$–	$\frac{41.0}{6.3}=1:0.15$
Length / Width									
(1) / Greatest width	$\frac{35.3}{32.1}=1:0.91$	$\frac{38.4}{34.1}=1:0.89$	$\frac{40.9}{39.8}=1:0.97$	$\frac{42.7}{39.1}=1:0.92$	$\frac{43.1}{41.1}=1:0.95$	$\frac{43.2}{40.2}=1:0.93$		$\frac{15.3}{11.9}=1:0.78$	$\frac{41.0}{34.0}$ 1:0.83
(1) / Width at anterior edge of orbits	$\frac{35.3}{20.0}=1:0.56$	$\frac{38.4}{21.1}=1:0.55$	$\frac{40.9}{23.1}=1:0.56$	$\frac{42.7}{24.5}=1:0.57$	$\frac{43.1}{23.5}=1:0.55$	$\frac{43.2}{24.9}=1:0.58$		$\frac{15.3}{8.12}=1:0.53$	$\frac{41.0}{20.8}=1:0.51$
Width / Height									
Width / Height from base of condyles				$\frac{39.1}{10.4}=1:0.27$	$\frac{41.1}{9.9}=1:0.24$	$\frac{40.2}{10.1}=1:0.25$			
PALATAL RATIOS									
Length / Average length palatal vacuities	$\frac{35.3}{18.3}=1:0.52$	$\frac{38.4}{19.5}=1:0.51$	$\frac{40.9}{21.0}=1:0.51$	$\frac{42.7}{22.4}=1:0.52$	$\frac{43.1}{21.7}=1:0.50$	$\frac{43.2}{22.5}=1:0.52$		$\frac{15.3}{7.69}=1:0.50$	$\frac{41.0}{19.5}=1:0.47$
Length / Length posterior to palatal vacuities	$\frac{35.3}{9.8}=1:0.28$	$\frac{38.4}{12.0}=1:0.31$	$\frac{40.9}{12.5}=1:0.31$	$\frac{42.7}{13.3}=1:0.31$	$\frac{43.1}{12.9}=1:0.30$	$\frac{43.2}{13.3}=1:0.31$		$\frac{15.3}{4.65}=1:0.30$	$\frac{41.0}{12.6}=1:0.31$
Length / Length anterior to palatal vacuities	$\frac{35.3}{11.3}=1:0.32$	$\frac{38.4}{11.6}=1:0.30$	$\frac{40.9}{12.6}=1:0.31$	$\frac{42.7}{11.9}=1:0.28$	$\frac{43.1}{13.2}=1:0.31$	$\frac{43.2}{12.2}=1:0.28$		$\frac{15.3}{4.39}=1:0.29$	$\frac{41.0}{12.6}=1:0.31$

TABLE I–B—MEASUREMENTS OF VERTEBRAE

					★ 3100–237 c			31099–12 ab	
ATLAS: Height with spine					8.9				
Width					8.5 (posterior)			2.40 (posterior)	
Thickness (ventral)					4.2			1.03	
AVERAGE MEASUREMENT OF 8 DORSAL VERTEBRAE: Height of "centrum"					7.15			2.00	
Width (ventral)					8.07			2.25	
Thickness (ventral)					3.16			1.22	

TABLE I-C. MANDIBLES

	B. howardensis								B. sp.	B. bakeri?
	31100–124		31100–91	31100–35	31100–90	31100–268	★ 31100–44	★ 31100–161	31025–11	31099–12b
(1) Length as articulated to skull	L 3.62	R 39.7	L 41.5	L 45.3	R 46.5	R 47.12	L 47.17	R 48.7	49— Est.	L 15.83
(2) Distance from posterior to back of tooth row		15.6	15.8 Est.	18.98	17.14	19.7 Est.	19.34	21.25	19.88	7.5 Est.
(3) Height at coronoid	6.05	5.67	8.7	9.08	9.15	10.52	9.4	9.17	9.31	2.12
(4) Greatest thickness at prearticular	5.5 Est.			5.55 Est.	5.5 Est.		6.52	5.80	5.3 Est.	1.31 Est.
(5) Tooth count dorsal Symphysial			60±2 Est. 7	64±2 6–7	59±2	60 Est.	64±2 7	62— Est.		60 Est. 7 Est.
(6) Length of tooth row		27.3	30— Est.	30.1	31.0 Est.	32.1 Est.	32.28	31.98		11.21
(1) ― (2)	R. 39.7:15.6 1:0.39		41.5:15.8 1:0.38	45.3:18.98 1:0.42	46.5:17.14 1:0.37	47.12:19.7 1:0.41	47.17:19.34 1:0.41	48.7:21.25 1:0.44	49.0:19.88 1:0.41	15.83:7.5 1:0.47

former have shorter postorbital-pineal regions and are more elongate rostrally than Dockum specimens of comparable size. In *Koskinodon princeps*, the extreme example, the considerable rostral elongation results in proportions which place the orbits in nearly a central position, but this tendency may be noted in the other smaller Chugwater genera which are longer in this region than Dockum forms of similar size. The Wyoming group does not seem to contain animals differing from each other in fundamental morphological characters other than proportions or structures which might easily be influenced by growth; e.g., *Borborophagus*, the smallest genus, differs principally from the larger individuals in thickness of the skull and in the number of sculpture depressions on dermal elements. *Koskinodon* apparently differs from *Anaschisma* and *Borborophagus* in minor details except for the considerably elongated rostral region. The latter may readily be explained as a senescent growth character predictable from the proportions known for the smaller Wyoming forms.

As noted, the Wyoming group is distinct from the Dockum in having more centrally placed orbits. It is possible that this difference could be interpreted as a more primitive condition. This may indictate the derivation of the Chugwater metoposaurids from an ancestral form with a more symmetrical skull, and the more specialized Dockum forms, with more anteriorly placed orbits, represent the change in proportions occurring between Chugwater and Dockum time.

The difference in proportions in the Dockum species of the genus *Buettneria* is but slight. *B. perfecta* has a narrower skull than *B. howardensis* and differs slightly in other ratios (Table I–A). *B. bakeri*, which may at present be represented by immature forms, differs from other species in morphological characters and proportions, but this animal could change with increase in size to resemble closely the proportions of larger forms. Case (1932) noted a "progressive lengthening of the middle portion" in a series of five individuals. If continued, such growth would result in a wider skull; the postorbital-pineal zone of intensive growth is crescentic in shape and could alter the skull width as well as the length.

An inspection of the differing proportions of the antorbital and postorbital-pineal zones of growth of the Dockum species encourages speculation on the changes in form of the skull in individuals with increase in size. The smallest skull has approximately equal zones, and in the interval between skull lengths of 15 cm. and 27 cm. there was probably a period of disproportionate rostral growth. This was evidently succeeded by a period of differential elongation in the postorbital-pineal region noticeable in individuals up to the adult size range of 35–50 cm. In the largest adult the two zones again become equal in length, indicating the possibility that senescent individuals become more elongate rostrally.

Braincase and Associated Structures

Wilson's (1941) analysis of the braincase has been confirmed in all of the more important features, and only minor differences in structure are listed in the descriptive sections of this paper. He has noted several conditions of the skull which exclude the Paleozoic form *Trimerorhachis* from ancestry of the Buettneriinae. These are largely based on the presence of better ossified elements of the braincase of *Buettneria*, including the proötic, epipterygoid, and basisphenoid, which are absent or chondrified in *Trimerorhachis*. Although there are many difficulties to overcome in other morphological characters, it may be suggested that if the latter be regarded as a neotenous form, the attendant lack of cranial ossifications could be attributed to incomplete development.

Branson and Mehl (1929) question the homology of the epipterygoid in *Koskinodon* and suggest a functional action of the

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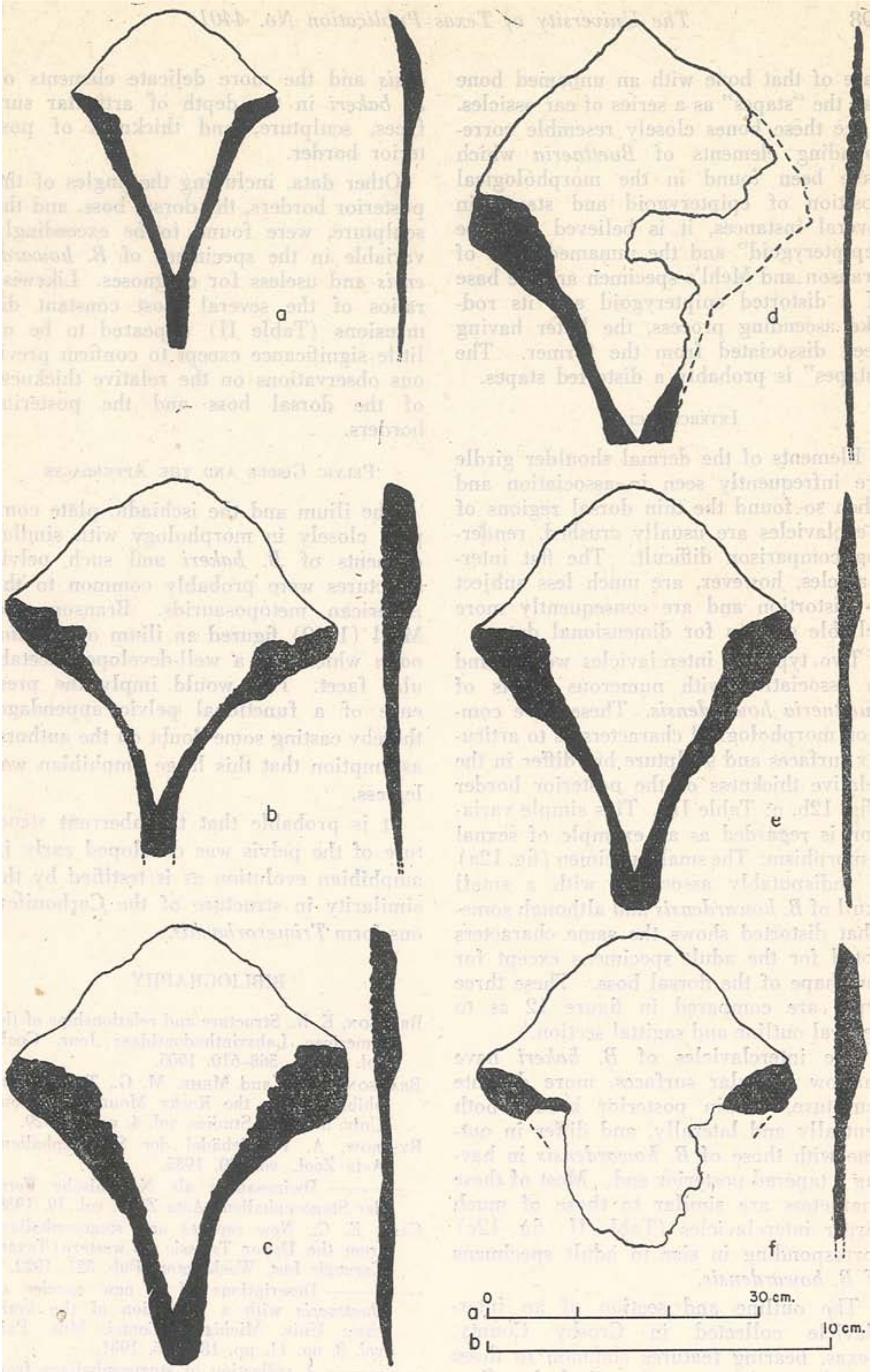
Explanation of Figure 12, illustration on opposite page.—Comparative diagrams of interclavicles. Sagittal section to right of outline. Scale *b* applies to figure d; scale *a* applies to all other figures. a, *Buettneria howardensis*, No. 31100–124. b, *B. howardensis*, No. 31100–40. c, *B. howardensis*, No. 31100–13. d, *B. bakeri?*, No. 31099–12b. e, *Buettneria* sp., No. 31098–6. f, *B. perfecta?*, No. 31173–23.



Comparative diagrams of interclavicles.
Scale "a" applies to figs. a, b, c, e, f.
Scale "b" applies to fig. d.

base of that bone with an unnamed bone and the "stapes" as a series of ear ossicles. Since these bones closely resemble corresponding elements of *Buettneria* which have been found in the morphological position of epipterygoid and stapes in several instances, it is believed that the "epipterygoid" and the unnamed bone of Branson and Mehl's specimen are the base of a distorted epipterygoid and its rod-like ascending process, the latter having been dissociated from the former. The "stapes" is probably a distorted stapes.

Interclavicles

Elements of the dermal shoulder girdle are infrequently seen in association and when so found the thin dorsal regions of the clavicles are usually crushed, rendering comparison difficult. The flat interclavicles, however, are much less subject to distortion and are consequently more reliable sources for dimensional data.

Two types of interclavicles were found in association with numerous skulls of *Buettneria howardensis*. These have common morphological characters as to articular surfaces and sculpture but differ in the relative thickness of the posterior border (fig. 12b, c; Table II). This simple variation is regarded as an example of sexual dimorphism. The small specimen (fig. 12a) is indisputably associated with a small skull of *B. howardensis* and although somewhat distorted shows the same characters noted for the adult specimens except for the shape of the dorsal boss. These three types are compared in figure 12 as to general outline and sagittal section.

The interclavicles of *B. bakeri* have shallow articular surfaces, more delicate sculpture, a thin posterior border both centrally and laterally, and differ in outline with those of *B. howardensis* in having a tapered posterior end. Most of these characters are similar to those of much larger interclavicles (Table II: fig. 12e) corresponding in size to adult specimens of *B. howardensis*.

The outline and section of an interclavicle collected in Crosby County, Texas, bearing features common to those for *B. perfecta* as described by Case (1921) are shown in figure 12f. This specimen is intermediate between *B. howardensis* and the more delicate elements of *B. bakeri* in the depth of articular surfaces, sculpture, and thickness of posterior border.

Other data, including the angles of the posterior borders, the dorsal boss, and the sculpture, were found to be exceedingly variable in the specimens of *B. howardensis* and useless for diagnoses. Likewise ratios of the several most constant dimensions (Table II) appeared to be of little significance except to confirm previous observations on the relative thickness of the dorsal boss and the posterior borders.

Pelvic Girdle and the Appendages

The ilium and the ischiadic plate compare closely in morphology with similar elements of *B. bakeri* and such pelvic structures were probably common to the American metoposaurids. Branson and Mehl (1929) figured an ilium of *Koskinodon* which has a well-developed acetabular facet. This would imply the presence of a functional pelvic appendage, thereby casting some doubt on the authors' assumption that this large amphibian was legless.

It is probable that the aberrant structure of the pelvis was developed early in amphibian evolution as is testified by the similarity in structure of the Carboniferous form *Trimerorhachis*.

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DECAPOD CRUSTACEANS FROM THE CRETACEOUS OF TEXAS

H. B. Stenzel

In the Tertiary and Cretaceous strata of Texas, decapod crustaceans are not uncommon, at least at some localities. There are even a few localities where these decapod crustaceans are amazingly abundant. California Crossing in Dallas County is one of these localities. The abundance and fine preservation of material from such localities present a challenge to the paleontologist, and this challenge is strengthened by the importance of much of the material.

So few fossil decapod crustaceans have been collected and described in this country that nearly every new locality also yields new species, and many of the genera are new to this country. In addition, the knowledge of decapod crustaceans here and abroad is very incomplete so that some of the finds result in significant extensions of the stratigraphic range of the genera.

It is fortunate that some of the species, notably *Cenomanocarcinus vanstraeleni* Stenzel, are represented by copious material, which makes it possible to describe nearly all parts of the animal — carapace, abdomen, and appendages. Such fully described species are very much needed as a firm standard around which may be grouped the less known species, that is, those described from isolated fragments. In such fully described species are the means of elucidating phylogenetic relations as, for instance, the relations between *Necrocarcinus* and *Cenomanocarcinus.* Also these fully known species may be used to correct misidentifications caused by insufficient material in other related species. A case in point is the recognition of the true nature of *Raninella (?) armata* Rathbun. Or the fully known species may be used to improve the understanding of related but less copious material. A case of this sort is the right manus of *Upogebia gamma* (Rathbun) which was originally described as the left manus.

These fossil crustaceans were collected partly by local enthusiastic collectors and partly by the staff of the Bureau of Economic Geology. The writer is indebted to the collectors for some of the finest specimens. Proper credit is given in the text to those who have helped to gather the material. The writer wishes to express his appreciation of their efforts and generosity.

NOTES ON THE COMPARATIVE ANATOMY OF THE MACRUROUS DECAPOD CRUSTACEANS

One of the clearly outstanding features of highly developed animals is the eye. Among many of these animals it is the eye which is the chief sense organ. Its proper function as an organ of vision aids the animal in protection from attack, in quest of food, in search for mates, and in other essential functions. Therefore, it is important that the eye be protected from any injury in fight or by accident. In the mammals this protection is afforded by bony structures surrounding the orbit of the eye. In those mammals which depend very much on the use of the eye — man is one of them — the orbit is protected by the bones of the nose, eyebrows, and cheeks. These bones encircle and surmount the orbit, so that the eye is freely movable and yet surrounded by hard ridges.

The same problem exists in crustaceans. The eye must be protected in those crustaceans in which the eye is of paramount importance as a sense organ. In the crustaceans, as in the mammals, this protection is accomplished by hard ridges. Naturally, the ridges are not composed of bones as in the mammals, because crustaceans do not have an interior bony skeleton. Among the crustaceans the ridges are parts of the exoskeleton. For example, the eye of a lobster (see text fig. 1) is surrounded by 11 protective spines. These spines form an oblong defense ring around the orbit, giving the eye the much needed protection from enemy or accident.

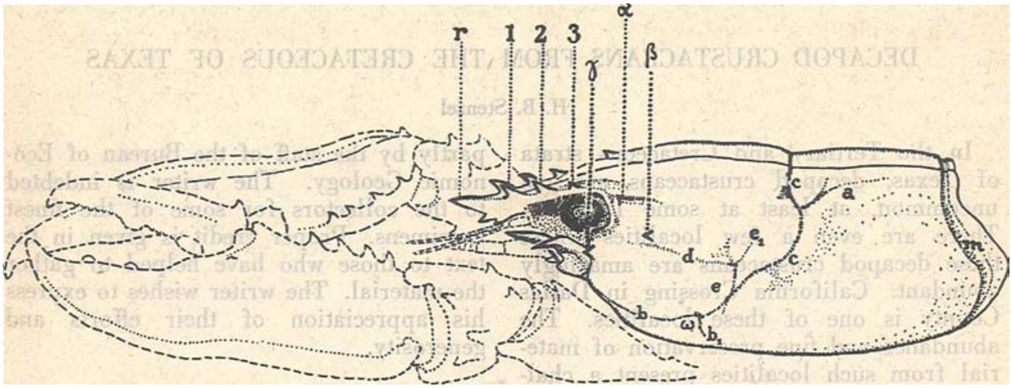

Fig. 1. The protection of the eye in an Astacuran crustacean, the American lobster, *Homarus americanus* H. Milne-Edwards, 2/3 of natural size.

For explanation of the symbols of the spines, see the text. Abbreviations of grooves on the carapace: a, branchio-cardiac; b, antennar; b_1, hepatic; c, postcervical; d, gastro-orbital; e-e_1, cervical; m, marginal. The position of the eminence omega is indicated by the Greek letter.

These protective circum-orbital spines are distributed in *Homarus americanus* H. Milne-Edwards as follows:

2 median spines on ventral surface of rostrum (unpaired)
1 tip of rostrum (unpaired)
3 spines at lateral edges of rostrum (paired)
3 spines on the carapace (paired)
1 spine on distal end of exopodital scale of antenna (paired)
1 spine on distal end of second protopodite segment of antenna (paired)

The two orbits together have 19 spines, because the 2 median spines on the ventral surface and the tip spine of the rostrum are unpaired. The 2 median spines of the ventral surface of the rostrum are present in *Homarus americanus* H. Milne-Edwards but are absent in *Homarus vulgaris* H. Milne-Edwards and in fossil species of the genus. Therefore, they will henceforth be omitted from consideration. The spines on the segments of the antenna are rarely preserved in fossil specimens. Thus are left the following spines:

1 tip of rostrum, unpaired (r)
3 lateral spines of rostrum, paired (1, 2, 3)
3 spines on carapace, paired (α, β, γ)

These 13 spines are preserved and recognizable in many fossil species of *Homarus*. However, their importance lies not only in their occurrence in this one genus but also in their occurrence in many genera. In other words, it is possible to find homologous structures in nearly all macrurous crustaceans.

In order that an unequivocal terminology may be used, these spines were labelled by Boas[1] with letters or numbers. His terminology has been used to advantage by other paleontologists and is retained here. In addition, a set of names is used for the spines.

Terminology of the circum-orbital spines of macrurous crustaceans.

Boas	*This paper*	
r	tip spine of rostrum	
1	first lateral rostral spine	on rostral ridge
2	second lateral rostral spine	
3	third lateral rostral spine	
α	supra-orbital spine	on carapace
β	sub-orbital spine	
γ	antennar spine	

In many instances the spines are developed from longitudinal ridges. The rostral spines are portions of the two rostral ridges (ρ), which extend along the lateral margins of the rostrum and unite in the tip spine. The supra-orbital, sub-orbital, and antennar spines are the anterior ends of more or less well-developed, longitudinal ridges or keels, which bear the terms supra-orbital, sub-orbital, and antennar ridges or keels respectively. In addition, there may be a median ridge

[1]Boas, J. E. V., Studier over Decapodernes Slaegtskabsforhold: K. danske vidensk. selsk. skr., 6 raekke, naturvid. math. Afd., vol. 1, art. 2, pp. 23–210, pls. 1–7, 1880.

(μ) along the midline of the rostrum and the carapace.

It has been mentioned above that the importance of these structures lies not only in their occurrence in the genus *Homarus* but also in their occurrence in many genera. The diagram (fig. 1) may serve to indicate the shape and arrangement of these features in the tribe *Astacura.*

The tribe *Palinura* differs from the *Astacura* in several features, among which the shape of the carapace is of concern to the present study. The carapace of the *Astacura* is subcylindrical, whereas the carapace of the *Palinura* is depressed. The shape of the carapace determines the relative position of the eyes or rather the relative distance from one eye to the other. If the carapace is subcylindrical, as in the *Astacura,* the eyes are relatively close together; if, on the other hand, the carapace is depressed, as in the *Palinura,* the eyes are comparatively far apart. If the eyes are close together they can be protected very effectively by a prominent rostrum projecting halfway between them. On the other hand, if the eyes are far apart they can not be protected effectively by a median rostrum unless the rostrum becomes unusually broad, in which case the rostrum may interfere with the essential function of the eyes. Therefore, if the eyes of the *Palinura* were to be protected, there was the choice of either broadening the median rostrum to fit the enlarged distance between the eyes or letting another organ take over their protection. In the latter case the rostrum would lose its prime function, that is, the role of protector of the eyes, and become reduced in size or even suppressed. That is precisely the condition among the *Palinura.* In this tribe the rostrum is either small or wanting (except in *Palinurellus* and the *Glypheidea*), the protection of the eyes is taken over by the supra-orbital spines (α), and the eyes are far apart. In addition, the depression of the carapace has put the antennar spines (γ) into a much more prominent and exposed position, namely, at the antero-lateral corner of the carapace. Such an exposed position necessitated the enlarging of these spines. Thus, the *Palinura* (with some exceptions) have as the most prominent features of the frontal part of the carapace the supra-orbital (α) and the antennar (γ) spines, between which the eyes find adequate protection. The diagram (fig. 2) shows the protection of the eye in *Astacodes* as an example of the *Palinura.*

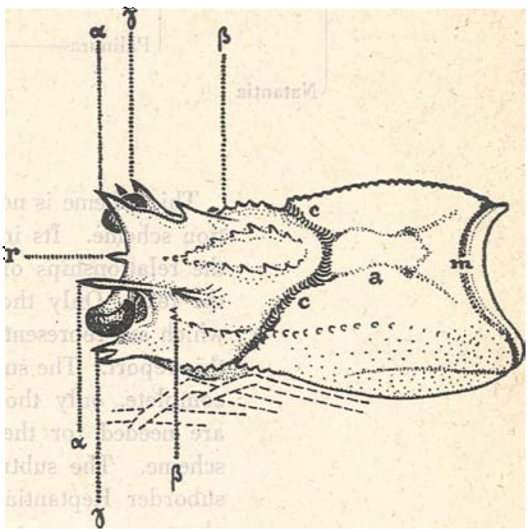

Fig. 2. The protection of the eye in a Palinuran crustacean, the fossil spiny lobster *Astacodes maxwelli* Stenzel, ⅔ of natural size.

Note the rudimentary nature of the rostrum (r) and the prominence of the spines (α) and (γ). For explanation, see text figure 1.

SCHEME OF CLASSIFICATION OF THE DECAPOD CRUSTACEANS

Order	Suborder	Tribe	Subtribe	Superfamily	Family
Decapoda	Reptantia	Brachyura	Hapalocarcinidea		
			Brachygnatha		
			Dromiacea	Thelxiopeidea	
				Dromiidea	Prosoponidae
			Oxystomata		Calappidae
			Gymnopleura		Raninidae
		Anomura		Paguridea	Paguridae
				Thalassinidea	Callianassidae
				Galatheidea	Galatheidae
				Hippidea	
		Astacura		Nephropsidea	Nephropsidae
					Erymidae
		Palinura		Glypheidea	
				Scyllaridea	Palinuridae
				Eryonidea	
	Natantia				

This scheme is not a complete classification scheme. Its intent is to show merely the relationships of the groups treated in the text. Only those families are shown which are represented by fossils treated in this report. The superfamilies are also incomplete, only those being shown which are needed for the understanding of the scheme. The subtribes and tribes of the suborder Reptantia are fully represented above.

STRATIGRAPHIC DISTRIBUTION

Genera→	Linuparus	Astacodes	Enoploclytia	Homarus	Nephrops	Galathea	Upogebia	Paqurus	Notopo-corystes	Necro-carcinus	Cenomano carcinus	Rathbun-opon
Post-Cretaceous												
Maestrichtian												
Campanian			E kimzeyi									
Santonian		A maxwelli	E.sp	H blossomanus								
Coniacian			E.triglypta									
Turonian	L grimmeri L watkinsi	A davisi		H.brittonestris H davisi			(U.) hacheochir		N dichrous	N? ovalis	C. van-straeleni	
Cenomanian												R. polyakion
Albian upper	L adkinsi	?A wenoensis	E.walkeri E.wintoni	H tarrantensis H dentonensis	N americanus	G cretacea G? limonitica			N parvus N punctatus	N graysonensis N moseleyi N renfroae N. texensis	C. oklahomensis C. armatus	
Albian middle				H travisensis				P travisensis				
Albian lower								P banderensis				
Aptian												
Barremian												
Hauterivian												
Valanginian												

Note: Distribution in Texas as it is known at present is shown by solid black vertical columns; outside of Texas by white vertical columns.

Tribe PALINURA Borradaile

Superfamily SCYLLARIDEA Stebbing

Family PALINURIDAE Gray

Genus LINUPARUS A. W. White, 1847

List of Crustacea in the British Museum, p. 70.[2]
Genotype.—*Linuparus trigonus* (De Haan) living, coasts of Japan.

LINUPARUS GRIMMERI Stenzel, n.sp.

Pl. 34, figs. 1–4; Pl. 35, figs. 1, 5, 6; Pl. 45, fig. 3; text fig. 3

Linuparus grimmeri Stenzel *in* Dallas Petroleum Geologists, Geology of Dallas County, Texas, p. 35, fig. 7, 1941.

Description.—Cephalothorax elongate-rectangular in outline, about twice as long as wide; greatest width of carapace in the vicinity of the postcervical grooves (c). Carapace only very gently convex from front to back. Length of the supra-orbital spines (a) is 1/12 the carapace length; there is neither a rostrum nor an accessory spine in the intervening sinus, and the sinus is broad V-shaped with a rounded end. To either side of the supra-orbital spines the front is very nearly straight and defined by an edge, which carries a row of fine tubercles with hair-pits and which slopes downward and outward to the antennar spine (γ). This stout spine has a triangular base and points forward, outward, and upward. The lateral carapace margins are defined anterior to the postcervical grooves by the antennar keel carrying about 6 spines and 1 or 2 spinules. The first of these spines is the antennar one at the fronto-lateral corner; this is also the strongest spine of the keel. The other spines are small. The keel is sigmoid in outline as seen from above, ends abruptly at the postcervical groove, and is not continued behind that groove. Posterior to the groove the lateral margin is at first defined by a short, finely tuberculated, inclined keel nearly parallel with the outer end of the groove. This keel flattens out in posterior direction into the vertical side

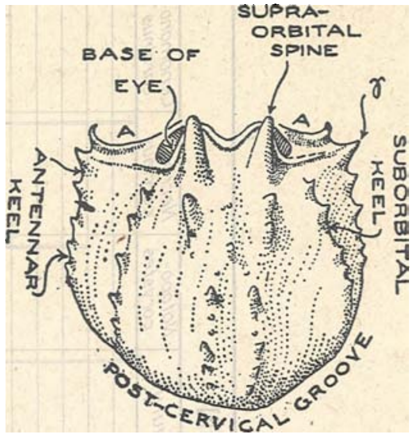

Fig. 3. *Linuparus grimmeri* Stenzel, x2, restored; carapace anterior to the postcervical grooves. A, position of antenna.

wall of the carapace. The posterior carapace margin is highly arched transversely and concave as seen from above; it has a marginal groove (m) and an elevated rim.

Surface of carapace is divided into a shorter anterior and longer posterior portion by the pair of deep and broad, V-shaped postcervical grooves, which are united in the middle by a short, broad, and shallow, transverse groove. The anterior portion of the carapace has 9 spinous keels. Two of these keels, the antennar keels, begin with the fronto-lateral spine and have been described above. Another pair, the supra-orbital keel pair, begins at the supra-orbital spines and extends in a very slight curve almost halfway to the postcervical grooves. Each supra-orbital keel carries the forward pointing supra-orbital spine, behind which is a smooth place; at the end are a forward-pointing spine and a small spinule. Between the supra-orbital and the antennar keel lies the sub-orbital keel (β). The two sub-orbital keels are gently curved, spreading to the posterior, and in line with the keel pair posterior of the postcervical grooves. They start very near the base of the supra-orbital spine and carry 5 to 6 small spines, of which the first and last ones are smaller than those in the mid-portion of the keel. In the midline and near the front is a short, obscure keel with only one small spine (μ). A fourth keel pair outlines

[2]For a discussion of nomenclatorial questions involving this genus see: Woodward, Henry, Further notes on podophthalmous crustaceans from the Upper Cretaceous formation of British Columbia, etc.: Geol. Mag., new ser., dec. 4, vol. 7, p. 394, 1900.

Woods, Henry, A monograph of the fossil macrurous Crustacea of England, pt. 2: Palaeontograph. Soc., vol. 77, pp. 26–27, 1925.

an oval area lying in the midline just in front of the postcervical grooves. Each keel carries 2 small spines and some spinules.

The portion of the carapace posterior to the postcervical grooves has 3 keels, one in midline and the pair at the lateral margins. The median keel has about 9 small spines and in some specimens one spinule just in front of the marginal groove (m). There is an additional small spine on the raised rim of the posterior margin. The paired keels carry each about 20 small, forward-pointing spines. The mid-portion of the carapace is roof-shaped; the two halves make an obtuse angle of 150° at the midline; the side walls are gently convex, slope down with a slight divergence from the outer keels, and are edged with a raised margin at the bottom. The surface of the carapace is covered with tiny spinules pointing forward and upward.

The abdomen has 3 spinous, longitudinal keels in line with the 3 keels of the posterior portion of the carapace. Each of the lateral keels is represented by 2 spines on each abdominal somite except on the first, which does not have any. The posterior of these two lateral spines is always the smaller; it may even be absent. The median keel is represented by one central, laterally compressed spine on the first somite, by two laterally compressed spines on the second, third, fourth, and fifth somites. On the sixth somite there are along the midline two parallel keels about 1 mm. apart, each carrying 4 spinules. The telson carries 2 spinules about 1 mm. apart.

Sternum narrow-triangular in outline, with a very low, broad tubercle on the anterior tip. Each sternite is separated from its successor by a pair of lateral, oblique incisions. The lateral edges of each sternite except the last are turned up and appear in outline concavely divergent toward the posterior. This upturned edge is surmounted in all sternites except the last by a tubercle, which is situated near or at the middle of the edge. The anterior and posterior corners of this upturned edge are drawn out into tubercle-like points. The fifth sternite has two small transverse tubercles transversely arranged near its center.

Antennae much longer than the carapace. Of the peduncular joints 3 are visible; they are spinous. The flagellum is slender and cylindrical, but with a longitudinal groove on its upper surface. Each flagellar segment has a row of hair-pits encircling its anterior margin.

Dimensions.—Syntype 1, length of carapace, 23.7 mm., width, 12.0 mm.; syntype 2, length of carapace, 30.7 mm., width, 15.5+ mm.; syntype 3, width of carapace from one antennar spine to the other, 28.3 mm.; syntype 4, width of carapace (crushed), 20.2 mm., length of carapace, 38.8 mm.

Remarks.—This species is found at the same locality as *Linuparus watkinsi* Stenzel. Therefore, the differences between the two species need to be emphasized.

Linuparus grimmeri Stenzel is slenderer than *L. watkinsi* Stenzel. The proportions of length of carapace to the distance between the paired lateral keels is as follows:

L. grimmeri Stenzel	2.33 to 1
L. watkinsi Stenzel	2.07 to 1

The front of *L. grimmeri* Stenzel has simple supra-orbital spines without accessory spines in the sinus intervening between the two spines, and the sinus is broad V-shaped with a rounded end. The front of *L. watkinsi* Stenzel has supra-orbital spines with accessory spines in the intervening sinus, and the sinus is U-shaped.

All spines of *L. grimmeri* Stenzel are weaker and smaller than the corresponding ones in the other species. However, some of the keels have more spines on *L. grimmeri* Stenzel than on the other species; this is particularly true of the 3 keels of the carapace posterior of the postcervical grooves. Granulation and tuberculation of the carapace surface is less rough in *L. grimmeri* Stenzel than in the other species. The two species may be distinguished at a glance by the greater roughness of *Linuparus watkinsi* Stenzel.

The species is named in honor of Mr. R. A. Grimmer of Dallas, who kindly donated syntype 1. Ten of the types were collected by Mr. W. T. Watkins and one by Mr. Forrest Kirkland of Dallas.

Type data.—Fourteen syntypes, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—California Crossing, north-facing bluff on right bank of Elm Fork of Trinity River upstream from and at Chicago, Rock Island & Pacific Railroad bridge, in southwest corner of Joshua McCants survey, on O'Connor dairy land, about 10 miles northwest of Dallas, Dallas County, Texas.

This locality appears to be the same as locality No. 16 of Moreman.[3] According to Moreman this was the site of Horton's Mill, where many of Hyatt's[4] Cretaceous ammonites were collected.

Geologic horizon.—Britton formation of Eagle Ford group, Gulf series, Cretaceous (lower Turonian or Salmurian).

At California Crossing the following fossils are found:

Chordata—Vertebrata:
- Teleost fin bones and vertebrae

Arthropoda—Crustacea:
- Linuparus grimmeri Stenzel
- Lin. watkinsi Stenzel
- Astacodes davisi Stenzel
- Homarus brittonestris Stenzel
- Homarus davisi Stenzel
- Upogebia rhacheochir Stenzel
- Notopocorystes dichrous Stenzel
- Cenomanocarcinus vanstraeleni Stenzel

Mollusca—Cephalopoda:
- Baculites gracilis Shumard
- Scaphites sp.
- Worthoceras vermiculus (Shumard)
- Neocardioceras septem-seriatum (Cragin)
- Eucalycoceras sp.
- Metoicoceras whitei Hyatt
- Proplacenticeras sp.
- Allocrioceras annulatum (Shumard)

Mollusca—Gastropoda:
- Naticoid indet.
- Cerithiid indet.

Mollusca—Pelecypoda:
- Inoceramus fragilis Hall & Meek

Echinodermata—Echinoidea:
- Echinoid indet.

Echinodermata—Ophiuroidea:
- Ophiuroid undescribed

LINUPARUS WATKINSI Stenzel, n.sp.

Pl. 34, figs. 5–8; Pl. 45, figs. 1, 2; text fig. 4.

Linuparus watkinsi Stenzel *in* Dallas Petroleum Geologists, Geology of Dallas County, Texas, p. 36, fig. 8, 1941.

Description. — Cephalothorax elongate-rectangular in outline, less than twice as long as wide; greatest width of carapace in the vicinity of the postcervical grooves (c). Carapace only very gently convex from front to back. Front of carapace nearly straight except for the projecting supra-orbital spine pair (a). Length of these spines is 1/8 the carapace length; each spine carries a short, accessory spine halfway down in the intervening sinus; the end of this sinus is U-shaped. To either side of the supra-orbital spine pair, the front is very gently concave or slightly flexuous in outline and defined by a finely tuberculate edge, which slopes downward and outward to the fronto-lateral corner. The front ends in a short, stout, forward and outward-pointing antennar spine (γ) with triangular base located at the extremity. The lateral margins of the

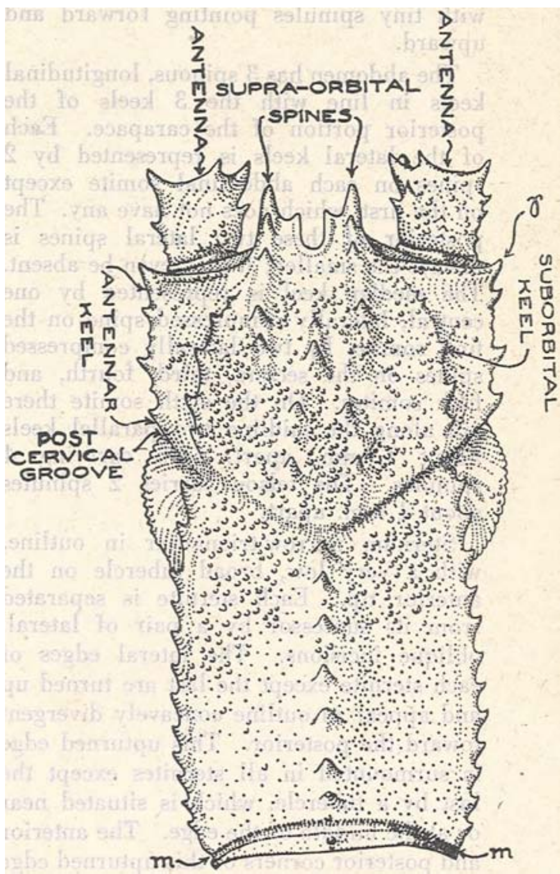

Fig. 4. *Linuparus watkinsi* Stenzel, x2; composite of several specimens; carapace with parts of antennae.

[3]Moreman, W. L., Paleontology of the Eagle Ford group of north and central Texas: Jour. Paleontology, vol. 16, no. 2, p. 197, 1942.

[4]Hyatt, Alpheus, Pseudoceratites of the Cretaceous: U. S. Geol. Survey Mon. 44, 1903.

carapace are defined anterior to the postcervical grooves by an antennar keel carrying 4 spines and a few irregular accessory spinules. The first of these spines is the antennar one at the frontolateral corner. This keel is gently sigmoid in outline, ends abruptly at the postcervical groove, and is not continued behind that groove. Posterior to the postcervical groove the lateral margin is at first defined by a short, densely tuberculated, inclined keel nearly parallel with the outer end of the groove. This keel flattens out in posterior direction into the vertical side wall of the carapace. Posterior margin of carapace highly arched in transverse direction and slightly concave as seen from above; it has a marginal groove (m) and an elevated rim.

Surface of carapace divided into a shorter anterior and longer posterior portion by the pair of deep and broad, V-shaped postcervical grooves, which are united in the middle. The anterior portion of the carapace has 9 spinous keels. Two of these 9 keels, the antennar keels, begin at the fronto-lateral corner, follow the lateral margin, and have been described above. Another pair, the supra-orbital keels, begins at the supra-orbital spines and extends in a slight curve almost halfway to the postcervical grooves. Each keel of this pair carries two unequal, closely spaced spines and some minor tubercles situated behind a low and smooth portion of the keel. To the front of this smooth portion the keel is a part of the supra-orbital spine; it is spinulous and merges into the tip of the spine. Between this keel pair and those at the lateral carapace margin lies the sub-orbital keel pair (β). These are gently curved, spreading to the posterior, and in line with the lateral keel pair posterior to the postcervical grooves. They start very near the base of the supra-orbital spine and carry 4 to 5 unequal spines, of which the first and last ones are smaller than those in the mid-portion of the keel. In the midline and near the front is a short, indistinct keel (μ) with either one spine or two unequal spines and some minor tubercles. A fourth keel pair outlines an oval area lying in the midline just in front of the grooves. Each keel carries 2 large spines and some minor spines and spinules.

The portion of the carapace posterior to the postcervical grooves has 3 keels, one in midline and the pair at the lateral margins. The median keel has 7 major spines and few accessory minor spines. In line with this keel and separated from it by the posterior marginal groove, there is a spine on the raised posterior margin. The paired keels carry each 12 major spines. The mid-portion of the carapace is roof-shaped; the two halves make an obtuse angle of 125° at the midline; the side walls slope down vertically or converge slightly downward from the outer keels and are edged at the bottom with a raised margin. The surface of the carapace is rough with scattered, tubercular hair sockets directed forward and upward.

Sternum narrow-triangular in outline, with a low, broad tubercle on the anterior tip. Each sternite is separated from its successor by a pair of lateral, oblique incisions. The lateral edges of each sternite except the last are turned up and appear in outline concavely divergent toward the posterior. This upturned edge is ornamented with a row of small tubercles in the first sternite; in the second and third sternites the edge has a small tubercle at the anterior corner and a high, compressed tubercle slightly anterior of the middle of the edge; in the fourth sternite there is, in addition to these two tubercles, a third one at the posterior corner of the edge; the fifth sternite has a high, two-headed tubercle in its center and short, straight, parallel, only slightly upturned lateral edges with a small tubercle at the anterior corner and a few small tubercles following. The posterior margin of the sternum is highly arched in transverse direction and carries a row of tubercles along its rim.

Abdomen has 3 spinous, longitudinal keels in line with the 3 keels of the posterior portion of the carapace. Each of the lateral keels is represented by 2 spines on each abdominal somite, except on the first, which does not have any. The median keel is represented by one central spine on the first and second somites, by two laterally compressed spines fortified by a few spinules on the third somite, by 4 spines arranged in groups of two on the fourth somite, and by two simple spines on the fifth somite. On the sixth somite there are along the midline two short, parallel keels about 1 mm. apart, each carrying 3 spinules. The pleura of the abdominal somites have serrated edges. The telson carries a spine on the midline near its anterior edge and has parallel sides. The uropods are narrow; their edges are sigmoid in outline.

Dimensions.—Syntype 1, length of carapace with exclusion of the supra-orbital spines, 25.7 mm., width, 14.6 mm.; syntype 2, width of carapace, 21.5 mm., length of sternum, 19.8 mm., greatest width of sternum, 11.9 mm.; syntype 3, width of carapace, 23.5 mm., length of supra-orbital spines, 4.0 mm.; syntype 4, length of carapace with exclusion of the supra-orbital spines, 30.0 mm., width, 18.7 mm.

Remarks.—This species is easily distinguished from most North American Cretaceous species of *Linuparus.* In *L. adkinsi* Rathbun,[5] *L. kleinfelderi* Rathbun,[6] and *L. vancouverensis* (Whiteaves),[7] crowded tubercles cover the keels of the carapace and spines are rare, being restricted to the anterior ends of the keels. *Linuparus watkinsi* Stenzel with its keels spinous throughout is much rougher than these species. However, *L. canadensis* (Whiteaves)[8] is very nearly related to *L. watkinsi* Stenzel. The Canadian species is much larger in size, being about 3 times as large as *L. watkinsi* Stenzel, but has very similar spinous keels. The most readily recognized difference is the arrangement of the spines in the middle of the carapace anterior to the postcervical grooves. According to Whiteaves (p. 88), in *L. canadensis* (Whiteaves) "next to the furrow, and in advance of it, in the median line, there are five tubercles arranged in two convergent rows of two pairs and an odd one, which if connected by lines, would have much the shape of an isosceles triangle, with its base near the furrow." The same spines of *L. watkinsi* Stenzel do not form a true triangle, because the two equal sides are curved with the convexity outward. There are also a few minor accessory spinules in these lines in *L. watkinsi* Stenzel, but not in *L. canadensis* (Whiteaves). The same is true of accessory spines along the supra-orbital keels.

If the ventral carapace surface described by Woodward[9] really belongs to *Linuparus canadensis* (Whiteaves) there are several differences in the tubercles of the two related species. Each sternite of *L.* cf. *canadensis* (Whiteaves) Woodward is ornamented with a pair of rounded, subcentral tubercles, except the first sternite. These tubercles are absent in *L. watkinsi* Stenzel, but there is in their stead a high, double-headed median tubercle on the last sternite.

The species is named in honor of Mr. W. T. Watkins of Dallas who collected three of the types of this species.

Type data.—Six syntypes, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Same as *Linuparus grimmeri* Stenzel.

Geologic horizon.—Same as *Linuparus grimmeri* Stenzel.

Genus ASTACODES Th. Bell, 1863

A monograph of the fossil malacostracous Crustacea of Great Britain, pt. 2, Crustacea of the Gault and Greensand: Palaeontograph. Soc., vol. 14, pp. 30–31.

Genotype.—*Astacodes falcifer* Bell from the Speeton clay (Hauterivian) of England. Genotype by monotypy.

ASTACODES MAXWELLI Stenzel, n.sp.

Pl. 35, figs. 2–4; Pl. 45, figs. 4–6; text figs. 2, 5.

Description. — Cephalothorax elongate in outline, not quite twice as long as wide; greatest width about halfway between the postcervical grooves and the posterior end. Carapace nearly straight from front to back and rounded-rectangular in transverse cross section. Carapace

[5] Rathbun, M. J., Fossil Crustacea of the Atlantic and Gulf Coastal Plain: Geol. Soc. Amer., Spec. Paper 2, p. 37, pl. 10, figs. 4–10, 1935.

[6] *Idem*, pp. 35–36; pl. 8; pl. 9, figs. 1–2; pl. 25.

[7] Woodward, Henry, Further notes on podophthalmous crustaceans from the Upper Cretaceous formation of British Columbia, etc.: Geol. Mag., new ser., dec. 4, vol. 7, pp. 395–396, pl. 15, 1900.

[8] Whiteaves, J. F., Contributions to Canadian paleontology, vol. 1: Geol. Nat. Hist. Survey Canada, pp. 87–88, pl. 11, 1885.

[9] *Op cit.*, pl. 16, fig. 1.

divided by the deep and wide postcervical grooves (c) into a smaller anterior and a larger posterior portion. Front of carapace nearly straight except for a short, narrow, projecting median rostrum. The rostrum is 1/20 of the carapace length. The rostrum is simple; its top surface flat, the sides vertical. To both sides of the rostrum the front rises concavely upward to the supra-orbital spine-ridges (α). These ridges are high, laterally compressed, widely separated, and upward divergent; backward they continue as low, rounded ridges for a short distance and disappear about midway between the front and postcervical furrows; they carry a strong, forward and upward-pointing spine posterior of the laterally compressed, frontal portion; only the

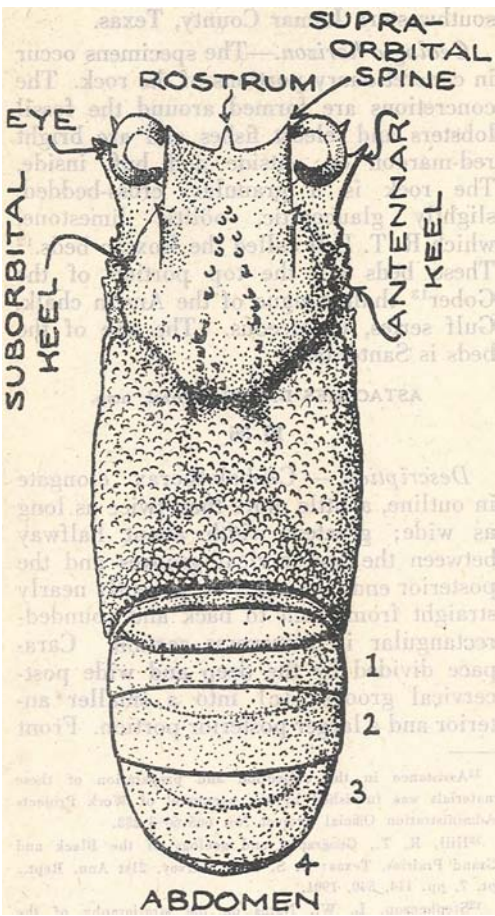

Fig. 5. *Astacodes maxwelli* Stenzel, x1; composite of several specimens.

bases of these spines are preserved. The gastric region is moderately convex and bears two lines of spinules or spines, which converge forward at an acute angle; their junction is their end and lies in the concave space between the supra-orbital spine-ridges; to the rear the two lines of spinules curve, become parallel, and disappear before reaching the postcervical grooves. The spinous sub-orbital keels (β) start at the front near the supra-orbital spine-ridges, curve with their convexity outward, and continue to the postcervical grooves; the size of these keels and their spines increases gradually to the back so that the anterior portion is a mere row of spinules and the posterior portion a spinous ridge; these ridges are in line with the rounded, obtuse, obsolete, lateral keels of the carapace, which are posterior to the postcervical grooves. A fourth pair of spinous ridges, the antennar keels (γ), is on the anterior portion of the carapace starting at its fronto-lateral corner; the anterior portion of this ridge is a high, laterally compressed two-pronged spine subparallel with and similar to the supra-orbital spine-ridge; to the rear this narrow ridge descends rapidly and forms a low keel, which extends to the groove and carries 3 to 4 spines in a row in front of the groove. Posterior to the groove this keel continues for about one centimeter and carries 2 or 3 spines.

The mid-portion of the postcervical grooves is transverse; the side portions are at right angles. From the mid-portion there extend backward the sigmoidally curved, shallow, and inconspicuous branchio-cardiac grooves (a), the posterior ends of which are connected by a very shallow transverse depression; a short groove radiates from the posterior end of each branchio-cardiac groove in the direction of the postero-lateral corner of the carapace. A narrow groove starts at each postero-lateral corner of the carapace and curves gently on the side walls of the carapace forward to the ends of the postcervical groove.

The posterior portion of the carapace is gently convex along the midline; toward the sides it is delimited by an obtuse, rounded, obsolete, longitudinal angulation, which is sharper near the groove than at the posterior margin; the side walls are gently convex and converge slightly downward. The posterior margin is highly arched in transverse direction and concave as seen from above. It is edged by a deep marginal groove (m), which is wider in the middle and narrows down to the sides; this deep and narrow marginal groove continues forward along the ventral margins of the carapace. The posterior portion of the carapace is covered with many forward-pointing, subsquamiform tubercles; the anterior portion carries some scattered, forward-pointing spinules.

Abdominal terga convex in transverse direction, flat in longitudinal direction; covered with numerous pits if not decorticated. Ambulatory legs long, slender, oval in cross section.

Dimensions.—Syntype 1, length of carapace, 62.5 mm., width of carapace, 37.0 mm.; syntype 2, length of carapace, 68.0 mm., width of carapace, 40.5 mm.; syntype 3, width of carapace, 33.9 mm.; syntype 4, length of carapace, 61.3 mm., width of carapace, 37.2 mm.

Remarks.—Hitherto the genus *Astacodes* was represented only by its type species, *Ast. falcifer* Bell, which was first mentioned as *Palinurus uncinatus* Phillips[10] in 1835. After 100 years the second and third species of the genus have been discovered. The 100 years attest to the rarity of the material. The second species, *Ast. maxwelli* Stenzel, extends the known stratigraphic range of the genus from the Hauterivian to the Santonian.

Both species are remarkably alike in many respects. The differences seem to be minor. *Astacodes falcifer* Bell has 2 spines in a row behind the supra-orbital spine-ridge; *Ast. maxwelli* Stenzel only one. *Astacodes falcifer* Bell has a double row of tubercles along the midline of the carapace between the postcervical grooves and the posterior margin; in *Ast. maxwelli* Stenzel there is no special arrangement of tubercles along that line. The abdominal terga of *Ast. maxwelli* Stenzel lack a median carina. The Texan species is also more than twice the size of the English.

The species is named in honor of Mr. J. B. Maxwell of Roxton and of Mr. Carlisle Maxwell of San Antonio. It is through the efforts of these gentlemen that much of the material was secured for scientific study.[11]

Type data.—Thirteen syntypes, Bureau of Economic Geology, The University of Texas, and the Texas Memorial Museum, Austin, Texas. One of the specimens is a loan from Mr. Carlisle Maxwell of San Antonio, Texas.

Type locality.—Quarries on east side of State highway No. 188 (Roxton-High road) extending from the vicinity of Arkansas Church, 2.1 miles, to 1.1 miles north of the railway depot in Roxton, southwestern Lamar County, Texas.

Geologic horizon.—The specimens occur in concretionary portions of the rock. The concretions are formed around the fossil lobsters and teleost fishes and are bright red-maroon on outside and buff inside. The rock is a granular, cross-bedded, slightly glauconitic, oölitic limestone, which R. T. Hill called the Roxton beds.[12] These beds are the top portion of the Gober[13] chalk tongue of the Austin chalk, Gulf series, Cretaceous. The age of the beds is Santonian.

ASTACODES DAVISI Stenzel, n.sp.

Pl. 36

Description. — Cephalothorax elongate in outline, a little more than twice as long as wide; greatest width about halfway between the postcervical grooves and the posterior end. Carapace apparently nearly straight from front to back and rounded-rectangular in transverse section. Carapace divided by the deep and wide postcervical grooves (c) into a smaller anterior and a larger posterior portion. Front

[10]Phillips, J., Illustrations of the geology of Yorkshire; or, A description of the strata and organic remains of the Yorkshire Coast, 2d ed., pt. 1, p. 170, 1835.

[11]Assistance in the collection and preparation of these materials was furnished by the personnel of Work Projects Administration Official Project No. 665–66–3–233.

[12]Hill, R. T., Geography and geology of the Black and Grand Prairies, Texas: U. S. Geol. Survey, 21st Ann. Rept., pt. 7, pp. 114, 340, 1901.

[13]Stephenson, L. W., Notes on the stratigraphy of the Upper Cretaceous formation of Texas and Arkansas: Bull. Amer. Assoc. Petr. Geol., vol. 11, p. 8, 1927.

of carapace nearly straight except for a short, narrow, projecting median rostrum. The rostrum is 1/20 of the carapace length. It is simple; the top surface is arched. To both sides of the rostrum the front rises concavely upward to the supra-orbital spine-ridges (α). These ridges are high, laterally compressed, widely separated, and upward divergent; backward they continue for a short distance carrying two spines, of which the posterior one is the smaller; the ridges disappear posterior to the latter spine about halfway between the front and the postcervical furrows. The gastric region is moderately convex and bears two lines of small spines, which converge forward at an acute angle; at their junction near the base of the rostrum there is a small, compressed spine and a spinule anterior to that; to the rear the two lines become parallel; each line has 4 laterally compressed, small spines and one spinule in the following sequence from front to back: spinule-interval-spine-interval-spine-long interval-spine-short interval-spine-postcervical groove. These two lines are continued posterior of the postcervical grooves, where the two lines converge again. Each line carries about 4 laterally compressed, subsquamiform tubercles. which are a little larger than those covering the remainder of the carapace. The sub-orbital lines (β) of spines start at the front near the supra-orbital spine-ridges, curve with their convexity outward to the postcervical grooves; the size of the spines increases gradually to the back; there are 4 small, forward-pointing spines in each line. These lines are in line with the rounded, obtuse, obsolete lateral keels of the carapace, which are posterior to the postcervical grooves. A fourth pair of spinous ridges, the antennar keels (γ), is on the anterior portion of the carapace starting at its fronto-lateral corner; each of these ridges carries 4 laterally compressed spines, which decrease in size to the posterior.

The mid-portion of the postcervical grooves is short and transverse; the side portions are curved sigmoidally.

The posterior portion of the carapace is gently convex along the midline; toward the sides it is delimited by an obtuse, rounded, obsolete, longitudinal angulation; the side walls are gently convex. The posterior margin is highly arched in transverse direction and concave as seen from above. It is edged by a deep marginal groove (m), which is wider in the middle and narrows down to the sides. The posterior portion of the carapace is completely covered with many forward-pointing, subsquamiform tubercles. The anterior portion carries many scattered spinules.

Abdominal terga convex in transverse direction, flat in longitudinal direction; each tergum has several either shallow or sharp transverse grooves; some parts of each tergum are punctate while others are finely tuberculate. A narrow, small median keel is present in terga 2 to 4. Each margin of a pleurum is lobulated and has a spine and several succeeding spinules. The telson has many fine, backward-pointing spinules. The uropods are smooth.

Dimensions.—Holotype, length of carapace exclusive of rostrum, 51 mm., length of rostrum, 2.5 mm., width of carapace, 23 mm.

Remarks.—This species is readily distinguished from *Astacodes falcifer* Bell by the different arrangement of spinules along the midline of the carapace. In other respects *Ast. davisi* Stenzel has closer relationship to *Ast. falcifer* Bell than *Ast. maxwelli* Stenzel.

The species is named in honor of Mr. Eugene Elmer Davis of Dallas, Texas, who collected the fine holotype specimen and kindly put it at the writer's disposal for description. The paratype was collected by the late Mr. Forrest Kirkland of Dallas.

Type data.—Holotype and paratype, the latter a portion of an abdomen, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Same as *Linuparus grimmeri* Stenzel.

Geologic horizon.—Same as *Linuparus grimmeri* Stenzel.

Tribe ASTACURA Borradaile

Superfamily NEPHROPSIDEA Alcock

Family ERYMIDAE Van Straelen

Genus ENOPLOCLYTIA F. McCoy, 1849

On the classification of some British fossil Crustacea, with notices of new forms in the University collection at Cambridge: Annals and Mag. Nat. Hist., ser. 2, vol. 4, p. 330.

Genotype.—*Enoploclytia leachii* (Mantell) from the Chalk (Turonian to Campanian) of England.

According to Woods[14] the genera *Palaeastacus* T. Bell 1850 (Bell, Th., Notes on the Crustacea of the Chalk formation, *in* Dixon, F., Geology and fossils of the Tertiary and Cretaceous formations of Sussex, p. 344, London, 1850; genotype *Palaeastacus dixoni* Bell *in* Dixon, p. 344, pl. 38, figs. 1–4, from the Lower Chalk (Cenomanian) of England) and *Phlyctisoma* T. Bell 1863 (Bell, Th., A monograph of the fossil malacostracous Crustacea of Great Britain, pt. 2: Palaeontograph. Soc., vol. 14, p. 34, 1863; genotype *Phlyctisoma tuberculatum* Bell, *ibid.*, p. 35, pl. 11, figs. 1–8, from the Cambridge greensand (Upper Albian) of England) do not differ in any essential respect from the genus *Enoploclytia*. The two former genera are, therefore, later synonyms of the latter genus, which takes precedence over them by reason of priority. It is obvious that Wood's conclusion must be respected, because he had available for his study materials comprising the genotype species of all three genera.

The North American species of *Enoploclytia* are in confusion. This confusion is due to wrong generic assignments and to the lack or neglect of stratigraphic information. The writer has attempted to eliminate some of the existing confusion and gives below a summary of all species of the genus reported from the United States of America:

Tertiary species of Enoploclytia:

(?) Enoploclytia selmaensis (Rathbun)
Paleocene, Alabama
Enoploclytia tumimanus (Rathbun)
Paleocene, Alabama

Cretaceous species of Enoploclytia:

Enoploclytia kimzeyi (Rathbun)
Campanian, Texas
Enoploclytia sp. Stenzel
Santonian, Texas
Enoploclytia triglypta Stenzel
Coniacian, Texas
Enoploclytia walkeri (Whitfield)
Upper Albian, Texas
Enoploclytia wintoni Stenzel
Upper Albian, Texas

Species which have been referred to Enoploclytia but are of doubtful generic position or validity:

"Enoploclytia" sculpta Rathbun
Maestrichtian, Tennessee
"Enoploclytia" wenoensis Rathbun
Upper Albian, Texas
Enoploclytia (?) sp. Rathbun
Campanian or Maestrichtian, Mississippi

ENOPLOCLYTIA KIMZEYI (Rathbun)

Palaeastacus kimzeyi Rathbun, M. J., Fossil Crustacea of the Atlantic and Gulf Coastal Plain: Geol. Soc. Amer., Spec. Paper 2, pp. 23–24; pl. 2, figs. 15–21, 1935.

Remarks.—This *Enoploclytia* has the postcervical groove (c) extending far down and joining the anterior branch of the hepatic groove (b_1) just behind the eminence omega.

Type data.—Holotype, No. 73797, and paratypes, No. 73841, U. S. National Museum, Washington, D.C.

Type locality.—About 3 miles southwest of Farmersville, Collin County, Texas; holotype, A. H. Kimzey collector, 1926, and paratypes, L. W. Stephenson collector, 1927, Coll. No. 13784.

Geologic horizon.—Base of Wolfe City sand of Taylor group, Gulf series, Upper Cretaceous (Campanian).

ENOPLOCLYTIA sp. Stenzel, n.sp.

Pl. 37, figs. 4–6

Description.—This species is mentioned only because it occurs with *Astacodes maxwelli* Stenzel. The material available consists of the dorsal part of a partly pressure-deformed carapace, a cheliped, and parts of the ambulatory legs.

Carapace traversed by deep grooves. Cervical groove (e-e_1) is the deepest and sharpest, begins at midline of carapace. and descends nearly in a straight line steeply forward. Groove (d) is broad and

[14] Woods, Henry, A monograph of the fossil macrurous Crustacea of England, pt. 6: Palaeontograph. Soc., vol. 82, pp. 81–86, 1930.

shallow and extends for only a short distance forward from the cervical groove. Postcervical groove (c) composed of two parts. It begins broad, shallow, and winding near the midline, then continues more sharply incised obliquely forward and downward, and ends not far from groove (e-e_1). Postcervical groove (c) is joined from below by the deeply incised hepatic groove (b_1). Branchio-cardiac groove (a) begins at the midline of the carapace immediately posterior to the postcervical groove (c) and descends obliquely and shallows out at about the middle of the side. Marginal groove (m) deep and sigmoidally curved at the posterior carapace margin.

Spiniform tubercles are present anterior to the grooves (a). Posterior to these grooves the carapace carries only slightly raised hair-pits.

Manus elongate, tumid-oval in cross section, with many hair-pits and few blunt tubercles or spines. Carpus with a few prominent spines and many hair-pits. Merus of cheliped with many hair-pits and a few spines; these are particularly concentrated at the distal margin; the two most prominent spines are at the two hinge points.

Dimensions.—Length of carapace without rostrum, 9 cm.; height of manus, 1.8 cm.

Type data.—Monotype, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Same as *Astacodes maxwelli* Stenzel.

Geologic horizon.—Same as *Astacodes maxwelli* Stenzel.

ENOPLOCLYTIA TRIGLYPTA Stenzel, n.sp.

Pl. 37, figs. 1–3; text figs. 6, 7

Description. — Carapace traversed by deep and sharp grooves. Cervical groove (e-e_1) slightly convex to the anterior, winding near the midline of the carapace; side walls of the cervical groove unequal in slope, anterior side wall gently sloping, posterior side wall very steep, in some places even vertical. Postcervical groove (c) sigmoid in outline, deep and steep-sided near the midline but shallowing and disappearing laterally. Branchio-cardiac groove (a) nearly parallel to the postcervical groove and undulating in outline, deep and steep-sided throughout its course, but widening toward the hepatic groove. Hepatic groove (b_1) very broad and shallow, concave toward the midline, but with an abrupt turn around the swelling omega. Antennar groove (b) concave toward the midline, broadening and shallowing in anterior direction. Inferior groove (i) concave toward the anterior, broad and deep, its anterior side wall less steep than its posterior one.

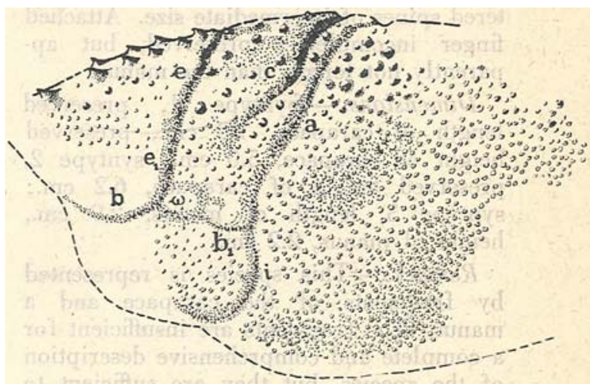

Fig. 6. *Enoploclytia triglypta* Stenzel, x1; left side of incomplete carapace.

The front is to the left, the dorsum at the top of the figure. Abbreviations of grooves: a, branchio-cardiac; b, antennar; b_1, hepatic; c, postcervical; e-e_1, cervical; i, inferior; ω, eminence omega.

Swelling omega (ω) distinct and elongate in shape. Carapace covered with regularly spaced, spiniform tubercles, each of which has a hair-pit on the anterior slope just below the tip. These spiniform tubercles are coarser toward the midline of the carapace than toward the lateral margins. The area above the groove (b_1) is nearly devoid of such tubercles. Three oblique rows of spines are in the space between the cervical and postcervical grooves on each side of the carapace. Three longitudinal rows of spines are anterior to the cervical groove on each side of the carapace. The pair of spine rows which is along the midline of the carapace seems to be continuous nearly to the posterior margin of the carapace.

Fig. 7. *Enoploclytia triglypta* Stenzel, x1: incomplete manus.

Manus short and stout, but longer than high; upper margin with 4 or 5 curved strong spines; lower margin with many smaller spines; outer surface with scattered spines of intermediate size. Attached finger incompletely preserved, but apparently not longer than the manus.

Dimensions. — Syntype 1, preserved length of carapace, 7.8 cm., preserved height of carapace, 5.0 cm.; syntype 2, preserved height of carapace, 6.2 cm.; syntype 3, length of manus, 2.9 cm., height of manus, 2.2 cm.

Remarks.—This species is represented by fragments of the carapace and a manus. The fragments are insufficient for a complete and comprehensive description of the species, but they are sufficient to characterize the species and to distinguish it from other species of the genus.

Among the English species of the genus, *Enoploclytia dixoni* (Bell)[15] seems strikingly similar to *En. triglypta* Stenzel in the outline of the grooves and rows of spines on the carapace. However, that English species is much smaller in size than the Texan species. One might be tempted to place the Texan material with the English species were it not for the large geographic separation of the two species.

For a discussion of the differences among *En. triglypta* Stenzel and some North American Cretaceous species of the genus, see the remarks under *En. walkeri* (Whitfield).

The specific name *triglypta* is derived from the Greek τρι, "three," and γλυπτος. "carved" or "grooved," and refers to the three prominent grooves of the carapace of this species.

Type data.—Three syntypes consisting of a fragment of the right side of the carapace (syntype 1), fragments of both sides of the carapace (syntype 2), and a chela (syntype 3), Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Rock pit on south side of an east-west road, by road 4.66 miles southeast of Savoy, Fannin County, Texas. Material was collected under supervision of Mr. Lloyd J. Ryman.[16]

Geologic horizon.—Chalk of Ector tongue of the Austin chalk, Gulf series, Cretaceous (Coniacian).

ENOPLOCLYTIA WALKERI (Whitfield)

Pls. 38, 39; text figs. 8, 9

Paramithrax? walkeri Whitfield, R. P., *in* White, C. A., Contributions to invertebrate paleontology, No. 2, Cretaceous fossils of the western states and territories: U.S. Geol. and Geog. Survey Terr. 12th Ann. Rept., pt. 1, sect. 1, pp. 37–38; pl. 16, fig. 1a-c; pl. 17, fig. 1a, 1880.

Merrill, G. P., Catalogue of the type and figured specimens of fossils, minerals, rocks, and ores: U.S. Nat. Mus. Bull. 53, pt. 1, p. 484, 1905.

Adkins, W. S., Handbook of Texas Cretaceous fossils: Univ. Texas Bull. 2838, p. 83, 1928.

Palaeastacus walkeri, Rathbun, M. J., Fossil Crustacea of the Atlantic and Gulf Coastal Plain: Geol. Soc. Amer., Spec. Paper 2, pp. 21–23; text fig. 1; pl. 3, figs. 7–9; pl. 4, figs. 1, 2; pl. 5, fig. 4. Not pl. 5, figs. 1–3, 1935.

Original description.—This species is represented only by the claw and part of the penultimate joint of the right anterior limb. The specimen is of a short, rather compact and robust form, and somewhat triangular in transverse section. The length of the hand, from its articulation with the preceding joint to the base of the fixed mandible, bears the proportion to the height and thickness that seven does to five and four; the latter measurement being exclusive of the nodes. The mandibles, both fixed and movable, are distinctly round, without any flattening or carination; are gently and nearly equally curved throughout their length, and the articulating processes strong and robust. The hand is somewhat flattened on the inside and angular on the outer surface: the angulation being rather below the middle of the height, giving it the triangular form. The next preceding joint is only preserved in part; it is strong, obliquely ovate

[15]Woods, Henry, A monograph of the fossil macrurous Crustacea of England, pt. 6: Palaeontograph. Soc., vol. 82, pp. 83–85; pl. 23, figs. 9–12; pl. 24, figs. 1–3, 1930.

[16]Assistance in the collection and preparation of these materials was furnished by the personnel of Work Projects Administration Official Project No. 665-66-3-233.

in form, and provided with a large flattened basal projection near the inferior articulation.

Surface of the specimen, with the exception of the inner face of the mandible, marked by numerous strong spine-like nodes or tubercles, which have probably been spines on the surface of the shell (the specimen being an internal cast). These nodes are arranged in longitudinal lines on the outside of the claw, and partly so on the inside; but on the latter there is also a line of large nodes extending obliquely downward from the upper edge, parallel to the margin of the socket of the movable mandible, and at a short distance from it, and continuing upon the mandible. The preceding joint is also marked by lines of strong nodes; a double transverse line on the inside parallel to the anterior margin, but divided from it by a broad, rounded channel, and a single line of stronger nodes on the outside. The flattened area forming the basal projection of the joint is also bordered by nodes.

The specimen, being an internal cast only, does not furnish the exact features of the shell itself, and as there is only a part of the limb known it is difficult to determine the generic characters in a satisfactory manner. There would appear to be but little reason to doubt, from its spiny character and the round claws, its relations to the group commonly called spider-crabs. Still there are some features which seem to differ from those of the generality of the species of that group, and it is therefore with some hesitation that I have referred it to the family Maiadae, and still more doubtfully to the genus *Paramithrax;* but I am not able to find any genus of strictly fossil crustaceans to which it seems so nearly allied. The specimen is of interest on account of its large size, and

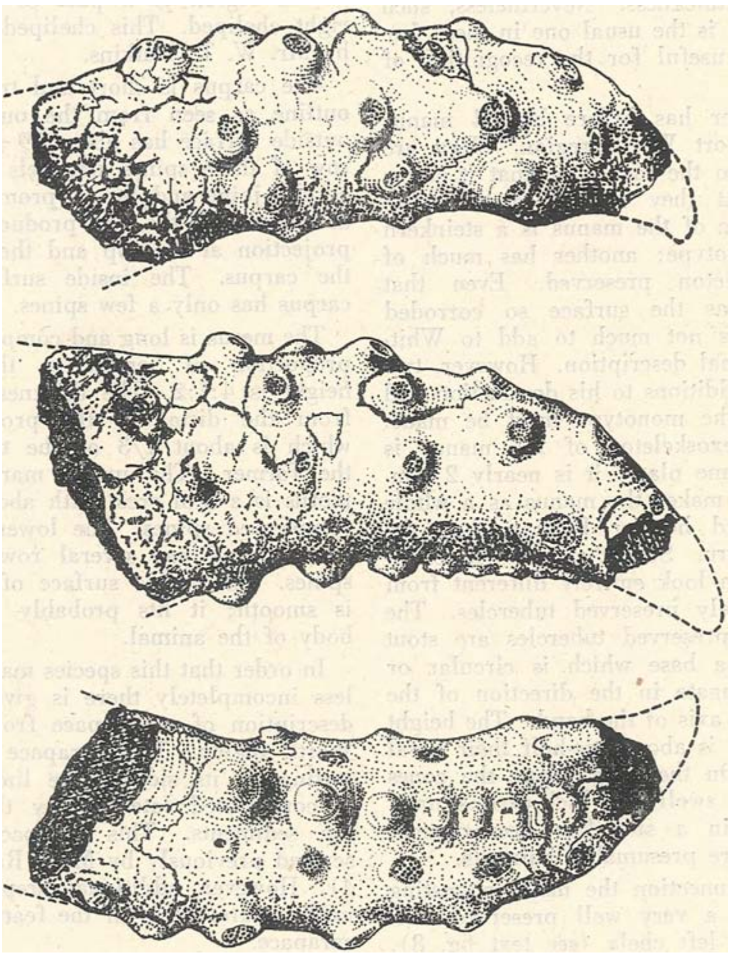

Fig. 8. *Enoploclytia walkeri* (Whitfield), x2; three views of the left movable finger. The view at the bottom shows the occludent surface. The view at the top shows the inner surface. The view at the top shows the top surface of the finger.

also as being the first of this group of crustaceans yet recognized from the Cretaceous formations of this country.

Locality and formation.—The specimen here described and figured was obtained from the Cretaceous rocks near San Antonio, Texas, by Mrs. N. S. Walker, of that place, and in honor of whom the specific name is given.

Revised description.—Whitfield's original description was based upon a manus and part of the attached carpus. This specimen was an internal mold with all the original exoskeleton missing. Such steinkerne are not very reliable for description in this group of animals, because usually the exoskeleton of their chelae is not only very thick but also of uneven thickness. Nevertheless, such preservation is the usual one in these fossils and is useful for the recognition of the species.

The writer has before him 4 manus from the Fort Worth region. They are so similar to the monotype that it seems obvious that they belong to the same species. One of the manus is a steinkern as the monotype; another has much of the exoskeleton preserved. Even that specimen has the surface so corroded that there is not much to add to Whitfield's original description. However, two important additions to his description and figures of the monotype must be made. First, the exoskeleton of the manus is thick: in some places it is nearly 2 mm. thick. This makes the manus as a whole plumper and heavier looking than the type steinkern. Second, the tubercles of the steinkern look entirely different from the completely preserved tubercles. The completely preserved tubercles are stout cones with a base which is circular or slightly elongate in the direction of the longitudinal axis of the hand. The height of the cones is about one-half their basal diameter. On the distal slope the cones have a slight swelling, which carries many small pits in a sieve-like arrangement. These pits are presumably hair-pits.

In this connection the most interesting specimen is a very well preserved dactylus of the left chela (see text fig. 8). This finger has many tubercles with sieve-like hair-pits. These tubercles are large on the upper and outer surface, but small on the inner surface of the dactylus and near the occludent teeth. All tubercles point distally, that is, forward and outward. They are more nearly ring-wall-shaped than conical and have again the sieve-like arrangement of the hair-pits. The occludent teeth are conical to hemispherical, worn by use at the top. The proximal ones are separate, but the distal ones are crowded so that there is only a tight cleft between adjoining tubercles. The specimen has 9 occludent teeth; but, of course, it is not a complete dactylus. The tubercles with the hair-pits and the shape of the dactylus are somewhat similar to a stalk of a compound coral.

One of the four manus from the Fort Worth region is a part of a complete right cheliped. This cheliped was found by Mr. W. T. Watkins.

The carpus is short and triangular in outline as seen from the outside. The outside surface has about 19 spines. One row of these spines parallels the manus-carpus joint and has a prominent spine at each end of the row, producing a sharp projection at the top and the bottom of the carpus. The inside surface of the carpus has only a few spines.

The merus is long and compressed. The proportion of length to thickness to height is 4:1:2. The thickness decreases from the distal to the proximal end, which is about 1/3 of the thickness of the former. The upper margin of the merus is a thin crest with about 8 large, compressed spines. The lower margin is broader and has several rows of small spines. The inside surface of the merus is smooth; it fits probably against the body of the animal.

In order that this species may be known less incompletely there is given below a description of a carapace from the Fort Worth region. This carapace was found resting on its side in the limestone and is compressed laterally by the load of the sediments. This carapace was described previously by M. J. Rathbun (Pl. 4). However, additional preparation has made clearer some of the features of this carapace.

Carapace very large, entire except for the rostrum. Carapace traversed by deep and sharp grooves. Cervical groove (e-e_1) slightly convex to the anterior,

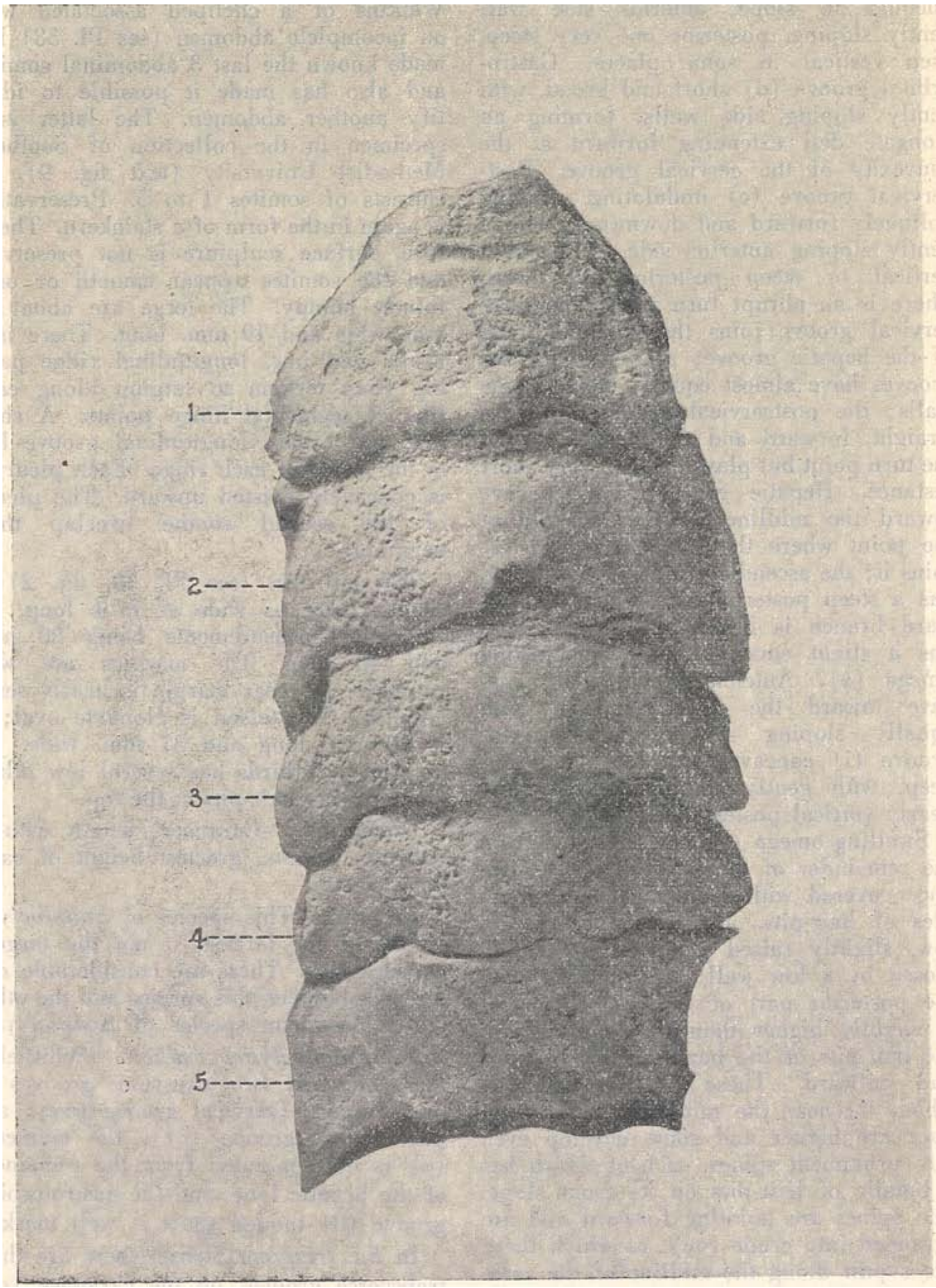

Fig. 9. *Enoploclytia walkeri* (Whitfield), x1; dorsal view of a decorticated abdomen. Collection of Southern Methodist University.

winding near the midline of the carapace; side walls of the cervical groove unequal in slope, anterior side wall gently sloping, posterior one very steep, even vertical in some places. Gastro-orbital groove (d) short and broad, with gently sloping side walls, forming an elongate dell extending forward at the convexity of the cervical groove. Postcervical groove (c) undulating, running obliquely forward and downward, with a gently sloping anterior side wall and a vertical or steep posterior side wall. There is an abrupt turn where the postcervical groove joins the ascending end of the hepatic groove; at that place the grooves have almost equally sloping side walls; the postcervical groove continues straight, forward and downward, beyond the turn point but plays out in a very short distance. Hepatic groove (b_1) concave toward the midline, turning sharply at the point where the inferior groove (i) joins it; the ascending branch is deep and has a steep posterior side wall; the forward branch is broad and shallow and has a slight curve around the swelling omega (ω). Antennar groove (b) concave toward the midline, deep, with equally sloping side walls. Inferior groove (i) concave toward the anterior, deep, with gently sloping anterior and nearly vertical posterior side wall.

Swelling omega (ω) not separated from the remainder of the hepatic lobe. Carapace covered with regularly spaced bundles of hair-pits. Each bundle is on a low, slightly raised pedestal and is enclosed by a low wall; in some instances the posterior part of the enclosing wall is slightly higher than the anterior and the hair-pits of the bundle point forward and outward. Those of the pedestals which lie near the midline of the carapace are higher and some develop even into prominent spines, each of which has a bundle of hair-pits on its front slope. The spines are pointing forward and are arranged into crude rows, of which there are a pair along the midline of the carapace and several diagonal ones farther away from the midline. Posterior margin of carapace with a smooth, deep marginal groove (m) and a smooth, angulated edge, sigmoid in outline to both sides of the midline.

Hitherto the abdomen of this species was unknown. However, the find by Mr. Watkins of a cheliped associated with an incomplete abdomen (see Pl. 38) has made known the last 3 abdominal somites and also has made it possible to identify another abdomen. The latter is a specimen in the collection of Southern Methodist University (text fig. 9). It consists of somites 1 to 5. Preservation is again in the form of a steinkern. Therefore, surface sculpture is not preserved, and the somites appear smooth or only faintly bumpy. The terga are about 44 mm. wide and 19 mm. long. There is a broad and low, longitudinal ridge passing from tergum to tergum along each line of segmental hinge points. A shallow and broad, longitudinal groove lies to the inside of each ridge. Each pleurum is concavely twisted upward. The pleura of the second somite overlap their neighbors.

The tail fan (see Pl. 38, fig. 2) is almost twice as wide as it is long, the respective measurements being 80 mm. and 46 mm. The margins are well rounded; the rear margin is nearly semicircular. The telson is elongate oval; it is 46 mm. long and 37 mm. wide. Its anterior two-thirds has several low tubercles carrying hair-pits at the top.

Dimensions.—Carapace, length without rostrum, 17 cm., greatest height of carapace, 9 cm.

Remarks.—This species of *Enoploclytia* is one of the largest, if not the largest, of the genus. There are considerable differences between this species and the other North American species of *Enoploclytia.*

In *Enoploclytia walkeri* (Whitfield) there are only two transverse grooves on the carapace (cervical groove (e-e_1) and postcervical groove (c)), the eminence (ω) is not separated from the remainder of the hepatic lobe, and the gastro-orbital groove (d) though short is well marked.

In *En. triglypta* Stenzel there are three transverse grooves on the carapace (cervical groove (e-e_1), postcervical groove (c), and branchio-cardiac groove (a)), the eminence (ω) is separated from the hepatic lobe, and there is only the barest indication of a gastro-orbital groove (d) as a very slight shallowing of the anterior side wall of the cervical groove.

In *En. kimzeyi* (Rathbun) there are three transverse grooves on the carapace as in *En. triglypta* Stenzel, but the post-cervical groove (c) extends all the way down to the hepatic groove (b_1).

It may be noted, incidentally, that Whitfield named the species for Mrs. N. S. Walker. Correct naming should have required *walkerae* for the specific name.

Type data.—The whereabouts of Whitfield's type is unknown. A plaster cast of his type, Cat. No. 8360, is at the U.S. National Museum, Washington, D.C.

The carapace, dactylus (text fig. 8), right cheliped, and telson are at the Bureau of Economic Geology, The University of Texas, Austin, Texas.

The abdomen (text fig. 9) is in the collection of Southern Methodist University at Dallas, Texas.

Type locality.—"Near San Antonio," according to Whitfield. No additional material from the vicinity of that town has come to the writer's attention. The exact location of the type locality remains unknown.

Most of the additional material came from the Forth Worth region. The carapace described above (Pl. 39) came from a small waterfall at crossing of Houston & Texas Central and International & Great Northern Railroad tracks in. Sycamore Creek valley, 2½ miles south-southeast of Fort Worth, Tarrant County, Texas. Bureau of Economic Geology Coll. No. 201, W. S. Adkins collector, 1919.

The dactylus described above (text fig. 8) was collected by Mrs. J. H. Renfro in the northeast corner of Alta Vista dairy farm land, on the east side of the road, about 6 miles north of Fort Worth, Tarrant County, Texas.

The right cheliped and the telson described and figured here (Pl. 38) were collected by Mr. W. T. Watkins on Toland's farm, 4 miles west of Argyle, Denton County, Texas.

The large abdomen (text fig. 9) in the collection of Southern Methodist University at Dallas, Texas, bears the label: "No. L23, Fort Worth limestone, towards Trinity from Tandy's Lake, Tarrant County, Texas." The specimen was loaned to the writer by Dean Ellis W. Shuler. The writer wishes to express his thanks for the loan.

Geologic horizon.—The geologic horizon of Whitfield's type is unknown. Cretaceous rocks exposed near San Antonio range from the Travis Peak formation, Comanche series, Lower Cretaceous (Aptian), to the Navarro formation, Gulf series, Upper Cretaceous (Maestrichtian). However, all additional material of this species has come only from the Georgetown limestone, Comanche series, Lower Cretaceous (upper Albian), or its stratigraphic equivalents. Therefore, it is probable that Whitfield's type came from the Georgetown limestone.

The material from the vicinity of Fort Worth except the large abdomen (text fig. 9) came from the limestone ledges in the basal part of the Weno formation, Washita group, Lower Cretaceous (upper Albian).

The large abdomen from the Southern Methodist University collection came from the Fort Worth limestone.

A specimen consisting of the merus, carpus, and manus of the left cheliped and figured on Plate 5, figure 4, by Rathbun came from the Fort Worth limestone equivalent of the Georgetown limestone (upper Albian) from the cliffs along the Georgetown-Belton road, 1 mile north of Georgetown, Williamson County, Texas.

The manus figured by Rathbun on Plate 5, figures 1–3, came from the Buda limestone, but the specimen does not belong to this species.

ENOPLOCLYTIA WINTONI Stenzel, n.sp.

Pl. 43, figs. 1, 2

Description.—Left and right manus equal in size and shape. Manus elongate and devoid of any ridges or keels; the proportion of length to width to thickness is about 7:4:3. Inner margin broadly rounded in cross section throughout its entire length, outer margin broadly rounded at the proximal end, but narrowing down toward the fixed finger. Upper surface gently convex in longitudinal direction, strongly and evenly convex in transverse direction so that the greatest inflation is along the middle.

Lower surface strongly convex in longitudinal direction at the proximal end but only gently convex toward the distal end, strongly and unevenly convex in transverse direction so that the greatest inflation occurs at the outer third of the surface and near the proximal end. Inner surface as a whole slightly more tumid than the outer. Both surfaces are covered with many spines and spinules, which are larger toward the inner than toward the outer margin. However, the spinules of the upper surface are larger than those of the lower surface, whereas the spines are of equal size on both surfaces. Only the bases of the spines are preserved. The joint which carries the movable finger is encircled by a raised rim and an adjoining deep and smooth groove. The rim carries some spines.

The fingers are straight, long, and slender; circular in cross section. The fixed finger has spines like the palm but they are restricted to the proximal end. The movable finger has a large spine near the proximal end. The occludent sides of the finger carry many, equal, vertical, spine-like teeth of 3 to 4 mm. length.

Dimensions.—Right manus, length, 39.2 mm., width, 22.3 mm., thickness, 16.3 mm.; preserved length of fixed finger. 47.2 mm.

Remarks.—The two manus are embedded in matrix in parallel position at one-half centimeter distance. Therefore, it is certain that they belong to the same individual. The material was found by Mr. Norman E. Nelson of Fort Worth.

This species is similar to *Enoploclytia tumimanus* Rathbun from the Paleocene of Alabama. However, *En. tumimanus* Rathbun has a more inflated manus with fewer spines. As far as they are known, the other Cretaceous Enoploclytias of North America have a manus of entirely different shape, except for the incompletely known *Enoploclytia* sp. Stenzel from the much younger Roxton beds.

Type data.—Monotype consisting of the two manus, Coll. No. N302, Geology Department, Texas Christian University, Fort Worth, Texas.

Type locality.—Near Crowley, Tarrant County, Texas.

Geologic horizon. — Weno limestone, Washita group, Comanche series, Lower Cretaceous (upper Albian).

"ENOPLOCLYTIA" SCULPTA Rathbun

Enoploclytia sculpta Rathbun, M.J., *in* Wade, Bruce, The fauna of the Ripley formation on Coon Creek, Tennessee: U.S.Geol. Survey Prof. Paper 137, pp. 187–188; pl. 66, figs. 1–5, 1926.

Rathbun, M. J., Fossil Crustacea of the Atlantic and Gulf Coastal Plain: Geol. Soc. Amer., Spec. Paper 2, p. 18, 1935.

Remarks.—This species has punctate abdominal terga free of major spines. The remainder of the animal is not well known. The lack of strong spines on the abdomen makes it highly improbable that this is a species of the genus *Enoploclytia*, because this genus is characterized by strong spines on the abdomen and carapace. The species should be listed as *Macruran genus, indet.* at present.

Type data.—Monotype, No. 73119, U. S. National Museum, Washington, D.C.

Type locality.—Dave Weeks' place on Coon Creek, in northeast part of McNairy County, Tennessee, 3½ miles south of Enville and 7½ miles north of Adamsville; Bruce Wade collector.

Geologic horizon.—Coon Creek tongue of Ripley formation, Gulf series, Upper Cretaceous (Maestrichtian).

"ENOPLOCLYTIA" WENOENSIS Rathbun

Enoploclytia wenoensis Rathbun, M. J., Fossil Crustacea of the Atlantic and Gulf Coastal Plain: Geol. Soc. Amer., Spec. Paper 2, p. 20; pl. 6, figs. 7, 8, 1935.

Remarks. — This species has smooth, punctate abdominal terga free of spines. The posterior part of the carapace, the only part that is known, is covered with small, subsquamiform tubercles and lacks any keels or spines. This is certainly not an *Enoploclytia;* presumably it is an *Astacodes.* However, new and additional material is needed to identify the genus.

Type data.—Monotype, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Brickyard pits, 1¾ miles southeast of Gainesville, Cooke County, Texas. Bureau of Economic Geology Coll. No. 191.

Geologic horizon. — Weno formation, Washita group, Comanche series, Lower Cretaceous (upper Albian).

ENOPLOCLYTIA (?) sp. Rathbun

Enoploclytia (?) Rathbun, M.J., Fossil Crustacea of the Atlantic and Gulf Coastal Plain: Geol. Soc. Amer., Spec. Paper 2, p. 20; pl. 2, fig. 6, 1935.

Remarks.—An unidentifiable fragment.

Type data.—Monotype, No. 73842, U. S. National Museum, Washington, D.C.

Type locality.—Cut of Southern Railroad, 3 miles southeast of Corinth, Alcorn County, Mississippi; L. W. Stephenson collector (6469).

Geologic horizon.—Base of Selma chalk just above the Coffee sand, Gulf series, Upper Cretaceous (Campanian).[17]

(?) ENOPLOCLYTIA SELMAENSIS (Rathbun)

Palaestacus selmaensis Rathbun, M. J., Fossil Crustacea of the Atlantic and Gulf Coastal Plain: Geol. Soc. Amer., Spec. Paper 2, p. 24; pl. 2, fig. 14, 1935.

Remarks.—This species is a part of the collections made by L. C. Johnson in 1883 in Alabama. These collections contained also *Enoploclytia tumimanus* Rathbun and other Paleocene Midway crustaceans. They were wrongly regarded by Rathbun to be Upper Cretaceous Selma chalk fossils.

It is to be regretted that this material was named *selmaensis,* because it does not originate from the Selma chalk.

The holotype, a left wrist fragment, is the only figured specimen. The descriptions and figure are insufficient to characterize the species. The writer is not convinced that it is a valid species or that it belongs to this genus.

Type data.—Holotype, No. 73848, and paratypes, Nos. 73849 and 73840, U. S. National Museum, Washington, D.C.

Type locality.—Holotype: Prairie Creek and Allenton, Wilcox County, Alabama, collection No. 281.

Paratypes: Prairie Creek and Pine Barren section, Wilcox County, Alabama, collection No. 284, and Prairie Creek, Wilcox County, Alabama, collection No. 264.

Geologic horizon.—Sucarnoochee shale, Midway group, Paleocene.

ENOPLOCLYTIA TUMIMANUS Rathbun

Enoploclytia tumimanus Rathbun, M. J., Fossil Crustacea of the Atlantic and Gulf Coastal Plain: Geol. Soc. Amer., Spec. Paper 2, pp. 4, 8, 18–20, pl. 1, figs. 1–12; pl. 2, figs. 1–5, 1935.

Remarks. — Rathbun described this species as coming from the Selma chalk, Gulf series, Upper Cretaceous. However, the type localities in Alabama cited by Rathbun are not in the Selma chalk but in the Paleocene Midway group. The species is common in the Midway group of the vicinity of the type locality, where the writer has collected many specimens.

Type data.—Holotype, No. 73799, and paratypes, U. S. National Museum, Washington, D.C.

Type locality.—Vicinity of Prairie Creek, Allenton, and Pine Barren section at stations 264, 281, and 284, Wilcox County, Alabama; L. C. Johnson collector. An original label for 284 gives "scattered shells and fragments picked up on prairies," sections 32 and 34, Township 12, Range 10, April 25, 1883. Rathbun's holotype specimen belongs in this latter lot.

Geologic horizon.—Sucarnoochee shale, Midway group, Paleocene.

The following crustaceans occur with this *Enoploclytia* in the Sucarnoochee shale of the type locality:

Homarus johnsoni (Rathbun)
Linuparus wilcoxensis Rathbun
Dromilites americana Rathbun
Symethis johnsoni Rathbun
Xanthilites alabamensis Rathbun

Family NEPHROSIDAE Stebbing

Genus HOMARUS H. Milne-Edwards, 1837

Histoire naturelle des crustacés, vol. 2, p. 333.
Genotype.—*Homarus vulgaris* H. Milne-Edwards, living.

HOMARUS TRAVISENSIS Stenzel, n.sp.

Pl. 41, figs. 14–16; text fig. 10

Description.—Monotype is the manus of the right cheliped with the fingers missing. Manus not quite twice as long

[17]Stephenson, L. W., and Monroe, W. H., The Upper Cretaceous deposits: Mississippi State Geol. Survey, Bull. 40, p. 110, 1940.

as wide and compressed-oval in cross section. Lower surface has its greatest convexity along a line lying about 1/3 of the palm width up from the outer margin and is slightly more swollen than the upper surface; greatest convexity of upper surface along a line lying about 2/3 of the palm width above the outer margin and thus diagonally opposite to the greatest convexity on lower surface. Outer margin narrowly rounded in cross section and curved in outline; the proximal 1/3 descends rapidly downward away from the manus-carpus joint; the distal 2/3 diverges only a little from parallelism with the inner margin. Inner margin sharp and narrow in cross section and nearly straight in outline.

Remarks.—The genus *Homarus* H. Milne-Edwards is rich in species. Over 50 fossil species have been named and described. The stratigraphic range of the genus is from the Valanginian to the present.[18] Its palaeogeographic distribution is nearly world-wide; it has been found in the fossil state in Patagonia and North America including Greenland, from England to southern Russia, in Australia, West Africa, and southern India.

In the United States east of the Rockies it is represented by eleven fossil species[19] ranging geographically from New Jersey to Texas, chiefly in the Atlantic and Gulf Coastal Plain. With the exception of one species all fossil North American *Homarus* are from the Cretaceous. Those

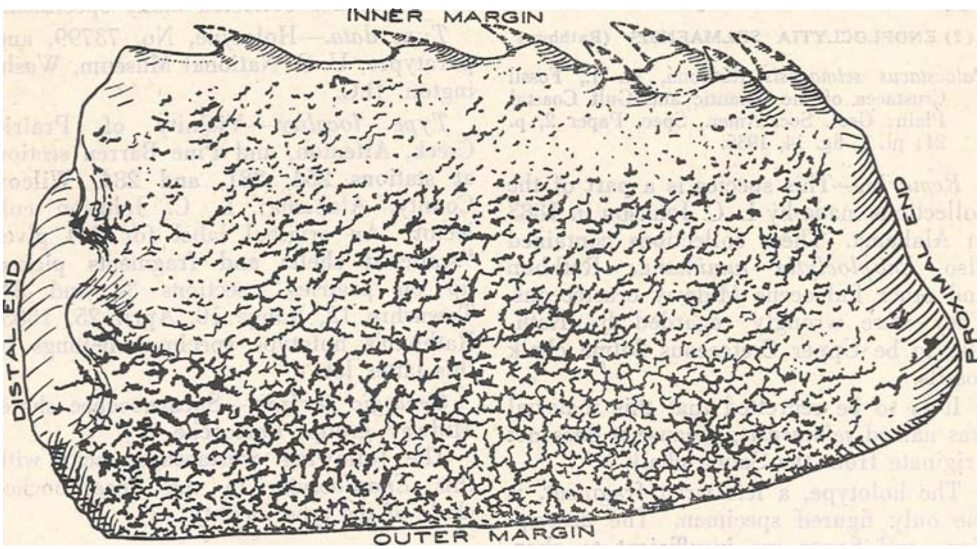

Fig. 10. *Homarus travisensis* Stenzel, x6; lower surface of right manus; monotype.

Upper and lower surfaces finely wrinkled and granulated. A small and low boss between the bases of the 2 fingers at the distal end of the lower surface. Outer margin smoother than either surface; inner margin with 7 broken spines, which point distally and upward. Of the 7 spines 5 lie in a row on the crest of the margin and two lie in a parallel row at the proximal end a little below the crest on the lower surface of the manus.

Dimensions.—Length, 20.7 mm.; width at distal end, 10.8 mm.; thickness, 5.7 mm.

from the Lower Cretaceous are *Homarus dentonensis* (Rathbun) and *Homarus tarrantensis* (Rathbun). Of these two, *H. tarrantensis* (Rathbun) is based on an abdomen and cannot be compared with the new species. *Homarus dentonensis* (Rathbun) has a palm one-half the size of

[18]Glaessner, M. F., Crustacea decapoda: Fossilium Catalogus, 1, pt. 41, 1929.

Woods, Henry, A monograph of the fossil macrurous Crustacea of England, pt. 6: Palaeontograph. Soc., vol. 82, pp. 86–88 1930.

[19]Rathbun, M. J., Fossil Crustacea of the Atlantic and Gulf Coastal Plain: Geol Soc. Amer., Spec. Paper 2, 1935.

H. travisensis Stenzel. In cross section the palm of *H. dentonensis* (Rathbun) is more tumid; the inner margin is narrowly rounded and not sharp as in *H. travisensis* Stenzel. However, the placing of the spines on the inner margin is somewhat similar in both species.

Type data.—Monotype, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Old road metal pit on southwest side of Austin—Bull Creek—Anderson Mill road, on divide between Dry Creek and Shoal Creek drainage, about 8000 feet northeast of Mount Bonnell in airline distance, Travis County, Texas.

The specimen was collected and generously donated by Mr. Ralph H. King and Mr. George Harris.

Geologic horizon.—Yellow clay marl of Walnut formation, Fredericksburg group, Comanche series, Cretaceous (middle Albian). The specimen was found within a few feet of the base of the Fredericksburg group. Collected with it was an ammonite of the genus *Engonoceras*.

HOMARUS BRITTONESTRIS Stenzel, n.sp.

Pl. 40, figs. 1–7; text fig. 11

Homarus brittonestris Stenzel *in* Dallas Petroleum Geologists, Geology of Dallas County, Texas, p. 37, fig. 9, 1941.

Description.—Animal small; fossil remains strongly compressed laterally by the settling of the enclosing sediment.

Carapace measured along the midline and with the rostrum excluded is slightly longer than the first 4 abdominal somites. Rostrum long and slender, about one-half the length of the remainder of the carapace. The rostrum is channeled on top; the margins of the rostrum are raised into narrow crests (ρ), which carry slightly curved and forward, upward, and outward-pointing spines. These spines alternate in position on the two crests; there are 3 spines on each side; they occupy the frontal half of the crests; the posterior half of the crests is free of spines. The tip of the rostrum is a sharp spine of similar appearance. Where the margins of the rostrum turn out and merge into the margin of the orbit, they leave the crests. which continue as narrow ridges on the gastric region. These

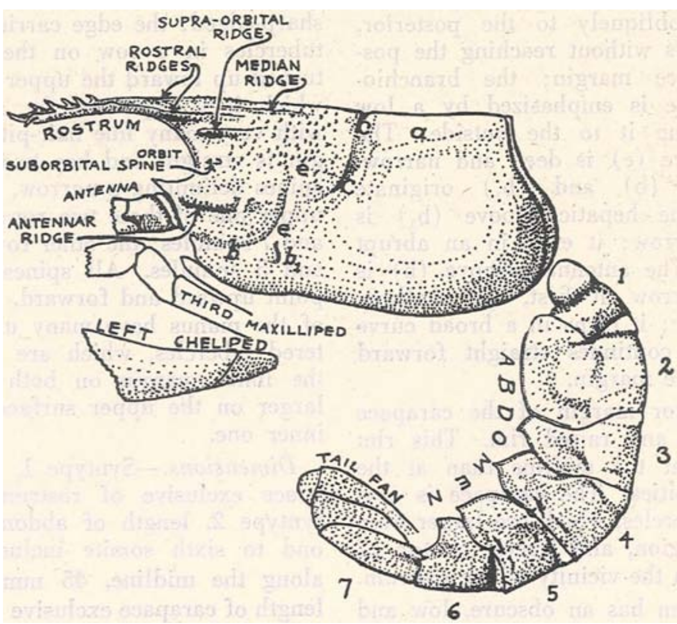

Fig. 11. *Homarus brittonestris* Stenzel, x2; composite of several specimens.

rostral ridges (ρ) diverge to the posterior at a very acute angle and play out in the frontal third of the gastric region. As these rostral ridges diverge they make room for a median ridge (μ), which is short and ends in the middle of the gastric region. Another pair of ridges is supra-orbital in position. These ridges begin abruptly with a spine about 1 or 2 mm. from the orbital margin, diverge to the posterior in the same way as the rostral ridges, and extend to the posterior only a short distance beyond the end of the rostral ridges. These 5 ridges, namely, the median one, the rostral pair, and the supra-orbital pair, are evenly spaced. There is a sub-orbital spine about 1 or 2 mm. from the orbital margin, but it is small and stands by itself. Opposite to the antenna there is a ridge, which begins abruptly with a forward-pointing spine placed next to the carapace margin. This antennar ridge is short and flattens out before reaching a spine, which is in line with it. The post-antennar spine is small and stands by itself.

The postcervical groove (c) is broad and deep, shallows and disappears laterally. The branchio-cardiac groove (a) begins as a slight notch in the posterior wall of groove (c), continues as a shallow groove obliquely to the posterior, and disappears without reaching the posterior carapace margin; the branchio-cardiac groove is emphasized by a low ridge adjoining it to the outside. The cervical groove (e) is deep and narrow. The grooves (b) and (b_1) originate from (e); the hepatic groove (b_1) is short and narrow; it ends in an abrupt short hook. The antennar groove (b) is deep and narrow at first, but shallows to the anterior; it turns in a broad curve forward and continues straight forward to the carapace margin.

The posterior margin of the carapace has a groove and raised rim. This rim is narrower at the midline than at the lateral extremities. The carapace is covered with tubercles, which are larger over the gastric region, and largest on top of the 5 ridges in the vicinity of the rostrum.

The abdomen has an obscure, low and broad ridge separating the pleura from the terga. The pleurum of the second abdominal somite is broad, its anterior margin is narrowly rounded; its posterior margin is broadly rounded; its extremity is gently curved. This pleurum overlaps the first pleurum completely and the third one partially. The pleura of the third, fourth, and fifth abdominal somites have arcuate margins meeting in a backward-pointing sharp angle. The pleurum of the sixth abdominal somite is pointed; its anterior margin is arcuate; its posterior margin is emarginate for insertion of the uropods. Tail fan without ridges. Telson with a longitudinal groove on either side parallel to the outer margins.

Parts of the cheliped are preserved in some specimens, but nearly all are too fragmentary for description. Only one right cheliped manus is well enough preserved to furnish a basis for description (see Pl. 40, figs. 5–7). Manus twice as long as wide and oval in cross section. Lower surface has its greatest convexity along the middle and is more convex than the upper; greatest convexity of the upper surface slightly below the middle. The manus is therefore distorted-oval in in cross section. The two margins diverge distally at an angle of 13°. Outer margin straight to faintly curved in outline and sharp-edged; the edge carries many small tubercles in a row on the crest and is turned up toward the upper surface, from which it is separated by a thin groove with very many fine hair-pits. Inner margin is straight and has two rows of fine spines delimiting a narrow, flat area. The upper one of these two rows has 5 spines and 7 spinules; the other row has 4 spines and 5 spinules. All spines and spinules point upward and forward. Both surfaces of the manus have many uniformly scattered tubercles, which are larger toward the inner margin on both surfaces and larger on the upper surface than on the inner one.

Dimensions.—Syntype 1, length of carapace exclusive of rostrum, 21.8 mm.; syntype 2, length of abdomen from second to sixth somite inclusive measured along the midline, 45 mm.; syntype 3, length of carapace exclusive of rostrum, 22 mm., length of entire abdomen measured along midline, 44 mm.

Remarks.—Eleven species of *Homarus* have been described from the Cretaceous of the United States east of the Rockies. However, among these 11 species the carapace or abdomen is known from only 4 species.

Homarus tarrantensis (Rathbun)[20] has much stronger longitudinal ridges on the abdomen separating the pleura from the terga, and its tail fan has longitudinal, radiating ridges. *Homarus brittonestris* Stenzel has very weak longitudinal ridges on the abdomen and no ridges on the tail fan.

Homarus dentonensis (Rathbun)[21] has a pleurum of the second abdominal somite with a clearly visible rectangular corner at the point where the outer and the posterior margins of the pleurum meet. The same point is present in *H. brittonestris* Stenzel, but it is very obscure, because it is rounded and the angle at which the two margins meet at this point is obtuse. The carapace of *H. dentonensis* (Rathbun) is too imperfect to permit comparisons.

Homarus tennesseensis (Rathbun)[22] has 3 distinct spines in a row occupying the position of the antennar ridge and hepatic spine of *H. brittonestris* Stenzel. There are also two spines apparently occupying the same position as the lone suborbital spine of *H. brittonestris* Stenzel. The pleura of the second and third abdominal somites of *H. tennesseensis* (Rathbun) are sculptured with a conspicuous submarginal groove; such grooves are missing or only very weakly developed on the pleura of *H. brittonestris* Stenzel.

Homarus mcnairyensis (Rathbun)[23] has a median ridge and two marginal ridges extending the entire length of the rostrum; in *H. brittonestris* Stenzel, the median ridge does not enter the rostrum, but stops posterior to the base of the rostrum. However, the 5 ridges in the vicinity of the rostrum are very similar in both species.

The species name is derived from the Britton member of the Eagle Ford formation. The Latin ending *estris* means "pertaining to."

Type data.—Nine syntypes, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Same as *Linuparus grimmeri* Stenzel.

Geologic horizon.—Same as *Linuparus grimmeri* Stenzel.

HOMARUS DAVISI Stenzel, n.sp.

Pl. 40, fig. 8

Description.—Monotype consists of a carapace with 4 abdominal segments largely pressure-deformed.

Carapace measured along the midline and with the rostrum excluded is about 1½ times as long as the first 4 abdominal somites. Rostrum preserved only at its posterior. There it is channeled on top; the margins are raised into round-topped ridges, which carry forward and upward-pointing spines. There are 2 of these spines on the preserved part of each rostral ridge. The rostral ridges (ρ) diverge to the posterior at a very acute angle and play out gradually in the frontal quarter of the gastric region. The orbits are encircled by a fine, thin, raised rim. This rim is smooth except where it runs forward on the side of the rostrum; it bears two spinules on the preserved part of the rostrum. The median ridge (μ) begins where the rostral ridges disappear; it is higher at its anterior and gradually fades out to the posterior; it ends at the posterior quarter of the gastric region. The median ridge is low and inconspicuous throughout; it carries 3 pairs of small spines; the spines of each pair are about 1 millimeter apart; the spacing of the pairs on the ridge is uneven; the first 2 pairs are close together near the front of the ridge. The supraorbital ridges (a) begin in the corner formed by the rostral ridge (ρ) and thin, raised rim of the orbit and rise rapidly

[20]Rathbun, M. J., Fossil Crustacea of the Atlantic and Gulf Coastal Plain: Geol. Soc. Amer., Spec. Paper 2, p. 27; pl. 6, fig. 20, 1935.
Described as *Hoploparia.*

[21]Rathbun, M. J., *op. cit.*, p. 26; pl. 2, figs. 7–13, 1935. Described as *Hoploparia.*

[22]Wade, Bruce, The fauna of the Ripley formation on Coon Creek, Tennessee: U. S. Geol. Survey Prof. Paper 137, pp. 186–187; pl. 64; pl. 65, figs. 1, 3, 6, 1926. Described as *Hoploparia.*

[23]Wade, Bruce, *op. cit.*, p. 187; pl. 65, figs. 2, 4, 5, 7, 8, 1926.
Described as *Hoploparia.*

to their first and most conspicuous spine, which is about 3½ millimeters from the orbital rim. These supra-orbital ridges diverge to the posterior only in that portion which is anterior to their first spine; to the posterior of that spine they are nearly parallel; they extend to the posterior only as far as the median ridge (μ) does; there are 3 spines on each supra-orbital ridge; the two posterior spines are small. These 5 ridges, namely, the median one (μ), the rostral pair (ρ), and the supra-orbital pair (α), are unevenly spaced; the distance between the rostral and supra-orbital ridges is smaller than the distance from the median to the rostral ridge. No suborbital spine or ridge is present. The antennar ridge begins opposite the antenna and extends continuously to the fork of the cervical (e), antennar (b), and hepatic (b_1) grooves; it carries at least 4 spines evenly spaced. In addition to these ridges and spines there are scattered, small, forward-pointing spines in the space between the end of the supra-orbital ridge and the cervical and postcervical grooves. The posterior border of the cervical groove (e) is surmounted by 4 equal, forward-pointing spines on each side of the carapace. The superior border of the hepatic groove (b_1) is studded with 5 spines, which decrease in size to the posterior. The inferior border of the antennar groove (b) is studded with a row of about 7 forward-pointing spines, of which those in the middle of the row are the largest. There are scattered spinules to the inferior of this row on the carapace. The remainder of the carapace. that is, the portion posterior of the transverse grooves, is devoid of spinules, spines, or ridges; but is covered like all the carapace with very many, uniformly distributed, forward-pointing hair-pits. The posterior border of the carapace has a groove and a thin, smooth, raised margin.

The grooves of the carapace are poorly recognizable on account of the pressure-deformation. The post-cervical groove (c) is deep and short. The branchio-cardiac groove is absent or not recognized. The cervical groove (e) is shallow. The grooves (b) and (b_1) diverge with an obtuse angle. The antennar groove (b) is longer than the hepatic groove (b_1), which is straight and shallows out rapidly.

The abdomen is incomplete; only the first 3 and part of the fourth somite are present. The first somite is very short; at each abdomen-carapace hinge point it overlaps the carapace with a rounded lobe. Only the terga are visible except for parts of the left pleurum of the second somite. This pleurum appears to have the usual broad, rounded outline overlapping its neighbors. The terga are smooth and punctate with many tiny pits.

Dimensions.—Monotype, length of carapace exclusive of rostrum, 44 mm.

Remarks.—This species is found at the same locality as *Homarus brittonestris* Stenzel. Therefore, the differences between the two species need to be emphasized. *Homarus davisi* Stenzel is about twice as large as *H. brittonestris* Stenzel; also the former lacks the suborbital spine, which is present in the latter. The anterior portion of the carapace of *H. davisi* Stenzel has many more spines than *H. brittonestris* Stenzel, so that it can be separated from the smaller species readily by the greater roughness of that part of the carapace. In detail there are numerous differences between the two species in the extent and the spines of the various ridges of the carapace. These differences cannot be explained by assuming merely an age difference.

The species is named in honor of Mr. Eugene Elmer Davis of Dallas, the collector of the monotype.

Type data.—Monotype, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Same as *Linuparus grimmeri* Stenzel.

Geologic horizon.—Same as *Linuparus grimmeri* Stenzel.

Genus NEPHROPS W. E. Leach, 1816

Encyclopaedia Britannica [Suppl. to ed. 4–6], i, 2, p. 420.

Genotype.—*Nephrops norvegicus* (Linné), living, south coast of Iceland, west coasts of Europe and western Mediterranean.

The species described below does not belong to the genus *Nephrops;* compare under "Remarks" below.

"NEPHROPS" AMERICANUS Rathbun

Pl. 41, figs. 1–6

Nephrops americanus Rathbun, M. J., Fossil Crustacea of the Atlantic and Gulf Coastal Plain: Geol. Soc. Amer., Spec. Paper 2, pp. 28–29: pl. 5, figs. 6–9, 1935.

Description.—Propodus squarish in outline and compressed. Upper margin nearly straight, apparently narrowly rounded in cross section, although all specimens at hand are crushed along that margin. Lower margin very slightly sigmoid in outline and slightly divergent from the upper margin, narrowly rounded in cross section; sharply set off from the outer surface of the propodus by a narrow groove, which is overhung by a row of elongate, squamiform hair-pit tubercles. Outer and inner surface of propodus gently convex in longitudinal, more so in transverse direction. Both surfaces have many transversely elongate, distally pointing tubercles, which have oval to semilunar to 8-shaped pits at their tips. It is not certain whether these pits are hair-pits or merely the worn tips of the tubercles. The same applies to the row of squamiform tubercles along the lower margin. There are many more tubercles on the outer than on the inner surface of the propodus, but the tubercles of the inner surface are larger. The inner surface has at its lower margin two rows of tubercles above and parallel to the row along the lower margin. Of these two rows the one nearer the margin has more but weaker tubercles than the other. Near the base of the fixed finger and at the interdigital sinus the inner surface of the propodus and the proximal end of the fixed finger are devoid of tubercles, but have instead many round to elongate-oval depressions. Some of the depressions are tiny: others are larger but nevertheless small in size. The bottom of each depression is perforated like a sieve by many fine hair-pits. Such hair-pit depressions are absent from the outer surface. A small, sharply raised, round lobe covers the hinge point of the movable finger on either side. Below this hinge point at the joint the distal edge of the propodus carries a slightly protruding, swollen area covered with about 10 to 12 small, round tubercles with pits at their tips. This feature is on both sides of the manus.

The fixed finger is short, stout, curved inward and upward. The three rows of tubercles on or near the lower margin of the propodus continue on the fixed finger for 2/3 of its length. A deep groove develops between the two lower and the upper of these three rows, so that the two lower rows are on a rounded, longitudinal ridge at the lower margin and the third row is on a rounded ridge on the inner surface of the fixed finger. A similar, third, rounded ridge is on the outer surface of the fixed finger just below the occludent teeth. However, this ridge carries only 2 or 3 pit-tubercles. The outer surface is concave between this ridge and the lower margin. A few pit-tubercles are on this concave part. From the interdigital sinus an angulation extends up along the fixed finger. This angulation is rectangular near the sinus but broadens distally. There are 3 to 4 pit-tubercles on the angulation near the root of the finger. The area between this angulation and the occludent teeth is concave and has many hair-pit depressions on its proximal half. The occludent teeth are along the narrow upper margin and are about 17 in number and small, rounded, and equal in size, except the most proximal one, which is slightly larger.

The movable finger is curved downward and inward and overlaps the fixed finger so that its tip is outside of the fixed finger tip. There are three parallel, rounded, longitudinal ridges separated by narrower, deep grooves; but toward the tip the two grooves disappear and the ridges join. One ridge is median, at the upper margin of the fixed finger. The other two ridges are to either side, each originating at the hinge point on either side of the propodus—finger joint. The areas between these ridges and the occludent margin of the finger are concave and carry hair-pit depressions like those of the propodus; the concave area on the inner surface is long and extends nearly up to the tip of the finger; the concave area on the outer surface is only half as long. Occludent teeth of movable finger like those of the fixed one.

Dimensions.—Left manus (Pl. 41, fig. 5), length, 15.6 mm., height at distal end, 13.4 mm., thickness (crushed, therefore too small), 6 mm.; left manus (figs. 3, 4), height at distal end, 10.4 mm., thickness, 6.5 mm.

Remarks.—This species was described by Rathbun from 3 separate fingers. Because the fingers were not connected to a manus, Rathbun misunderstood the material and described the fixed as the movable finger and vice versa. The material at hand is more complete and allows the correction of the fingers. In addition the nature of the propodus is such that it is clear that the species does not belong in the genus *Nephrops.* The lobster *Nephrops* has a greatly elongate propodus of nearly four-sided cross section, due to the fact that there are strong median keels on the surfaces of the propodus in addition to the two strong keels along the margins. "*Nephrops*" *americanus* Rathbun has no such propodus. The generic position of "*Nephrops*" *americanus* Rathbun remains dubious until additional material is discovered.

Type data.—Two figured syntypes of Rathbun are at the Bureau of Economic Geology, The University of Texas, Austin, Texas. The third, unfigured syntype of Rathbun is at the U. S. National Museum, Washington, D.C.

Type locality.—One-half mile south of Baptist Seminary, 4 miles southwest of Fort Worth, Tarrant County, Texas; W. S. Adkins and W. M. Winton collectors.

The species occurs at many other localities in the vicinity of Fort Worth, and the collections of Texas Christian University, brought together by W. M. Winton and Gayle Scott, contain numerous specimens from that area. The following are the localities of the specimens figured in the present paper:

High bluff opposite Cobb brick plant, 100 yards north of the Houston & Texas Central Railroad bridge on Sycamore Creek between Mansfield road and crossroad going east from Katy Lake; south-southeast of the center of Fort Worth, Tarrant County, Texas (collection numbers M541, G850, Texas Christian University). Dr. Gayle Scott, collector; see Plate 41, figure 6.

Watauga; gullies in pasture about 0.1 mile east and within sight of U. S. highway No. 377, Fort Worth–Denton road, opposite a Texas & Pacific Railroad trestle and 0.2 mile north of Watauga schoolhouse, northern Tarrant County, Texas (Bureau of Economic Geology locality No. 219–T–3). Mr. J. H. Renfro, collector; see Plate 41, figures 3–5.

Watauga; slopes at the head of a short, right tributary to a wide, flat-bottomed branch which is a left tributary of Big Fossil Creek; 0.51 mile east of U. S. highway No. 377 or 0.40 mile east and 0.08 mile north of Watauga schoolhouse, northern Tarrant County, Texas (Bureau of Economic Geology locality No. 219–T–4). Mrs. J. H. Renfro, collector; see Plate 41, figures 1, 2.

Geologic horizon.—Rathbun's type material came from the Pawpaw shale, Washita group, Comanche series, Cretaceous (upper Albian). Additional material came chiefly from the Pawpaw shale, but one specimen came from the Denton formation, Washita group, Comanche series, Cretaceous (upper Albian). The fossil seems most abundant in the Pawpaw shale.

Tribe ANOMURA Milne-Edwards

Superfamily GALATHEIDEA Henderson

Family GALATHEIDAE Dana

Genus GALATHEA Fabricius, 1793

Entomologia systematica emendata et aucta, vol. 2, p. 471.

Genotype.—*Galathea strigosa* (Linné), living.

GALATHEA CRETACEA Stenzel, n.sp.

Pl. 43, fig. 3

Description.—Carapace small, elongate rectangular in outline; the length to width proportion is 6 to 5. Carapace depressed, nearly straight along midline, but convex from side to side. Rostrum 1/3 to ½ the length of the carapace, elongate triangular in outline with the sides concave in outline and the broad base as wide as the length of the rostrum, dorsoventrally strongly compressed, and thin; dorsally with a broad, V-shaped median groove, ventrally with a corresponding V-shaped keel; dorsal surface of rostrum with many short, arcuate rugae to each side of the median groove. Some of these rugae produce small denticles at the margins of the rostrum. Greatest width of the carapace at the posterior quarter; lateral margins slightly convergent to the anterior of the greatest width, to the posterior rapidly curving inward. Posterior margin concave as seen from above. Cervical, antennar, and hepatic grooves smooth and deep. Cervical groove curved, antennar groove sinuous, hepatic groove nearly straight. Hepatic groove meets the lateral margin at a right angle. The median groove of the rostrum extends backward in a pair of short and shallow gastro-orbital grooves, which enclose an acute angle. Entire carapace covered with transverse rugae, some of which are short while others are long enough to extend across the entire width of the carapace or at least from groove to groove. There are 7 precervical entire rugae; of these 2 abut against the cervical groove and 5 against the antennar grooves; two entire precervical rugae are cut by the gastro-orbital grooves; there are 5 rugae between the hepatic and the antennar grooves; of the postcervical rugae only the last 3 reach across the entire width of the carapace; those anterior to the last three rugae are arranged in three tiers, one of which is median or cardiac: the other two are lateral or branchial in position. There are 4 rugae in the cardiac tier and 5 in the branchial tiers; the ends of the cardiac rugae are not in line with the branchial rugae. All rugae have a row of innumerable and very fine pits along their crest. The rugae which lie anterior to the greatest width of the carapace and which reach the lateral carapace margins produce spinules at the margins. Six spinules are posterior to the hepatic groove, 5 spinules are between the hepatic and antennar groove, about 3 spinules are anterior to the antennar groove.

The first 3 abdominal segments are visible; they are simple, transversely grooved. The abdomen is curved under the carapace.

The small, pyritized nodule containing the monotype specimen shows also traces of the legs.

Dimensions.—Length of specimen, 9.9 mm.; length of rostrum, 2.5 mm.; length of carapace without rostrum, 6.0 mm.; width of carapace, 5.1 mm.

Remarks.—This is the first fossil species of the genus described from North America. It is also the oldest known *Galathea.* The next one in age is *Galathea ubaghsi* Pelseneer[24] from the upper Senonian of Limburg. The specimen is a pyrite micromorph. The specimen was collected by Mrs. J. H. Renfro of Fort Worth, Texas.

Type data.—Monotype, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Watauga; gullies in pasture about 0.1 mile east and within sight of U. S. highway No. 377 (Fort Worth–Denton road), opposite a Texas & Pacific Railroad trestle, and 0.2 mile north of Watauga schoolhouse, northern Tarrant County, Texas (Bureau of Economic Geology locality No. 219–T–3).

Geologic horizon. — Pawpaw shale, Washita group, Comanche series, Cretaceous (upper Albian).

GALATHEA (?) LIMONITICA Stenzel, n.sp.

Pl. 43, fig. 4

Description.—Carapace small, incompletely preserved, its length presumably 4/3 of its width. Carapace depressed, nearly straight along midline, but convex from side to side. Rostrum not preserved. Cervical, antennar, and hepatic grooves smooth and deep. Cervical groove curved; antennar groove straight; hepatic groove slightly curved with the concave side to the anterior. The antennar groove gives off two short grooves at one point: one of these extends to the frontal margin, the other to the lateral margin of the carapace. The mesogastric area is delimited by a pair of smooth gastro-orbital grooves. In front just behind the base of the rostrum this groove pair is united, making a single groove of less than 1 millimeter length; to the posterior they separate at an acute angle and then turn to run parallel for about 1 millimeter, thus enclosing the extremely

[24]Pelsenseer, P., Notice sur les crustacés décapodes du Maestrichtien du Limburg: Mus. royal Histoire nat. Belgique Bull., vol. 4, p. 166, fig. 5, 1886.

narrow anterior extension of the mesogastric area; then they spread broadly asunder and extend to the point where the cervical, antennar, and hepatic grooves meet. This groove pair which delimits the mesogastric region to the anterior and at the sides is less deep than the other grooves of the carapace. A faint median keel extends from the tip of the mesogastric area back to the middle of that area. Entire carapace covered with transverse rugae, some of which are short while others are long enough to extend from one groove to its counterpart. There are 5 very short transverse rugae in the very narrow anterior extension of the mesogastric area; six long and one short rugae cross the remainder of the mesogastric area; of these the two posterior ones abut with their ends against the cervical groove; protogastric area with 5 transverse rugae, which are anterior, and 6 oblique rugae, which are posterior; hepatic area with short, irregular rugae. The postcervical rugae are arranged in 3 tiers, one of which is median or cardiac and the other two are lateral or branchial in position. Cardiac tier with 5 long anterior rugae and 2 short posterior ones; lateral tiers incompletely preserved. The cardiac tier is delimited to the posterior by a curved, V-shaped groove pair. which is only partly preserved. Posterior to this groove pair there were some more rugae, but these are preserved only in a small piece.

Dimensions.—Length of carapace without rostrum, 6.8 mm.; width of carapace, about 6 mm.

Remarks.—For exact generic determination it is necessary that the rostrum of this species be found, because the two genera *Galathea* Fabricius and *Munida* Leach[25] are distinguished by the shape of the rostrum. The rostrum of *Galathea* is depressed, whereas the rostrum of *Munida* is compressed in shape.

Galathea(?) limonitica Stenzel differs in many surface markings from *Galathea cretacea* Stenzel. The former has many more grooves on the carapace than the latter. *Galathea(?) limonitica* Stenzel is a limonitized pyrite micromorph.

Type data.—Monotype, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—South of Fort Worth, Tarrant County, Texas. Collected by Mr. Norman E. Nelson, Coll. No. N301, Texas Christian University, Fort Worth, Texas.

Geologic horizon. — Pawpaw shale, Washita group, Comanche series, Cretaceous (upper Albian).

Superfamily THALAESSINIDEA Dana

Family CALLIANASSIDAE Bate

Genus UPOGEBIA W. E. Leach, 1814

Edinburgh Encyclopaedia, vol. 7, p. 400.
Genotype.—*Upogebia stellata* (Montagu).

UPOGEBIA RHACHEOCHIR Stenzel, n.sp.

Pl. 42; text fig. 12

Upogebia rhacheochir Stenzel *in* Dallas Petroleum Geologists, Geology of Dallas County, Texas, p. 38, fig. 11, 1941.

Description.—Carapace too poorly preserved for description. First abdominal somite is the smallest of all seven; its anterior margin is one-half the width of its posterior margin; the center is occupied by a large, elongate boss behind the groove which delimits the carapace-abdomen joint; a pair of hair-pits is just behind that groove spaced far apart; a line of four hair-pits is on the posterior slope of the central boss; a line of about 8 crowded hair-pits is on a low ridge, which separates the tergum from the pleura; the pleura are simple and narrow. The second abdominal tergum is large and squarish in outline; its smooth, shiny surface is interrupted by 4 pairs of widely separated hair-pits; the anterior pair is near the middle, the 2 posterior pairs are at the posterior edge, the 4 pits on either side are not in line; the low, smooth ridge separating the tergum from the pleura is sigmoid; the pleura are triangular with their greatest width at the posterior, the point is narrowly rounded; an oblique line of crowded hair-pits begins at the posterior edge and separates the rounded point from the remainder of the pleurum. The third abdominal tergum is rectangular, broader

[25]Leach, W. E., Malacostraca Podophthalma Britanniae, explanation of pl. 29, 1815. Genotype, *Munida bamffia* (Pennant).

than long, and smaller than the second; a curved, well-defined ridge with a shallow, adjoining groove above separates the tergum from the pleura; tergum with 8 pairs of hair-pits, some of which are on either side parallel to and just above the groove; two pairs of slanting hair-pits are at the posterior margin of the tergum; an oblique line of crowded hair-pits runs forward and outward from the middle of the ridge which separates tergum from pleurum; behind this line there are on the pleurum a few scattered pits near this ridge; a hair-pit is near the anterior end of this ridge. The fourth tergum is smaller than but similar to the third; there are 4 evenly spaced rows of hair-pits; the outer rows each with 4 pits are near the lateral groove of the tergum; the inner rows each with 5 pits are slightly convergent; the lateral groove and ridge of the tergum are well defined; the pleura

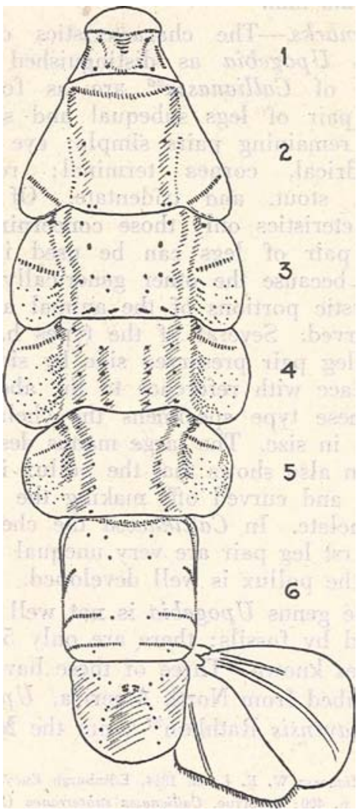

Fig. 12. *Upogebia rhacheochir* Stenzel, x3; composite of several specimens; abdomen.

are similar to those of the third somite, but the line of crowded hair-pits is more anterior in position and runs outward and backward; scattered hair-pits are on the pleurum behind this line. The fifth tergum is almost the same size as the fourth; it has a line of 6 hair-pits in the lateral groove; this groove and its accompanying ridge are less distinct; the pleura are evenly rounded at the margin and are almost semicircular; the oblique line of crowded hair-pits is far to the anterior and runs outward and backward; scattered hair-pits occupy the middle of the pleurum behind that line. The sixth abdominal tergum is larger and elongate rectangular; 3 curved lines of crowded hair-pits are on each side running up on the tergum from its posterior corner; the last pair of lines almost meets in the middle; there are 5 pairs of hair-pits on the tergum; the first 4 pits are near the anterior margin of the tergum; the two inner ones of these and 2 additional pairs form a pair of lines of unevenly spaced pits; another widely spaced pair is near the posterior margin; the lateral margins of this somite are curled down forming rudimentary pleura; the lateral edges have narrow rims. The tail is well developed; the telson has parallel sides and is ovally rounded at the end; a small, median boss with several hair-pits at its top is near the anterior edge; a pair of slightly divergent rows of hair-pits is on the posterior half of the telson; a curved, transverse row of widely spaced pits is at the anterior edge of the telson and extends through the boss; the outer uropod fin has 2 radiating ridges, of which only one extends to the margin; on one specimen there is a row of setae along the inner margin of this fin; the inner uropod fin has one ridge running near its inner margin and accompanied by a row of widely spaced hair-pits.

The chelae of the first legs are equal in size and elongate. Carpus short, less than one-half the length of the manus; greatest thickness about 3/4 of its height; height equal to the length; surface polished; upper margin narrowly rounded; lower margin broadly rounded and with a shallow transverse constriction near the carpus joint; upper margin ends distally in an inconspicuous, well-rounded point; spines are absent. Manus elongate; its length twice its height; height slightly increasing distally; its greatest thickness 3/5 of its height; upper margin narrowly rounded and with 3 unevenly spaced hair-pits in a row on its crest; toward the outer surface the upper margin is delimited by a narrow rim; the upper margin and this rim are straight except at the proximal end, where they curve rapidly down to the manus-carpus joint; a similar rim delimits the outer surface below and extends to the tip of the pollux; the lower margin of the manus is so nearly flat that it forms something of a narrow lower surface; this lower surface curves narrowly into the inner surface forming a rounded longitudinal edge, which extends to the tip of the pollux, but flattens there; along this rounded edge on the lower surface there is a line of about 7 hair-pits, which are wider spaced at the proximal end; the outer surface is at its lower distal part twisted inward to the pollux, which is curving forward and inward; aside from this twist the outer surface is gently convex, but at its upper third there is a very slight longitudinal dell, which is more conspicuous distally and flattens out near the middle; the inner surface is slightly more tumid than the outer; near its upper margin are two pits in a row, one near the middle, the other at the anterior quarter; the lower surface is very slightly convex in transverse direction and twisted in longitudinal direction, its slant being downward and outward at the distal end. The point of the pollux is bruised in the best specimen (see Pl. 42, figs. 7–10) but can not have added much to its length, which is 1/5 of that of the manus; the pollux is twisted inward so that it points inward and forward; its outline is short triangular; its outer surface is slightly concave: its inner surface is tumid; its lower surface is gently convex; the occludent margin may have had a low proximal tooth.

The manus of a smaller specimen (female?, Pl. 42, figs. 11–14) differs in the following features: the outer surface is more tumid, the dell is not developed, and the twist toward the pollux is slighter; the inner surface is also more tumid; the lower surface is slightly more convex and the distal twist is absent; the rims delimiting the outer surface above and below are less sharp; there is only one hair-pit on the upper margin; it is in the middle; the pollux is only slightly curved inward, slenderer, and longer; its length is about 1/3 of that of the manus.

Dimensions.—Syntype 1, length of entire abdomen, 40 mm., length of telson, 5.5 mm., length of outer tail fin, 8.3 mm.; syntype 2, length of abdomen exclusive of first segment, 37 mm., length of telson, 6 mm., length of outer tail fin, 8 mm.; syntype 5, length of entire abdomen, 41 mm., length of manus, 9.7 mm.; syntype 6, length of abdomen exclusive of telson, 33 mm., length of manus, 10 mm., height at distal end, 5.3 mm., thickness of manus, 3.1 mm.; syntype 7, length of abdomen exclusive of telson, 27 mm., length of manus, 7.4 mm., height at distal end, 3.2 mm., thickness, 2.2 mm.

Remarks.—The characteristics of the genus *Upogebia* as distinguished from those of *Callianassa*[26] are as follows: first pair of legs subequal and subchelate, remaining pairs simple; eye stalks cylindrical, cornea terminal; rostrum short, stout, and tridentate. Of these characteristics only those concerning the first pair of legs can be used in this case, because the other generically characteristic portions of the animal are not preserved. Several of the types had the first leg pair preserved side by side and in place with reference to the abdomen. In these type specimens the chelae are equal in size. The large manus described herein also shows that the pollux is very short and curved off, making the manus subchelate. In *Callianassa* the chelae of the first leg pair are very unequal in size and the pollux is well developed.

The genus *Upogebia* is not well represented by fossils; there are only 5 fossil species known. Three of these have been described from North America. *Upogebia midwayensis* Rathbun[27] from the Midway

[26]*Callianassa* W. E. Leach 1814, Edinburgh Encyclopaedia, vol. 7, p. 400; genotype, *Callianassa subterranea* (Montagu).

[27]Rathbun, M. J., Fossil Crustacea of the Atlantic and Gulf Coastal Plain: Geol. Soc. Amer., Spec. Paper 2, pp. 66–67; pl. 16, figs. 1, 2, 1935.

group of Alabama unfortunately is figured only very poorly, but the description indicates a subquadrilateral furrow on the pleura of the fourth and fifth abdominal somites. Such furrows are apparently not present on the new species.

Upogebia eocenica Rathbun[28] from the Eocene of Washington has an entirely different manus than *Up. rhacheochir* Stenzel. There are also considerable differences in the abdomen of the two species.

Callianassa gamma Rathbun[29] from the Paleocene Sucarnoochee shale of Alabama, which is based on a single manus, is so similar to the manus of *Upogebia rhacheochir* Stenzel that one can not escape the conclusion that the two species are congeneric. Also, comparison with the more plentiful material of *Upogebia rhacheochir* Stenzel indicates that the described manus of *Upogebia gamma* (Rathbun) is the right and not the left manus, as given by Rathbun. Several specimens of *Upogebia rhacheochir* Stenzel are available which have the two hands preserved side by side in parallel position. Such specimens allow correct interpretation of the position of the manus.

The species name is derived from the Greek nouns ῥαχις, "ridge," and χεῖρ, "hand," and refers to sharp rims delimiting the outer surface of the hand above and below.

Type data. — Twenty-two syntypes, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Same as *Linuparus grimmeri* Stenzel.

Geologic horizon.—Same as *Linuparus grimmeri* Stenzel.

[28]Rathbun, M. J., The fossil stalkeyed Crustacea of the Pacific slope of North America: U. S. Nat. Mus. Bull. 143, pp. 124–125; pl. 29, figs. 1–2; pl. 30, 1926.

[29]Rathbun, M. J., Fossil Crustacea of the Atlantic and Gulf Coastal Plain: Geol. Soc. Amer., Spec. Paper 2, pp. 68–69; pl. 17, figs. 7–10, June 25, 1935. Name preoccupied by *Callianassa gamma* Stenzel (Stenzel, H. B., Middle Eocene and Oligocene decapod crustaceans from Texas, Louisiana, and Mississippi: Amer. Midland Naturalist, vol. 16, pp. 393–394; pl. 15, figs. 5–6, May 27, 1935).

Superfamily PAGURIDEA Dana

Family PAGURIDAE Boas

Genus PAGURUS Fabricius, 1775

Syst. Entom., p. 410.

Genotype.—*Pagurus bernhardus* Linné.

PAGURUS BANDERENSIS Rathbun

Pl. 45, figs. 7–15

Pagurus banderensis Rathbun, M. J., Fossil Crustacea of the Atlantic and Gulf Coastal Plain: Geol. Soc. Amer., Spec. Paper 2, p. 39, pl. 9, figs. 7–8, 1935.

Original description.—The distal portion of a right chela showing fingers and adjacent palm. Surface for the most part covered with large pointed granules not contiguous and directed obliquely distad; on the inner surface the longitudinal furrow on immovable finger is smooth, also that part of palm not bordering the fingers. Lower margin of specimen concave except near tip of finger where it is slightly ascending. Fingers gaping at base. Immobile finger half as high at base as it is long and of uniform height to its middle; outer surface as well as inner with a shallow longitudinal furrow; prehensile edge with about eight lobiform teeth, the largest one at the bend in the outline; tip blunt. Dactylus closed within fixed finger, equally high at base gradually diministing, upper line arcuate, outer surface with a narrow furrow on which granules are scanty, prehensile edge concave and furnished with small tubercles; tip lacking, but did not reach end of fixed finger. Palm vertical at base of dactyl, swollen outwardly along the gape and the fixed finger as far as the bend; upper margin lacking.

Revised description.—Thanks to the efforts of W. T. Watkins there is available not only the distal portion of a right chela but several entire right chelae, several left manus, and part of an ambulatory leg.

Right manus about as long as high, compressed-oval in cross section. Outer surface more convex in transverse than in longitudinal direction. Inner surface straight in longitudinal direction except for the proximal half, which is convex; highly convex in transverse direction.

Upper margin gently arched in longitudinal direction and slightly divergent with reference to the lower margin; in transverse section it is thickly rounded at the distal end and narrows down somewhat toward the proximal end; it carries an irregular row of small, vertical, cylindroconical tubercles of various sizes. Lower margin is straight as seen from the side, but curves into the lower margin of the curved fixed finger as seen from below; it is thickly rounded in transverse section; its ornamentation is the same as the one of the outer surface. Outer surface with many, low, distally inclined tubercles, which are more prominent toward the distal end and the upper margin; at the latter they grade into the vertical tubercles of the upper margin, at the former they continue without change on the fixed finger. Inner surface with similar and similarly distributed but weaker tubercles.

Fingers fitting closely together as seen from outer surface. Fixed finger a little less than half as high at base as it is long and continuing so to near the middle; there begins a quick taper producing a hump at the middle of the finger. Tip curved inward and outward. Prehensile edge from median hump to tip with about 14 rounded tubercles; no tubercles on proximal half of this edge from the interdigital sinus to the median hump. An edge extends from the tip to the sinus on the inner surface. At the tip this inner edge carries about 4 rounded tubercles similar to those of the prehensile edge. Between these two edges the fixed finger has a concave surface, into which the mobile finger fits. Mobile finger is hinged obliquely; the inner hinge point is much lower than the outer one; the latter is very near the upper margin of the finger. Top of mobile finger fits into a concave place on fixed finger.

Left manus smaller than right, about as long as it is high, oblique-quadrangular in outline. Outer surface convex, with a median, longitudinal, convex ridge. Many low tubercles of several sizes cover the outer surface. Inner surface with a diagonal, straight ridge arising near the lower proximal corner and extending diagonally to the base of the movable finger. Above this ridge the inner surface is deeply concave, making the upper margin crest-like. Many low tubercles cover the inner surface except the concave portion, which has only two feeble rows of them. Upper margin gently arched in longitudinal direction and slightly convergent distally with reference to the lower margin; in transverse section it is narrow, crest-like; the crest carries two rows of tubercles; the inner row has 7 tubercles each with a hair-pit on top; the outer row has about 7 feebler tubercles. Lower margin very thickly rounded to flat. Fixed finger uniformly tapering; lower margin angular in cross section carrying a row of squamiform tubercles; prehensile edge sharp carrying a single row of crowded, tubercular teeth. Outer surface of fixed finger convex and covered with tubercles as the manus. Inner surface with an obscure ridge, which originates on the lower margin of the manus, carrying tubercles and hair-pits.

A fragment of an ambulatory leg is available. It is 15 mm. long, curved. The outside has 4 longitudinal rows of fine tubercles, between which are 3 rows of widely spaced, large hair-pits. The inner surface has two rows of widely spaced, small hair-pits.

Dimensions. — Figured right chela, length, 26.7 mm., height, 14.2 mm., thickness, 9.0 mm.; figured left chela, length, 16.2 mm., height, 7.4 mm., thickness, 5.1 mm.; figured right fixed finger, length of fragment, 17.2 mm. Ambulatory leg fragment, length, 15.0 mm.

Remarks.—The superfamily Paguridea is rather poorly represented in the Cretaceous, although it is better represented in Jurassic and very well represented in recent faunas. In this connection the material described here is a welcome addition to the knowledge. The two species of *Pagurus* from the Cretaceous of Texas also help to extend the range of the genus into the Lower Cretaceous. Before *Pagurus banderensis* was described by M. J. Rathbun, the oldest known *Pagurus* was Eocene in age.

One of the important points of the present paper is the discovery and description of the left chela of *Pagurus banderensis* Rathbun, of which only the right chela had been known before. As the two chelae differ very considerably in shape and ornamentation and as they were found loose among chelae of other crustaceans, it is only by inference that both can be placed in the same species. Among the other chelae found by Mr. Watkins at the same locality there are some which obviously can have nothing to do with *Pagurus,* because they belong clearly to other well-established and unrelated genera such as *Callianassa.* Some of the other chelae are present in pairs of right and left, thus eliminating all chances that one of them might be part of *Pagurus banderensis* Rathbun. Such processes of elimination leave unaccounted for several left manus, right manus, right fixed fingers, and the leg fragment. The right manus have no other match except the left manus and vice versa, leaving no doubt that they belong to the same species, which has to be *P. banderensis* Rathbun because the right manus and fingers belong there. This species is the most abundant crustacean at this locality.

Type data.—Figured specimens, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Locality.—On State highway No. 16 (Bandera–Pipe Creek road), 2 miles east of Bandera, Bandera County, Texas. M. J. Rathbun's monotype came from 1 mile east of Bandera on the same road as the other material.

Another right chela was found by Mr. Carl Chelf in an excavation on the northwest side of an isolated hill with road metal pits, 0.15 mile south of State highway No. 29 (Burnet-Austin road), and 0.07 mile east of the Southern Pacific Railroad track, 1.42 miles airline distance east of the courthouse in Burnet, Burnet County, Texas.

Geologic horizon.—The material collected by Mr. Watkins and described above was found together with *Douvilleiceras* sp. probably *D. mammillatum* (Schlotheim) and *Salenia texana* Credner in the Glen Rose formation, Comanche series, Cretaceous (lower Albian).

PAGURUS TRAVISENSIS Stenzel, n.sp.

Pl. 45, figs. 16–18

Description.—Right manus short and high. Upper margin gently curved in longitudinal direction and distally divergent from lower margin; in transverse section narrow and crest-like, surmounted by two rows of tubercles. The inner row consists of 7 tubercles decreasing in size distally; the proximal 5 are nearly vertical, high cones, the distal two are small cones. The outer row is less conspicuous and consists of 4 unevenly spaced small cones in the proximal half of the margin. Lower margin straight, well though narrowly rounded in transverse section, covered with tubercles like the outer surface. Outer surface convex in middle, concave along lower margin, faintly concave along upper margin; covered with many small conical tubercles; weathering has etched part of the surface into a reticulate, pitted framework. Inner surface concave except for a small portion at the upper proximal corner, which is faintly concave; covered with many low, conical tubercles, which are slightly larger and in obscure rows near the upper margin.

Dimensions.—Monotype, right manus, length, 21.6 mm., height, 22.8 mm., greatest thickness, 10.8 mm.

Remarks.—This species is readily distinguished from *Pagurus banderensis* Rathbun by the greater height of the manus in proportion to its length. In addition *P. travisensis* Stenzel is much less tumid than the other species; whereas the right manus of *P. banderensis* Rathbun is thick or even perhaps tumid, the same manus of *P. travisensis* Stenzel is compressed. In keeping with the shape of the manus both margins are narrower in *P. travisensis* Stenzel than the corresponding margins in the other species.

Type data.—Monotype, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Cut on south side of road on road leading from Bull Creek valley westward to Lake Austin Park and abandoned CCC Camp MA-3-T, CO No. 1805, 0.7 mile from road fork in West Bull Creek valley, 1 mile north of Lake

Austin or 3.4 miles northwest of Mt. Bonnell (airline distance), northwest of Austin, Travis County, Texas.

Geologic horizon.—In nodular, fossiliferous limestone, the basal bed of the Comanche Peak formation, Fredericksburg group, Comanche series, Cretaceous (middle Albian). The fossil was found approximately 10 feet above the basal disconformity of the Fredericksburg group. The specimen was collected by Mr. Chester Wallace.

Tribe BRACHYURA Latreille

Subtribe GYMNOPLEURA Bourne

Family RANINIDAE Dana

Genus NOTOPOCORYSTES F. McCoy, 1849

On the classification of some British fossil Crustacea, with notices of new forms in the University collection at Cambridge: Annals and Mag. Nat. History, ser. 2, vol. 4, p. 169.

Genotype.—*Notopocorystes stokesii* (Mantell) from the Gault (Albian) of England.

NOTOPOCORYSTES DICHROUS Stenzel, n.sp.

Pl. 43, figs. 5–7; text fig. 13

Notopocorystes dichrous Stenzel *in* Dallas Petroleum Geologists, Geology of Dallas County, Texas, p. 37, fig. 10, 1941.

Description.—Carapace elongate, nearly 1/4 longer than wide, greatest width through the last lateral spines. Fronto-orbital width between 4/5 and 4/6 of that of the carapace. Carapace flattish, very gently convex from front to back,, more convex from side to side. Rostrum four-pointed and bifid, ending in 2 short, diverging points, convexly curved with its tip pointing downward and forward; sinus between the advanced points is rounded; the second pair of rostral points is on the lateral margin of the rostrum a short distance back of the other points; midline of the rostrum is occupied by a narrow median ridge flanked by slightly wider, deep grooves; the median ridge extends to the frontal sinus of the rostrum, but the grooves diverge forward and open into the lateral sinuses between the 2 pairs of points of the rostrum. Orbits wide, about 3 times as wide as high, and slightly contracted in middle; slanting downward and outward with the lateral slope of the carapace. Upper orbital margin with 2 fissures; adjoining the rostrum there is a broad, rounded sinus, which ends against a short spine at the inner fissure; between the 2 fissures there are 2 obtuse points close together; beyond the outer fissure is a short obtuse point, which is separated from the outer orbital spine by a rounded sinus; outer orbital spine long and slightly in-curved. Antero-lateral margin with 5 spines, of which the orbital spine is the first; the size of the spines decreases posteriorly; the last is a mere point; the sinuses are unequal in depth, the last is very shallow, the first and third are a little deeper than the second, the first three sinuses are rounded. Postero-lateral margin gently flexuous to straight, well defined, obtusely angulated and carinated with the aid of coarse, crowded tubercles strung up along it. This marginal row of tubercles begins at the fourth antero-orbital spine. Posterior margin concave and short.

Surface of carapace smooth as a whole, the regions poorly defined. The most conspicuous division occurs along a jagged line running from the root of the rostrum to the end of the postero-lateral margin. This line divides the carapace into two unequal portions; the portion anterior to the line is rough with widely spaced, small granules; the portion posterior to the line is smooth with granules, which have flat, polished tops and are so densely crowded that their interspaces are mere chinks or occasional pits; the two portions also differ in color in all well-preserved specimens; the anterior portion is the darker and bluish, the posterior portion is light gray; the posterior portion is higher than the anterior portion of the carapace along this line, so that the line presents a step or scarp a fraction of a millimeter high. This boundary line is jagged because it has 8 forward-pointing, rounded lobes, that is, 4 on each side; and 7 backward-pointing, sharp-pointed recesses, of which one is median and the others paired. The third lobe of this line (counting from the midline of the carapace) is the most elevated and narrowest in outline. From the fourth lobe to the posterior the boundary line runs alongside the postero-lateral margin of the carapace. The por-

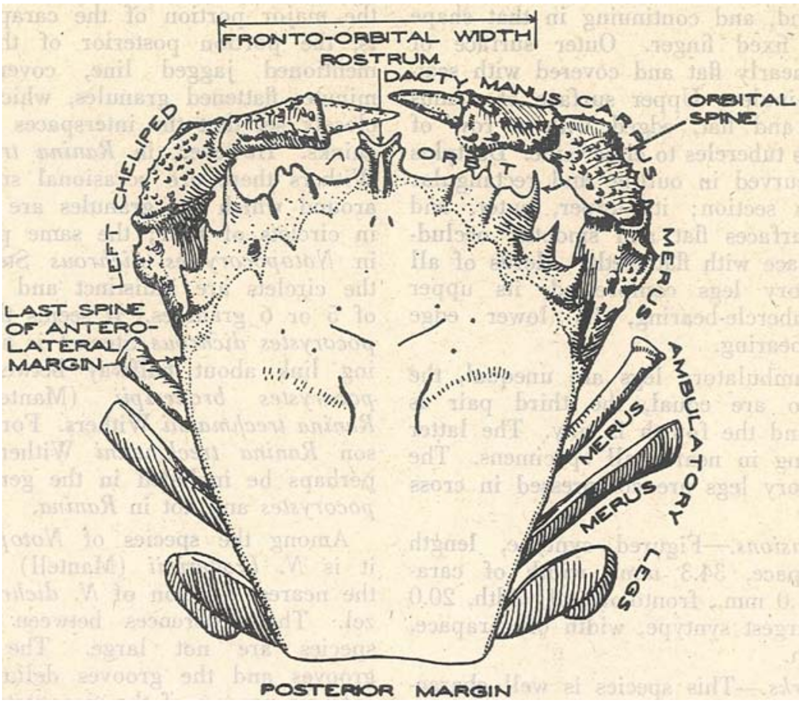

Fig. 13. *Notopocorystes dichrous* Stenzel, x2; composite of several specimens; complete animal except for the eyes, abdomen, last legs, and distal parts of other ambulatory legs.

tion of the carapace anterior to this boundary line is devoid of sculpture except for the above-mentioned granules, a short, spinous tubercle on each hepatic region, and a groove which starts at the antero-lateral margin between the third and fourth spines and extends a short distance forward and inward in the direction of the tip of the fourth lobe of the boundary line. The portion of the carapace posterior to the boundary line is devoid of spines or swellings but has an obtuse, rounded, obsolete median keel, which is best developed between the cardiac groove pair and disappears in a short distance both in front of the cervical groove and behind the cardiac grooves. The cervical groove consists of a pair of short, straight, linear grooves, which do not join in the midline. They form an obtuse angle of about 120 degrees. A pit is situated about 1 millimeter forward and inward from the outer end of each groove. The cardiac grooves are short and curved. In a line with the anterior prong of each of the cardiac grooves lie 2 pits, of which the posterior one is the deeper and about 2.2 mm. apart from both the outer pit and the end of the cardiac groove. A third groove pair lies a short distance posterior to the end of the median ridge of the rostrum. These grooves are very short, straight, linear, and separate 'and make an acute angle of 45 degrees.

Chelipeds equal in size. Merus thick and rounded except for the flat surface in contact with the carapace; its posterior edge armed with spinules; the outer or posterior surface has an inclined, curved, sharp ridge situated near the distal end of the merus. This ridge is sharp-crested and carries tubercles on the crest. Spinules cover the outer surface of the merus. Outer surface of carpus with spinules and a short, straight, inclined ridge ending in a distal spine and situated near and parallel with the manus-carpus joint. Manus compressed; the lower edge with tubercles, narrowly rounded at proximal end, increasing in sharpness to a sharp edge toward the distal end, and continuing in that shape on the fixed finger. Outer surface of manus nearly flat and covered with scattered spinules. Upper surface of manus narrow and flat, edged with a row of spinuous tubercles to either side. Dactylus gently curved in outline and rectangular in cross section; its upper, outer, and inner surfaces flat and smooth; occluding surface with flat teeth. Merus of all ambulatory legs compressed, its upper edge tubercle-bearing, its lower edge spinule-bearing.

The ambulatory legs are unequal, the first two are equal, the third pair is small, and the fourth is tiny. The latter is missing in nearly all specimens. The ambulatory legs are compressed in cross section.

Dimensions.—Figured syntype, length of carapace, 34.3 mm., width of carapace, 27.0 mm., fronto-orbital width, 20.0 mm.; largest syntype, width of carapace, 47.4 mm.

Remarks.—This species is well characterized by the jagged line which divides the carapace into two unequal portions. This line is well developed and conspicuous in all specimens. However, in this feature it is not unique among the species of *Notopocorystes*. *Notopocorystes broderipii* (Mantell), *N. carteri* McCoy,[30] and *N. syriacus* Withers[31] and possibly other species have this line or portions of this line, but in these species the line is easily overlooked, because other structural features overshadow its importance. The same line occurs well developed in *Ranina trechmanni* Withers,[32] but in this form the line is more advanced in position and lies closer to the antero-lateral and orbital margins of the carapace. The Jamaican species is also very similar in the peculiar ornamentation of the carapace. Both *Ranina trechmanni* Withers and *Notopocorystes dichrous* Stenzel have the major portion of the carapace, that is, the portion posterior of the abovementioned jagged line, covered with minute, flattened granules, which are so closely set that the interspaces are mere chinks. However, in *Ranina trechmanni* Withers there are occasional small pits, around which the granules are arranged in circlets of four; the same pits occur in *Notopocorystes dichrous* Stenzel but the circlets are indistinct and made up of 5 or 6 granules. It seems that *Notopocorystes dichrous* Stenzel is a connecting link about halfway between *Notopocorystes broderipii* (Mantell) and *Ranina trechmanni* Withers. For that reason *Ranina trechmanni* Withers should perhaps be included in the genus *Notopocorystes* and not in *Ranina*.

Among the species of *Notopocorystes* it is *N. broderipii* (Mantell) which is the nearest relation of *N. dichrous* Stenzel. The differences between the two species are not large. The cervical grooves and the grooves delimiting the anterior process of the mesogastric region are longer in *N. broderipii* (Mantell) than in *N. dichrous* Stenzel. Also, *N. broderipii* (Mantell) has one spine less on the antero-lateral carapace margin than *N. dichrous* Stenzel; the median keel is longer and more prominent in *N. broderipii* (Mantell) extending very nearly to the posterior carapace margin.

Two other species of *Notopocorystes* are known from the Cretaceous of Texas. They are *N. punctatus* Rathbun and *N. parvus* Rathbun.[33]

The specific name *dichrous* is derived from the Greek adjective διχροος, "two-colored," and refers to the two-colored carapace of the species, which is its most striking feature.

Type data.—Several syntypes, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Same as *Linuparus grimmeri* Stenzel.

Geologic horizon.—Same as *Linuparus grimmeri* Stenzel.

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[30]Compare Bell, Th., A monograph of the fossil malacostracous Crustacea of Great Britain, pt. 2, Crustacea of the Gault and Greensand: Palaeontograph. Soc., vol. 14, pp. 14–15, 17–18, pl. 2, figs. 8–13, 14–17, 1863.

[31]Withers, T. H., New Cretaceous crabs from England and Syria: Annals Mag. Nat. History, ser. 10, vol. 2, pp. 159–460; pl. 13, figs. 1–3, 1928.

[32]Withers, T. H., *Ranina trechmanni*, a new Cretaceous crab from Jamaica: Geol. Mag., vol. 64, no. 754, pp. 176–180, pl. 7, 1927.

[33]Rathbun, M. J., Fossil Crustacea of the Atlantic and Gulf Coastal Plain: Geol. Soc. Amer., Spec. Paper 2, pp. 48–49; pl. 12, figs. 14–16 and 11–13, 1935.

Subtribe OXYSTOMATA De Haan

Family CALAPPIDAE Alcock

Genus NECROCARCINUS Th. Bell, 1863

A monograph of the fossil malacostracous Crustacea of Great Britain, pt. 2, Crustacea of the Gault and Greensand: Palaeontograph. Soc., vol. 14, p. 19.

Genotype.—*Necrocarcinus labeschii* (Deslongchamps) from the Cambridge greensand. Cretaceous (Albian), of England.

NECROCARCINUS MOSELEYI Stenzel, n.sp.

Pl. 41, fig. 12; text fig. 15

Description.—Monotype is a carapace fragment. Carapace small, apparently circular in outline, greatest width of carapace anterior of its center, lateral extremity rounded. Carapace slightly convex from front to back, less so from side to side. Rostrum missing. Orbits medium, pointing forward and upward, wider than high. Upper orbital margins upturned and mostly broken away; but a fissure is visible on the right orbit near the outer orbital corner. Lower orbital margins with two fissures, of which the outer one is twice as deeply incised as the inner. Right antero-lateral margin is preserved but somewhat decorticated; it has 8 tiny tubercles, of which 6 occur anterior to the hepatic notch. At the lateral extremity there are 3 small tubercles grouped together with the high epibranchial tubercle. Postero-lateral and posterior margins mutilated.

Dorsal surface of carapace with many bosses. Each protogastric subdivision with 2 broad bosses; of these bosses the inner one is high, transverse, and conspicuous, the outer is merely a slight rise on the long outer slope of the other. All 4 protogastric bosses form a broad, low, continuous, transverse ridge. A broad, rounded median ridge extends from the mesogastric to the cardiac region: it is surmounted by a short, elongate and a short, transverse tubercle in metagastric position arranged in the shape of an inverted T; the cardiac region of this median ridge is slightly higher but it is not well separated from the gastric region. Hepatic region is a depressed basin with the deepest place posterior to the outer orbital angle and a small tubercle near its postero-lateral corner. A low, broad ridge extends from the mesobranchial back through the metabranchial subdivision; this ridge has two swellings near its anterior end. The ridge connects at its anterior end with the similar, but short and transverse, epibranchial ridge. At the outer end of the epibranchial ridge is the elongate epibranchial tubercle, which is very near the lateral extremity of the carapace.

The entire carapace surface is covered with very fine granules, which are coarser toward the tops of the major tubercles and ridges; the granules are also coarser on the branchial region.

The branchial regions are separated from the gastric and cardiac regions by a pair of broad, rounded grooves traversing the carapace and merging to the anterior with the hepatic depression. A pair of short, linear, subparallel grooves outlines the anterior extension of the mesogastric subdivision. A pair of very short, linear, transverse pits are set 1 millimeter apart, one at each side of the front tip of the metagastric tubercles which form an inverted T. From each of the pits extends a dark line for about 2 millimeters obliquely outward and forward; these two lines form a broad obtuse V. The semilunar branchio-cardiac grooves are well marked.

Dimensions. — Fronto-orbital width, 7 mm.; width of carapace (reconstructed), 13.5 mm.

Remarks. — This is another species of *Necrocarcinus* which is transitional to *Cenomanocarcinus.* In *Necrocarcinus moseleyi* Stenzel the metabranchial and epibranchial ridges are well developed and in these two features the species comes very close to *Cenomanocarcinus.* However, both ridges are short and carry only a few tubercles. On the other hand, the hepatic ridge, which is so well developed in *Cenomanocarcinus,* is reduced in this species to a single small tubercle.

The *Necr. moseleyi* Stenzel finds its place among the following related species: *Necr. graysonensis* Rathbun, *Necr. texensis* Rathbun, and *Necr. tricarinatus* Bell.

There are numerous differences in the number and arrangement of the carapace tubercles among these species. The differences are shown by text figure 15.

The species is named in honor of Mr. Fred T. Moseley of Dallas, who discovered the monotype.

Type data.—Monotype, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—From an ant hill located in the dell between two hills, of which the northern one is cut by State highway No. 114, about 2 miles northwest of Roanoke on highway No. 114 and about 200 feet south of the highway, Denton County, Texas.

Geologic horizon. — Pawpaw shale. Washita group, Comanche series, Cretaceous (upper Albian). A rich fauna of micromorphs occurs with this crab.

NECROCARCINUS (?) OVALIS Stenzel, n.sp.

Pl. 41, figs. 7–9; text figs. 14, 15

Necrocarcinus ovalis Stenzel *in* Dallas Petroleum Geologists, Geology of Dallas County, Texas, p. 39, fig. 12, 1941.

Description. — Carapace small, transverse-oval, ½ wider than long, outline rounded; greatest width of carapace falling through its center, lateral extremity rounded. Carapace slightly convex from side to side, slightly more convex from front to back. Rostrum convex from front to back, pointing forward and downward, with a broad, obtusely V-shaped median groove, which back of the root of the rostrum forks into two rapidly shallowing grooves, which diverge at an acute angle. Orbits medium, deeply emarginate, only slightly wider than high, with elevated margins; the orbits look forward and upward and slightly outward. Nearly all orbital margins are broken off at the edge, but at least one notch is visible near the outer end of the upper margin. Antero-lateral margin short and convex in outline, interrupted by a deep, rounded hepatic notch. Margin in front of hepatic notch with a group of 2 subequal tubercles; these 2 tubercles are connected by a short, narrow ridge; anteriorly they are separated by a shallow, broad groove from the elevated orbital rim. Antero-lateral margin behind the hepatic notch with 2 groups of 2 subequal tubercles each, each group being similar to the group on the hepatic portion. The 2 groups are separated by a small and shallow notch. The anterior group is smaller; the posterior one lies at the lateral extremity of the carapace and adjoins the large epibranchial tubercle of the carapace surface. Postero-lateral margin longer than antero-lateral, convex in outline, rounded to subangulated, free of tubercles except for one very small one near the lateral extremity of the carapace. Posterior margin short, concave in outline.

Dorsal surface of carapace with many bosses. Subdivisions of gastric region very poorly defined. Mesogastric subdivision with one central boss, from which a low median ridge slopes downward and backward. A very slight rise on this ridge indicates a uro- or metagastric boss. Each protogastric sudivision with 2 low, broad, poorly defined swellings; these four swellings lie in a straight, transverse line; a very inconspicuous tubercle lies at the end of the protogastric subdivision back of and near the outer orbital corner. Hepatic region small, with a small, well-defined boss near the hepatic notch. Branchial subdivisions very poorly defined. A large, broad boss on the mesobranchial subdivision; the epibranchial subdivision with a high, transverse boss near the extremity of the carapace; a broad swelling on the metabranchial subdivision. Cardiac region with a large boss. Intestinal region simple, without any bosses. Cervical grooves deep and broad, extending to the margin of the carapace. A narrow and short but deep groove divides the hepatic region. A broad, shallow groove bounds the posterior of the orbital rims. The cardiac region is bounded on all sides by deep and broad grooves.

Ventral surface of carapace descends vertically from the margin and is smooth. A groove originates at the hepatic notch. This groove descends at first vertically, but later curves forward and extends parallel with the antero-lateral margin, and finally abuts against the middle of the lower orbital margin.

Dimensions.—Length, 12.0 mm., width, 15.3 mm., fronto-orbital width, 7.3 mm.

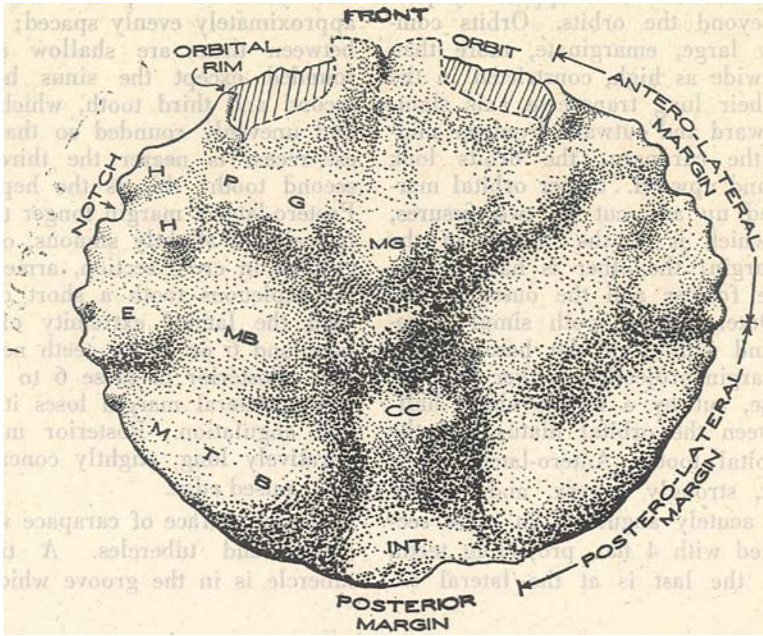

Fig. 14. *Necrocarcinus ovalis* Stenzel, x6; monotype; carapace. CC, cardiac; E, epibranchial; H, hepatic; INT, intestinal; MB, mesobranchial; MG, mesogastric; MTB, metabranchial; PG, protogastric areolation.

Remarks.—This species does not conform closely to the genotype species of *Necrocarcinus* and should be placed in a new genus presumably. However, at this stage of knowledge and with the material at hand, it is inadvisable to propose a new genus.

The species has been placed temporarily in *Necrocarcinus(?)*, because its nearest relations seem to be with the genus *Necrocarcinus* and because it is related to *Necrocarcinus graysonensis* (Rathbun).

The holotype of *Necrocarcinus graysonensis* Rathbun is a small fragment of a carapace. As far as structural features are preserved in that fragment they agree closely with those of *N. (?) ovalis* Stenzel. The differences between the two species are mainly in the shape and to lesser degree in the number of the tubercles. Those tubercles which are common to both species are in the same structural position in both.

Type data.—Monotype, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality. — Three and one-half miles west of Cedar Hill, Dallas County, Texas (Bureau of Economic Geology Coll. No. 460). Collected by Mr. Q. O. Gaither and submitted by Mr. V. V. Waite, Atlantic Oil Producing Company, Dallas, Texas.

Geologic horizon.—Eagle Ford group, Gulf series, Cretaceous (Turonian). In the same collection are the following fossils:

Clidastes sp., lower jaw fragments
Ptychodus cf. whippleyi Marcou
Fish vertebrae
Gastropod cast near Actaeon
Gastropood cast near Natica
Inoceramus prisms and hinge fragments
Worm tubes

The first three fossils listed were identified by Dr. J. T. Gregory.

NECROCARCINUS RENFROAE Stenzel, n.sp.

Pl. 41, fig. 13; text fig. 15

Descrip'ion.—Carapace medium in size, subcordiform in outline; greatest width of carapace anterior of its center, width and length about equal; lateral extremity with a spine but not conspicuous. Carapace flattish, slightly more convex from side to side than from front to back.

Rostrum broken off but apparently projecting beyond the orbits. Orbits comparatively large, emarginate, more than twice as wide as high, constricted in the middle, their long transverse axis slanting downward and outward from the midline of the carapace; the orbits look forward and upward. Upper orbital margin turned up and cut by two fissures, one of which is in the middle of the upper margin; the other is halfway between the former and the outer orbital angle. Outer orbital tooth simple, projecting, and with triangular base. Lower orbital margin projecting farther than the upper one, cut by a fissure about halfway between the orbital hiatus and the outer orbital tooth. Antero-lateral margin short, strongly convex, and rapidly receding, acutely angulated in cross section, armed with 4 flat, projecting teeth, of which the last is at the lateral extremity of the carapace. The 4 teeth are approximately evenly spaced; the sinuses between them are shallow and evenly rounded except the sinus between the second and third tooth, which is deeper and unevenly rounded so that its greatest recess is nearer the third than the second tooth; this is the hepatic notch. Postero-lateral margin longer than antero-lateral and slightly sinuous, obtusely angulated in cross section, armed with one inconspicuous tooth a short distance behind the lateral extremity of the carapace and 6 or 7 tiny teeth near its middle. Posterior to these 6 to 7 teeth the postero-lateral margin loses its definition and angulation. Posterior margin comparatively long, slightly concave, with a thin, raised edge.

Dorsal surface of carapace with narrow ridges and tubercles. A tiny, round tubercle is in the groove which encircles

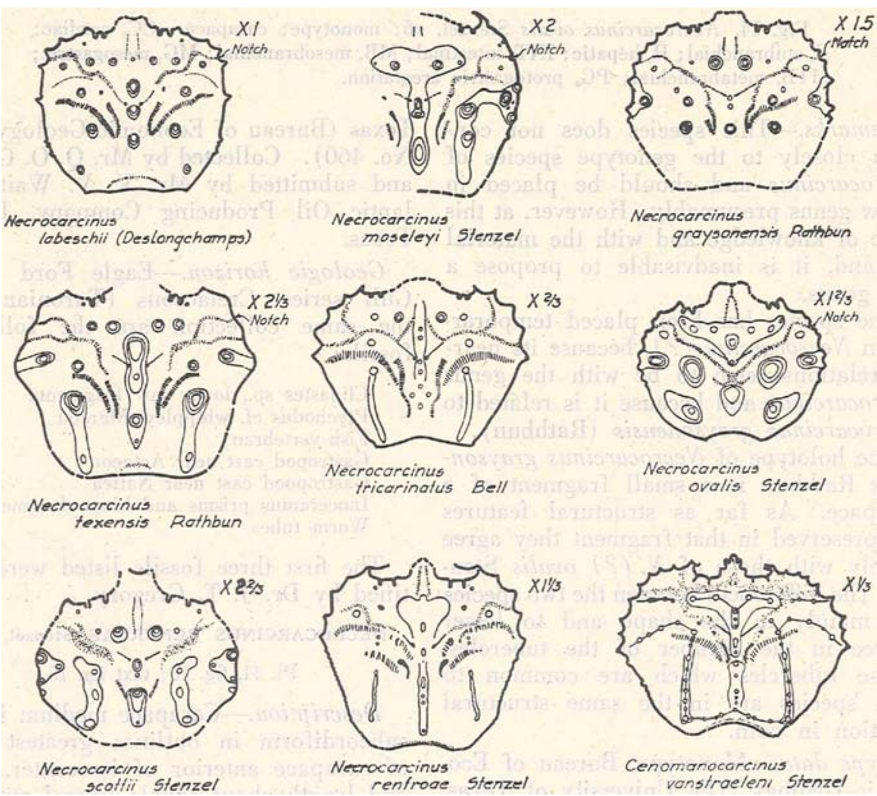

Fig. 15. Outlines of the carapaces of *Necrocarcinus* and *Cenomanocarcinus*. Height and shape of tubercles and swellings are outlined by form contour lines, grooves by stipples, and muscle imprints by cross-hatchures.

the upper orbital margins; it is near and to the outside of the outer orbital fissure. Gastric subdivisions of the carapace poorly defined. The frontal extension of the mesogastric region defined by a pair of parallel, shallow grooves. A small, elongate, narrow, median tubercle is in mesogastric and a similar one is in metagastric position on a median ridge. The median ridge extends from the mesogastric region through to the intestinal region; it carries besides the meso- and metagastric tubercles about 7 unevenly spaced tubercles of which some are narrow and elongate. To either side of the last of these tubercles is a low tubercle very near the posterior margin. Each protogastric region has a very low, broad swelling and a conical tubercle; these four lie in a transverse and nearly straight line with the tubercles at the outside; the tubercles are also in line with the metabranchial ridges. Each hepatic region with a low tubercle. A group of 2 small tubercles arranged longitudinally occupies mesobranchial position. From this group extends a low, rounded, slightly curved ridge outward to the tooth at the lateral extremity of the carapace. Another ridge extends from the same mesobranchial tubercles backward toward the ends of the posterior margin. This metabranchial ridge carries about 10 tiny tubercles in a row. This tubercle row is connected in front by a low, tubercle-free portion of the metabranchial ridge with the mesobranchial tubercles; the last of the 10 tubercles is the highest; with this high tenth tubercle the ridge ends without reaching the posterior margin.

The semilunar branchio-cardiac grooves are deep; obliquely in front of their end is a slightly elongate pit. A pair of short, linear grooves forming a right-angle V is on the median ridge with its tip centering in the metagastric tubercle. A tortuous depression extends from each branchio-cardiac groove forward around and in front of the mesobranchial and the hepatic tubercles and ends in the hepatic notch.

Dimensions.—Holotype: fronto-orbital width, 9.8 mm., width, 18.7 mm., length, 18.0 mm.

Type data.—Holotype and two paratypes, Bureau of Economic Geology, The University of Texas, Austin, Texas.

The species is named in honor of Mrs. J. H. Renfro, of Fort Worth, Texas.

Type locality.—Watauga; slopes at the head of a short, right tributary to a wide, flat-bottomed branch, which is a left tributary of Big Fossil Creek; 0.51 mile east of U. S. highway No. 377 (Fort Worth–Denton road) or 0.40 mile east and 0.08 mile north of Watauga schoolhouse, northern Tarrant County, Texas (Bureau of Economic Geology locality No. 219–T–4); holotype.

Watauga; gullies in pasture about 0.1 mile east and within sight of U. S. highway No. 377, opposite a Texas & Pacific Railroad trestle and 0.2 mile north of Watauga schoolhouse (Bureau of Economic Geology locality No. 219–T–3); paratype.

Buffalo Creek; hills surrounding the headwaters of Buffalo Creek, about 0.2 mile east of south-north road, which leads to Haslet, about 0.35 mile south of the road cross, about 0.5 mile airline distance southeast of Blue Mound and 2.2 miles south of Haslet, northern Tarrant County, Texas (Bureau of Economic Geology locality No. 219–T–2); paratype.

Geologic horizon. — Pawpaw shale. Washita group, Comanche series, Cretaceous (upper Albian). The following fossils occur at the same locality and horizon as the holotype:

Arthropoda—Crustacea:
- Caloxanthus americanus Rathbun
- Ophthalmoplax comancheensis Rathbun
- Xanthosia aspera Rathbun
- Notopocorystes punctatus Rathbun
- Ischnodactylus texanus Rathbun
- Homarus

Mollusca—Cephalopoda:
- Engonoceras serpentinum (Cragin)
- Turrilites worthensis Adkins and Winton
- Submantelliceras worthense (Adkins)

NECROCARCINUS SCOTTI Stenzel, n.sp.

Pl. 41, figs. 10, 11; text fig. 15

Description.—Carapace small, oval in outline, width to length in proportion of 5 to 4, greatest width of carapace falling through its center, lateral extremity rounded. Carapace slightly convex both in longitudinal and transverse directions.

Rostrum longitudinally convex, pointing forward and downward; it is broken off, but the imprint indicates that it is far advanced and bifid at the tip. Rostrum with a median groove, which splits back of the root of the rostrum into a pair of short, shallow, parallel, and closely spaced grooves. This groove pair reaches almost to the high tubercles of the protogastric region. Orbits large, poorly preserved. Antero-lateral margin evenly convex in outline; a small tubercle halfway between orbit and lateral extremity of carapace; two larger, conical, equal tubercles, closely spaced, one behind the other, at the lateral extremity of the carapace. Immediately behind the posterior one of these two tubercles there is a small one at the postero-lateral margin of the carapace. A fourth, epibranchial tubercle is on the dorsal surface of the carapace placed in an equilateral triangle with the two large tubercles of the lateral extremity of the carapace. All four tubercles are on an eminence which occupies the lateral extremity of the carapace. Postero-lateral margin nearly straight, poorly preserved, with only one tubercle, which has been described above. Posterior margin not preserved.

Dorsal surface of carapace with 17 tubercles. Mesogastric region without tubercles or swellings and triangular in outline; its anterior extremity long, narrow, and parallel-sided, extending forward between the two short parallel grooves to the root of the rostrum. Protogastric region each with 2 conical tubercles in a transverse row so that all 4 tubercles are in one transverse line. Of these 4 tubercles the inner pair is high, the outer pair low. Metagastric region with a slightly elongate, round-topped tubercle. On the posterior slope of this subercle is a small, round tubercle, which is urogastric in position. Cardiac region with a high, rounded tubercle, whose anterior slope is steeper than the posterior. Posterior to this tubercle there is a low median ridge, which bears two slight swellings. Mesobranchial region each with two small tubercles forming a short, oblique line. Epibranchial region each with one tubercle near the extremity of the carapace mentioned above. Metabranchial region each with two large, conical tubercles in a longitudinal row.

A pair of broad, continuous grooves separates the branchial from the cardiac and gastric regions. A short, linear groove extends from each side of the metagastric tubercle forward and outward, both grooves forming a broadly obtuse V. Posterior to these grooves are the semilunar branchio-cardiac impressions.

Left carpus small, a little longer than high; the outer surface with 6 equal tubercles. Left manus not quite twice as long as it is high; its lower margin very narrow but rounded in cross section, slightly convex as seen from the outer side; its outer surface gently convex in longitudinal direction, but more convex in transverse direction; the upper portion of the outer surface is turned inward so much as to form a nearly flat, wide upper surface for the manus; outer surface with 3 to 4 obscure, longitudinal rows of about 5 tubercles each; upper margin narrow but rounded in cross section; inner surface of manus with a slightly oblique, longitudinal row of 3 tubercles extending from the manus-carpus joint to the center; inner surface slightly concave just below the upper margin and gently convex through the center.

Dimensions.—Length of carapace without rostrum, 7.8 mm., width of carapace, about 9.4 mm.; height of left manus, 3.6 mm., length of left manus, 5.8 mm.

Remarks.—This species is related to *Necrocarcinus(?) ovalis* Stenzel. The two species have in common the general shape of the carapace and the group of 4 tubercles at the lateral extremity of the carapace. This group is nearly identical in the two species. The only differences are that the epibranchial tubercle of this group is much larger and placed more inward in *N. ovalis* Stenzel than in *N. scotti* Stenzel. The other tubercles of the carapace are similar in a general way in both species, but there are numerous differences between them as to number, shape, and relative position of the tubercles.

Type data.—Monotype, carapace, left manus, and carpus, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Above a muddy tank to the left of the Frisco Railroad tracks, 1 mile northeast of Denison, northeastern Grayson County, Texas (Texas Christian University Coll. No. M542, G852).

Geologic horizon.—Denton clay, Washita group, Comanche series, Cretaceous (upper Albian).

Genus CENOMANOCARCINUS V. Van Straelen, in Stenzel, new gen.

Van Straelen, V., Crustacés décapodes nouveaux ou peu connus de l'époche crétacique: Mus. royal histoire nat. Belgique Bull., vol. 12, no. 45, pp. 37–39, 1936.

Stenzel, H. B., Decapod crustaceans from the Cretaceous of Texas: Univ. Texas Pub. 4401, 1944 [1945].

Genotype.—*Cenomanocarcinus inflatus* (A. Milne-Edwards ms.) from the Cenomanian sands of Le Mans, France, is herewith designated the genotype. The genoholotype is the specimen figured by Van Straelen on Plate 4, figure. 8.

Remarks.—When Van Straelen proposed this genus in 1936 he assigned two species to it: *C. inflatus* (A. Milne-Edwards ms.) Van Straelen, which he described for the first time, and *C. oklahomensis* (Rathbun), to which he gave a pertinent literature reference. However, Van Straelen failed to designate which of the two species is the genotype. According to article 25c(3) of the International Rules of Zoological Nomenclature, it is absolutely necessary to designate definitely and unambiguously the genotype species if the genus is to be valid. This rule applies to all generic names proposed after December 31, 1930. Hence, *Cenomanocarcinus* Van Straelen 1936 is not valid. In order to preserve the name, *Cenomanocarcinus* is herewith proposed anew, and a definite type is proposed. Were it not for the impossibility of getting in touch with Dr. Van Straelen at this time, he would have been asked to validate the genus himself.

CENOMANOCARCINUS VANSTRAELENI Stenzel, n.sp.

Pl. 44; text fig. 15

Description. — Carapace large, transverse-oval, ¼ wider than long; greatest width of carapace through its middle and the lateral spines; lateral extremity with a spine. Carapace equally convex in transverse and longitudinal direction. Fronto-orbital width slightly more than 1/3 of the carapace width. Rostrum convex from front to back; tip pointing forward and downward; outline triangular; with 3 points, the 2 lateral tips turned up; a broad, deep, rounded, V-shaped groove along the middle. Orbits small, deeply emarginate, pointing forward and upward and slightly outward; height about 5/8 of width. Upper orbital margins are turned upward. In going around the orbital margins there is an obtuse dent at the inner end of the upper margin, a well-developed sinus, a short, obtuse point adjoining the first fissure, a short, obtuse point between the two fissures, then follows the second and deeper fissure, a sinus, and the strong outer orbital dent; on the lower margin there is a small point near the outer orbital dent. Antero-lateral margin is acutely angular in cross section and at first nearly straight and transverse, then curving convexly to the lateral extremity. There are 9 spinous tubercles on the antero-lateral margin, the outer orbital dent is the first and the lateral spine the ninth of these. Tubercles 2 to 5 are increasing in size to the posterior, they are separated from the next by the deep, rounded hepatic sinus; among the next tubercles the eighth is the smallest, the seventh is next in size, and the ninth or last is the largest. The postero-lateral margin is gently sinuous; it is obtusely angular in cross section and has only minor tubercles. The first of these tubercles is not far from the lateral spine, the second and third are near the middle of the postero-lateral margin, the others follow immediately behind and are decreasing in size. Posterior margin convex from side to side and concave as seen from above; it is delimited by a groove and narrow rim.

Dorsal surface of carapace with several tubercle-carrying ridges, of which the 3 posterior ones are most conspicuous. The entire surface of the carapace carries granules, but these are coarser and more crowded on the crest of the ridges and the orbital margins. A median ridge extends from the mesogastric to the intestinal region; it is crossed by a deep and broad saddle at the gastro-cardiac boundary. This ridge carries one elongate tubercle on the mesogastric and one on the metagastric region: each of these tubercles is higher in front than in back; on the posterior slope of the metagastric one is a tiny urogastric tubercle. Six tubercles unequal in size and spacing are on the median ridge in the cardiac and intestinal regions. A pair of posteriorly divergent and gently curved ridges begins at the mesobranchial region and extends to the ends of the posterior margin. Each of these ridges has 10 tubercles of unequal size and spacing. The last of the 10 tubercles is the strongest. A transverse ridge connects the two last tubercles; this transverse ridge is very near the posterior margin; it carries up to 9 tubercles of which the median one and the 2 outermost are also on the above described ridges. A curved ridge is on each epibranchial region; it connects with the second tubercle of the other branchial ridge on one side and with the lateral spine on the other side. There are 4 tubercles on this ridge, not counting the lateral spine. A short curved ridge is on each hepatic region; it connects with the sixth spine of the antero-lateral margin and carries 3 tubercles. There are 2 tubercles on each protogastric region arranged transversely. In old age many tubercles of the ridges become nearly confluent and indistinct (see Pl. 44, fig. 2); they are most clearly visible on interior casts of the carapace.

The semilunar branchio-cardiac grooves are deep; their posterior ends are connected by a transverse saddle over the median ridge. Nearly in prolongation of their anterior prong is an isolated pit. A pair of linear and shallow grooves, at right angles one to the other, is on the slope of the median ridge. A tortuous depression extends from the branchio-cardiac grooves forward and outward and delimits the outside of the gastric region; this depression swings outward, just anterior to the hepatic region, and ends in the notch between the fifth and sixth antero-lateral spines. This depression is well marked in the young, but becomes shallow with age.

Coxa of cheliped narrow L-shaped, armed with 4 to 5 spinous tubercles, one of which is very large. Basis is as long as wide. Ischium wider at the anterior side than the posterior, with 3 spines at the distal margin and one spine at the anterior proximal corner. Merus strong, rounded-triangular in cross section; its 3 edges armed with strong spines; additional spines on the lower anterior surface of the merus. Carpus unknown. Manus compressed-oval in cross section, its upper and lower margins straight and divergent; outer surface gently convex and with an obscure, spinulous, longitudinal ridge through its middle; spinules arranged in obscure rows on the outer surface; upper and lower surface narrow and with spinules along their edges. Pollux and dactylus slender, compressed, and high; rectangular in cross section; rows of spinules along their outside edges; toward the curved tips the spinules disappear and are replaced by narrow keels; outer surface of dactylus and pollux with obscure rows of fine spinules; occludent margins with about 6 triangular teeth. Coxa of first ambulatory leg with 2 spines in the middle and 2 small spines at the distal margin; basis short; ischium with 2 spines at the distal margin; merus compressed; rectangular in cross section, armed with small spines along the edges. Second ambulatory leg similar, but its coxa has the two median spines smaller and the two distal spines larger and the ischium has additional spines at its posterior edge. Third ambulatory leg has the coxa with a flaring, spinous, distal edge and the ischium with a rectangular cross section and spines along its edges. The fourth ambulatory leg is missing (see Pl. 44, fig. 3); there is room only for a small leg.

Outer maxilliped is slender: the merus of the endognath widens distally.

Abdomen of female is known (see Pl. 44, fig. 3). The first segment is unknown. The second to fifth segments are short and wide and have three transverse tubercles in a row; these tubercles are transversely elongate; the median tubercle is higher than the lateral pair; on the fourth and fifth segments a transverse ridge starts at the lateral tubercles and extends to the lateral margin; these 4 ridges may carry minor tubercles. The sixth abdominal segment is rectangular, a little wider than long; its 3 tubercles are not in line; the median tubercle is in or near the center, the lateral ones are near the proximal region; all 3 are smaller than those of the preceding segment; the distal corners of the sixth segment are turned up. The seventh segment is poorly preserved; it is presumably triangular. Two continuous, longitudinal depressions extend from segment to segment between the 3 tubercles.

Dimensions.—Syntype 1: fronto-orbital width, 19.5 mm., length of median ridge, 34.5 mm.; syntype 2: width of carapace (restored), 37 mm., fronto-orbital width, 14.5 mm., length of median ridge, 19.7 mm.; syntype 3: greatest width of abdomen, 21 mm.

Remarks.—The genus *Cenomanocarcinus* contains at present the following species:

Cen. inflatus (A. Milne-Edwards), upper Cenomanian, France
Cen. armatus (Rathbun),[34] upper Albian, Texas
Cen. oklahomensis (Rathbun),[35] upper Albian, Oklahoma
Cen. vanstraeleni Stenzel, Turonian, Texas

There are also certain species which are transitional between *Cenomanocarcinus* and *Necrocarcinus.* These species are:

Necr. tricarinatus Bell,[36] Cenomanian, England
Necr. texensis Rathbun,[37] upper Albian, Texas
Necr. graysonensis Rathbun,[38] upper Albian, Texas

[34]Rathbun, M. J., Fossil Crustacea of the Atlantic and Gulf Coastal Plain: Geol. Soc. Amer., Spec. Paper 2, pp. 50–51; pl. 11, figs. 32, 33, 1935.

[35]Rathbun, M. J., *op. cit.*, pp. 44–45; pl. 11, fig. 9.

[36]Bell, Thomas, A monograph of the fossil malacostracous Crustacea of Great Britain, pt. 2. Crustacea of the Gault and Greensand: Palaeontograph. Soc., vol. 14, pp. 21–22; pl. 4, figs. 9–11, 1863.

[37]Rathbun, M. J., *op. cit.*, pp. 45–46; pl. 11, figs. 20–22.

[38]Rathbun, M. J., *op. cit.*, p. 45; pl. 11, figs. 23–25.

Whereas in the genus *Cenomanocarcinus* the carapace ridges on the carapace are distinctive, the transitional species have the ridges entirely or partially dismembered into rows of separate tubercles. In *Necrocarcinus texensis* Rathbun the carapace ridges are intact on the metabranchial and gastric regions; but the median ridge is not developed on the cardiac region, where a large solitary round tubercle replaces the ridge. In *Necrocarcinus graysonensis* Rathbun there are no ridges, but the tubercles are arranged in rows and these rows coincide in position with the ridges of *Cenomanocarcinus.* In typical *Necrocarcinus,* that is, in the genotype species *N. labeschii* (Deslongchamps), the tubercles are also arranged in obscure rows and these rows coincide in position with the ridges of *Cenomanocarcinus,* but the number of tubercles is reduced making the arrangement in rows rather obscure.

Among the species of *Cenomanocarcinus, Cen. armatus* (Rathbun) is somewhat doubtful, because it is based merely on a part of the abdomen. It was described by Rathbun as *Raninella(?),* but the abdomen is almost exactly like the one of *Cen. vanstraeleni* Stenzel, except that it is much smaller and that the median spines are much larger in proportion. Therefore, it seems probable that this abdomen represents a *Cenomanocarcinus* or possibly a genus very nearly related to *Cenomanocarcinus,* such as *Necrocarcinus.* On the other hand, the stratigraphic position of *Cen. armatus* (Rathbun) precludes the possibility that it be the abdomen of a young *Cen. vanstraeleni* Stenzel.

Differences between the other three species of *Cenomanocarcinus* are summarized below.

Species	Number of Tubercles on Ridges				
	Proto-gastric	Hepatic	Epi-branchial	Meso-meta-branchial	Cardiac-intestinal
Cen. inflatus (A. Milne-Edwards)	2	2	2	8	3
Cen. oklahomensis (Rathbun)	2	2	2	8	3
Cen. vanstraeleni Stenzel	2	3	4	10	6

Cenomanocarcinus vanstraeleni Stenzel is the most spinous and most tuberculate of the three species. It is named in honor of Dr. Victor Van Straelen, director of the Musée royal d'Histoire naturelle de Belgique.

Type data.—Nine syntypes, Bureau of Economic Geology, The University of Texas, Austin, Texas.[39]

Type locality.—Same as *Linuparus grimmeri* Stenzel.

Geologic horizon.—Same as *Linuparus grimmeri* Stenzel.

Subtribe DROMIACEA de Haan

Superfamily DROMIIDEA Alcock

Family PROSOPONIDAE von Meyer

Genus RATHBUNOPON Stenzel, new gen.

Genotype.—*Rathbunopon polyakron* Stenzel, n.sp.

This genus contains so far only two species; one is the genotype species, the other is *Rathbunopon oblitum* (Carter)[40] from the Cambridge greensand (upper Albian) of England. Carter had placed the species under the genus *Mithracia* Bell;[41] however, Glaessner recognized that it did not belong there, but should be placed in a new genus. This was indicated by Glaessner[42] in listing the species under "Nov. gen." As Glaessner did not propose a name for this new genus it is necessary to name it now. The name proposed is in honor of the late M. J. Rathbun, the outstanding carcinologist. The genus is based on the Texas species rather than the English one, because the former is better known to the writer.

Generic definition of Rathbunopon.—Carapace ovoid in outline, slightly longer than wide; fronto-orbital width about 3/4 of width. Frontal rostrum short, barely projecting, triangular and with a median groove. Orbits well defined, about twice as wide as high, with two notches on the upper margin and a projecting dentiform tubercle on the lower margin. Lateral margins of carapace poorly defined. Cervical and other grooves deep. Urogastric and metagastric regions well separated and of the shape of transverse bars. Mesobranchial region bilobed toward the cardiac grooves. Metabranchial regions large, confluent or nearly confluent at midline.

The geological range of the genus is upper Albian and lower Cenomanian.

For convenience of comparison, the original description of *Rathbunopon oblitum* (Carter) is repeated below.

RATHBUNOPON POLYAKRON Stenzel, n.sp.

Pl. 41, figs. 18–21; text fig. 16

Description.—Carapace small, ovoid in outline, slightly longer than wide; greatest width of carapace across the middle of the posterior half of the carapace, lateral extremity ill defined. Carapace gently and uniformly convex in transverse direction, slightly more convex from front to back. Rostrum triangular in outline, convex so that the very tip points straight down; with a broad, obtusely V-shaped, pronounced median groove, which continues from the tip to the posterior and merges into the 2 grooves enclosing the mesogastric region. Orbits large, deeply emarginate, about twice as wide as high; their margins occupied by 4 dentiform tubercles, which are separated by grooves or deep notches; in going around the orbital margin there is an obtuse dent at the inner end of the upper margin, a deep groove follows, then a low, dentiform tubercle in the middle of the upper margin, a deep and narrow notch, a high, curved dent at the outer end of the orbit, another deep and narrow notch, then a flat, triangular dent in the middle of the lower margin, and last a deep and wide notch which is the orbital hiatus. The fronto-orbital width is large. Antero-lateral margin receding and nearly straight except for the interruptions of bosses and grooves. Notch separating orbital from hepatic portion of antero-lateral margin pronounced and narrow; notch separating

[39]Assistance in the preparation of these materials was furnished by the Work Projects Administration Official Project No. 665-66-3-233.

[40]Carter, James, A contribution to the paleontology of the decapod Crustacea of England: **Geol. Soc. London** Quart. Jour., vol. 54, pp. 31–32; pl. 2, fig. 4, 1898.

[41]Bell, Thomas, A monograph of the fossil malacostracous Crustacea of Great Britain, pt. 1, Crustacea of the London clay: Palaeontograph. Soc., vol. 10, p. 9, 1858. Genotype by monotypy, ***Mithracia libinoides*** Bell, from the Eocene of England.

[42]Glaessner, M. F., Crustacea decapoda: Fossilium Catalogus, I, pt. 41, p. 427, 1929.

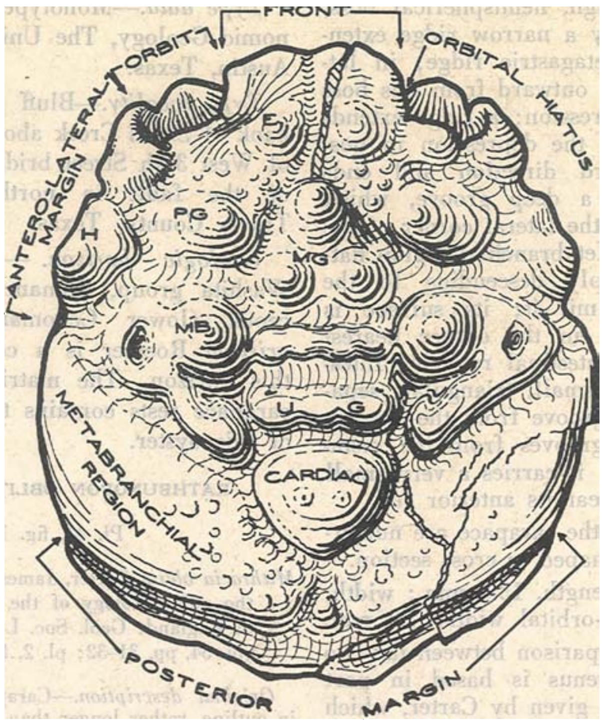

Fig. 16. *Rathbunopon polyakron* Stenzel, x6; monotype; carapace. E, epigastric; H, hepatic; MB, mesobranchial; MG, mesogastric; PG, protogastric; UG, urogastric areolation.

hepatic from metabranchial portion pronounced and wide. Hepatic portion of margin with a conical boss pointing up and out. Lateral margin of the metabranchial region narrowly rounded at its most anterior point, but rapidly and completely losing definition in posterior direction. Posterior margin raised for a width of about one-half millimeter, and separated from the remainder of the dorsal surface by a well-defined groove, which is wide in the middle but narrow toward both sides.

Dorsal surface of carapace with many bosses in its anterior half. Subdivisions of the regions very well defined by grooves. Mesogastric subdivision with 3 conical bosses in an equilateral triangle, the median and anterior one of the 3 bosses being the highest and sharpest. Each epigastric subdivision with a conical boss placed far forward between the orbits; each protogastric subdivision with a wide boss in line with the anterior mesogastric cone; between these two bosses, the epigastric and protogastric, is a slightly swollen, granulated area; the protogastric boss has a steep inner slope and a gentler, humpy outer slope. Metagastric region is a narrow, round-topped, slightly humpy, transverse ridge connecting by a narrower extension with the large mesobranchial bosses to both sides. Urogastric region is also a narrow, round-topped, slightly humpy, transverse ridge, but it is slightly narrower in its middle than at the ends, its ends descend abruptly into a deep and narrow groove, and it has on its anterior slope two widely spaced pits, each near the end of the ridge. Cardiac region is a transverse triangle with curved sides; its top is gently curved, the sides descend steeply into the enclosing grooves; there are two tiny pits a little more than a millimeter apart in a transverse row on its top. Hepatic region very small, without boss except the one at the anterolateral margin. Mesobranchial region occupied by a high, hemispherical boss, which connects by a narrow ridge extension with the metagastric ridge; in lateral direction and outward from this boss lies a walled depression; a ridge extends from the wall of the depression in posterior and inward direction and ends abruptly toward a deep groove, which separates it from the lateral corner of the cardiac region. Metabranchial region flat-topped and steeply descending to the grooves which limit it; its surface is slightly granulate in the corner nearest the cardiac and intestinal regions. Intestinal region very small, triangular, separated by a deep groove from the cardiac and by shallow grooves from the metabranchial regions; it carries a very small conical tubercle near its anterior end.

The grooves of the carapace are numerous, deep and U-shaped in cross section.

Dimensions.—Length, 13.8 mm.; width, 12.1 mm.; fronto-orbital width, 7.8 mm.

Remarks.—Comparison between the two species of this genus is based in part on the description given by Carter, which is not clear in some points. It is impossible to compare the orbits in detail, because Carter neglected to describe them in *Rathbunopon oblitum* (Carter). The anterior half of the carapace is much more sculptured in *R. polyakron* Stenzel than in *R. oblitum* (Carter), particularly the mesobranchial region. This region seems to be devoid of tubercles or depressions in *R. oblitum* (Carter), but has a high, hemispherical boss and a round depression in *R. polyakron* Stenzel. There is considerable difference in the shape of the hepatic region. The tubercles on the protogastric region are different or differently placed in the two species. The shape of the cardiac region is pentagonal in *R. oblitum* (Carter) and triangular in *R. polyakron* Stenzel. A small, triangular intestinal region such as is indicated in *R. polyakron* Stenzel is absent in *R. oblitum* (Carter), in which the two metabranchial regions are joined in the center.

The specific name is derived from the Greek πολυς, "many," and ακρον, "height," and refers to the numerous elevations on the carapace.

Type data.—Monotype, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Bluff on west or right bank of Shoal Creek about 900 feet south of West 34th Street bridge and northwest of the fault in northwestern Austin, Travis County, Texas.

Geologic horizon. — Grayson marl, Washita group, Comanche series, Cretaceous (lower Cenomanian). *Exogyra arietina* Roemer is a common fossil at this horizon. The matrix on which the carapace rests contains two upper valves of this oyster.

RATHBUNOPON OBLITUM (Carter)

Pl. 41, fig. 17

Mithracia oblita Carter, James, A contribution to the palaeontology of the decapod Crustacea of England: Geol. Soc. London Quart. Jour., vol. 54, pp. 31–32; pl. 2, fig. 4, 1898.

Original description.—Carapace broadly ovoid in outline, rather longer than wide, highly vaulted transversely, strongly deflexed in front. Rostrum small, entire. Orbito-frontal border equal to two-thirds the length of the carapace. Posterior border slightly wider than the orbito-frontal. A sharp cervical sulcus indents the antero-lateral border, crosses the carapace, and marks off the cephalic region, which occupies scarcely the anterior third of the dorsal area, and is rendered nodular by the prominent gastric lobes. The two nodules near the base of the rostrum represent the epigastric lobes; a small tubercle intervenes between the epigastric and the orbit; three nodules occur upon the mesogastric, and one on each metagastric;[43] the hepatic lobe is very small; the urogastric is unusually large: cardiac lobe pentagonal, and slightly elevated. A deep sulcus extends from the angles of the cardiac lobe and runs parallel with the cervical sulcus. Epibranchial lobe piriform; inner half of the mesobranchial bilobed; metabranchials large and confluent posteriorly. The whole of the dorsal surface of the carapace bears traces of depressed tubercles of moderate size. Orbits small, round, four diameters apart. Abdomen of the female seven-jointed (?); each segment trilobed, and the penultimate the largest; telson rather small. Limbs and other appendages undetermined. Length of carapace=16 mm. Width (metabranchial)=15 mm.

Original remarks.—This species has a general resemblance to *M. libinioides* of the London Clay, of which it is probably an ancestral form. It is

[43]Carter presumably means the protogastric region in this instance [Stenzel].

of smaller size, and may be further distinguished from that species by the more delicate granulation of the surface, and by the nodulated cephalic area; the hepatic and branchial lobes are less inflated, and the anterior branchial lobes relatively larger, consequently the space between the cervical and transverse branchial sulci is greater than in *M. libinioides.* The granulation of the dorsal surface being much less distinctly marked than in *M. libinioides* renders the carapace comparatively smooth.

Distribution.—Cambridge Greensand.

PLATE 34

PAGE

Linuparus grimmeri Stenzel, n.sp., x2 406

1, 2. Dorsal view of carapace, syntype 2. Figure 2 shows traces of the natural coloration. Figure 1 was photographed after coating with white ammonium chloride sublimate.

3, 4. Dorsal and ventral views of portion of carapace anterior to postcervical grooves with the first antennar segment attached, syntype 3.

From California Crossing, north-facing bluff on right bank of Elm Fork of Trinity River upstream from and at Chicago, Rock Island & Pacific Railroad bridge, in southwest corner of Joshua McCants survey, on O'Connor dairy land, about 10 miles northwest of Dallas, Dallas County, Texas; Britton formation of Eagle Ford group, Gulf series, Cretaceous (lower Turonian or Salmurian).

Linuparus watkinsi Stenzel, n.sp., x2 408

5. Dorsal view of carapace with first antennar segment and some legs, syntype 3.

6. Dorsal view of complete abodomen, syntype 4. This is the same specimen as Plate 45, figure 2; the abdomen was unrolled for this figure by taking separate photographic exposures of ea[illegible] [illegible]gment and assembling the photographs in sequence.

7, 8. Ventral and dorsal v[illegible] syntype 2. Note the prominent jaws in figure 7; sternu[illegible] pairs of ambulatory legs are also visible.

From California C[illegible] [illegible]-facing bluff on right bank of Elm Fork of Trinity River upstream [illegible] and at Chicago, Rock Island & Pacific Railroad bridge, in southwest co[illegible] of Joshua McCants survey, on O'Connor dairy land, about 10 miles northw[illegible]st of Dallas, Dallas County, Texas; Britton formation of Eagle Ford group, Gulf series, Cretaceous (lower Turonian or Salmurian).

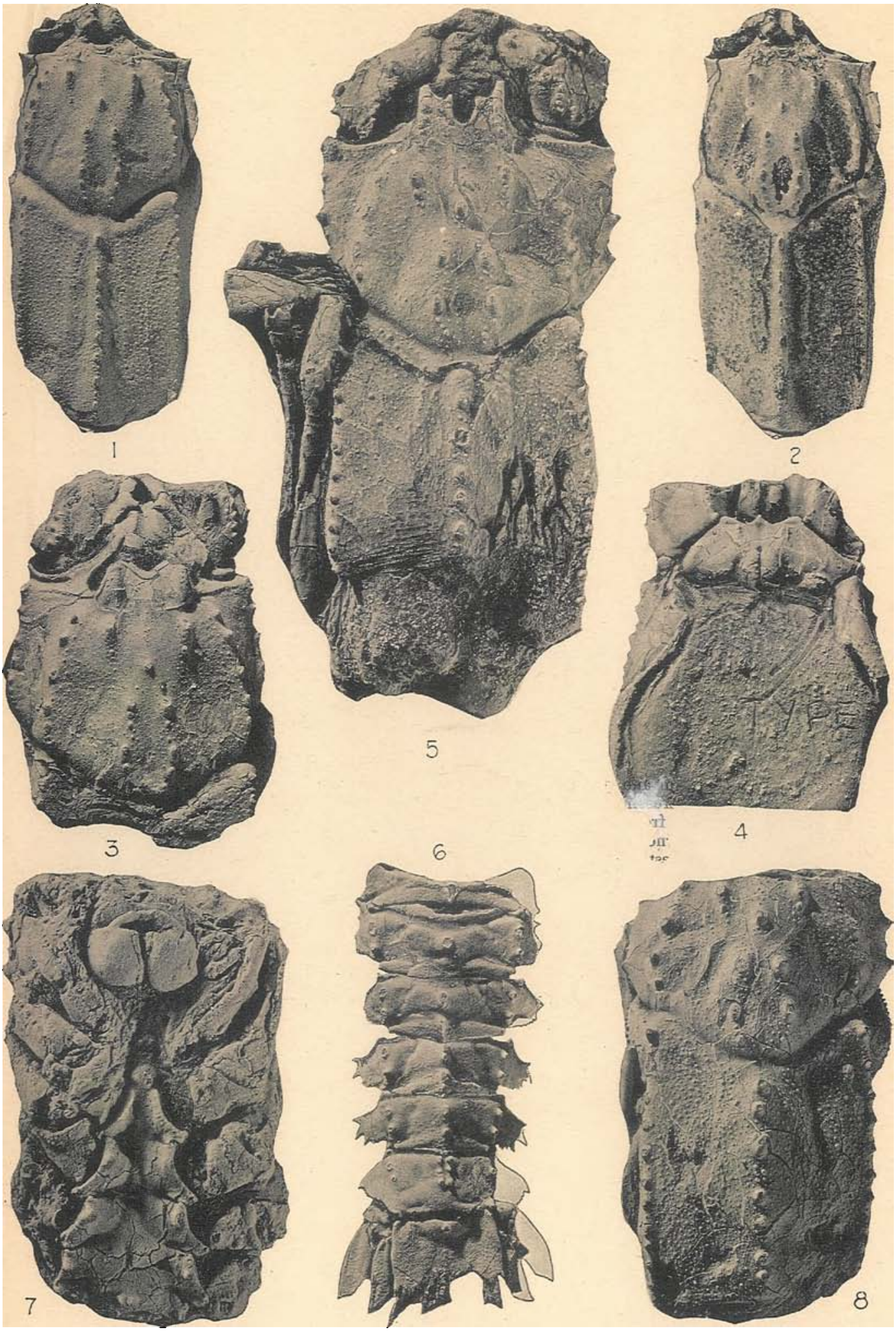
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PLATE 35

PAGE

Linuparus grimmeri Stenzel, n.sp. 406

1. Oblique dorsal view of nearly complete specimen lying on the matrix of a long calcareous concretion, syntype 1, x1½.

5, 6. Ventral and dorsal views of carapace and attached abdomen, syntype 4, x2.

From California Crossing, north-facing bluff on right bank of Elm Fork of Trinity River upstream from and at Chicago, Rock Island & Pacific Railroad bridge, in southwest corner of Joshua McCants survey, on O'Connor dairy land, about 10 miles northwest of Dallas, Dallas County, Texas; Britton formation of Eagle Ford group, Gulf series, Cretaceous (Lower Turonian or Salmurian). Syntype of figure 1 collected by Mr. R. A. Grimmer.

Astacodes maxwelli Stenzel, n.sp., x¾ 410

2. Oblique dorsal view of specimen with eyes, some legs, and extended abdomen, syntype 4.

3, 4. Dorsal and lateral views of specimen with traces of antennae and partly rolled-in abdomen, syntype 1.

From quarries on east side of State highway No. 188 (Roxton-High road) extending from the vicinity of Arkansas Church, 2.1 miles, to 1.1 miles north of the railway depot at Roxton, southwestern Lamar County, Texas; Roxton limestone, top part of Gober chalk tongue of Austin chalk, Gulf series, Cretaceous (Santonian).

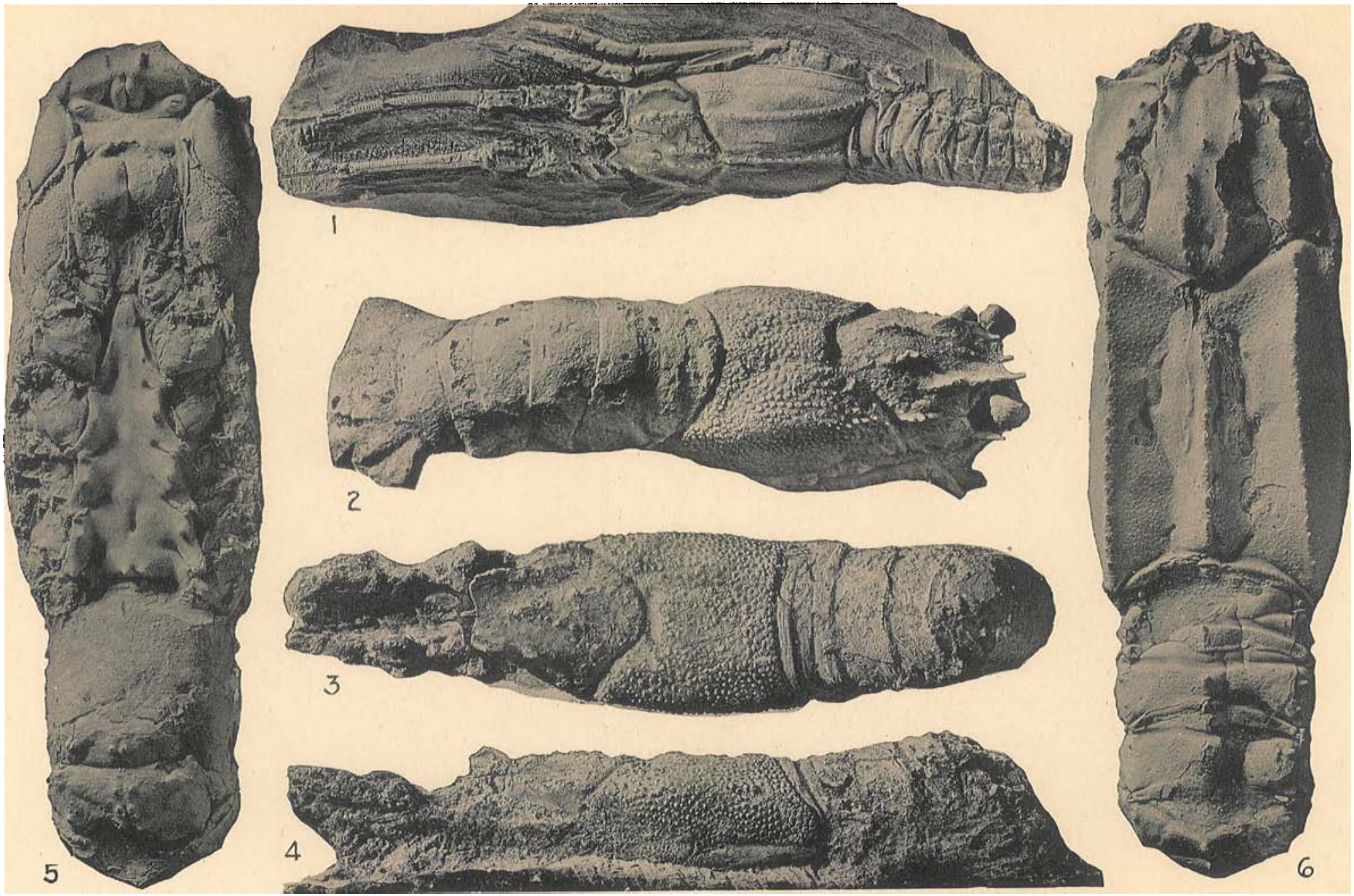

Plate 35

PLATE 36

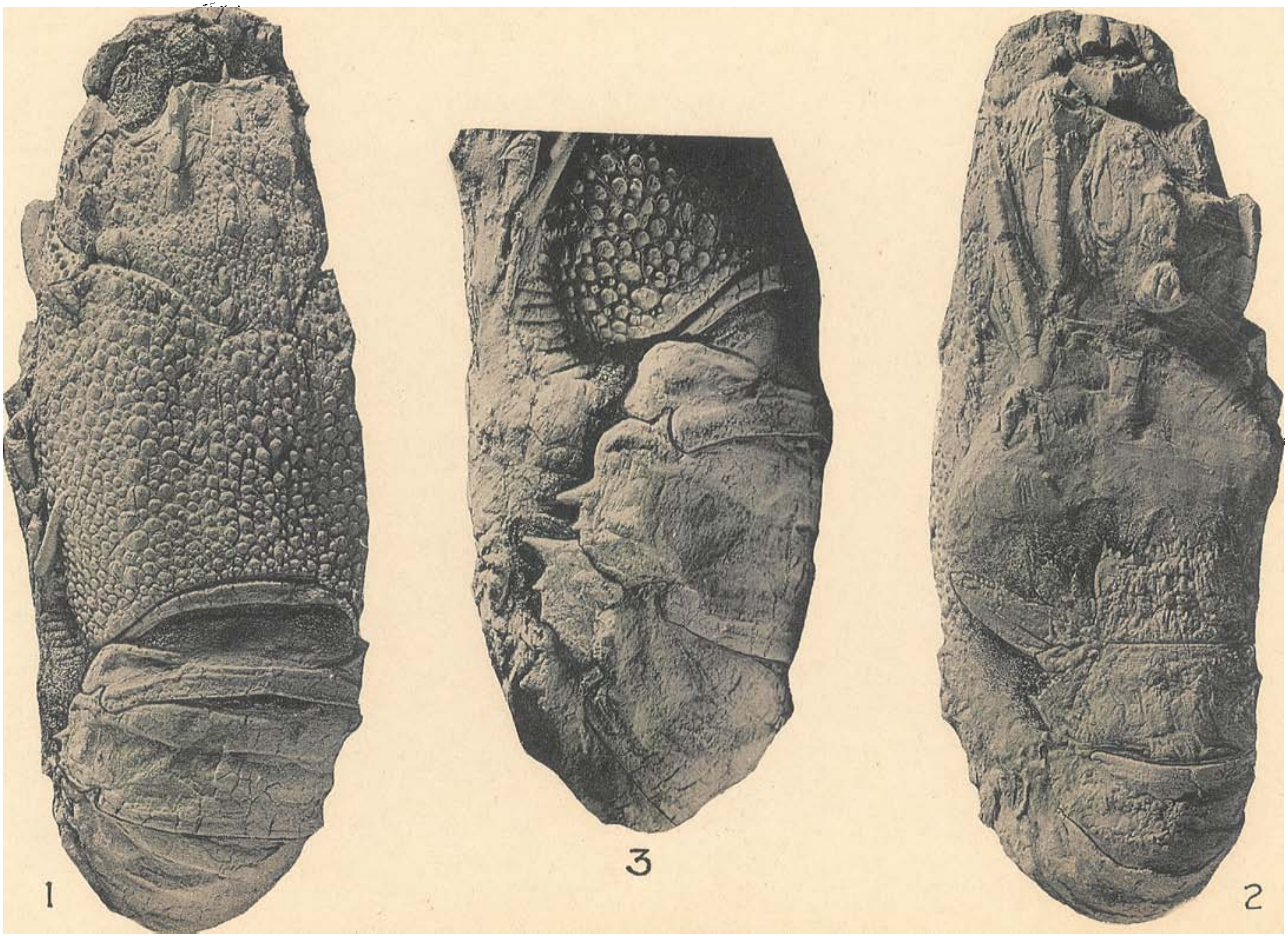

Plate 36

PLATE 37

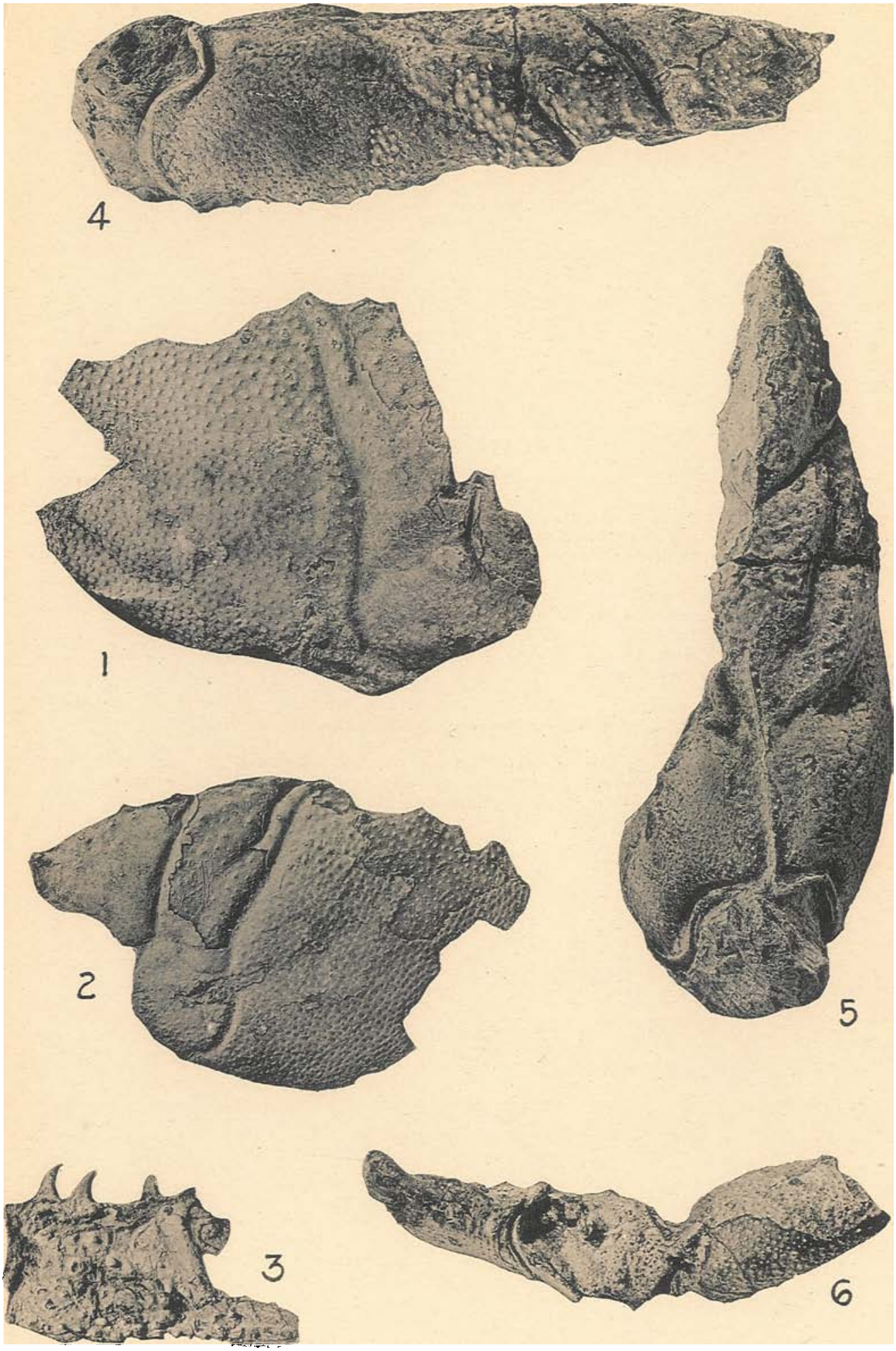
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PLATE 38

1, 2. Outside surface of complete right cheliped and dorsal view of tail fan with two preceding abdominal segments (segments 5 and 6) belonging to the same individual.

From Toland's farm, 4 miles west of Argyle, Denton County, Texas; Weno formation, Washita group, Comanche series, Cretaceous (upper Albian); Wm. T. Watkins, collector.

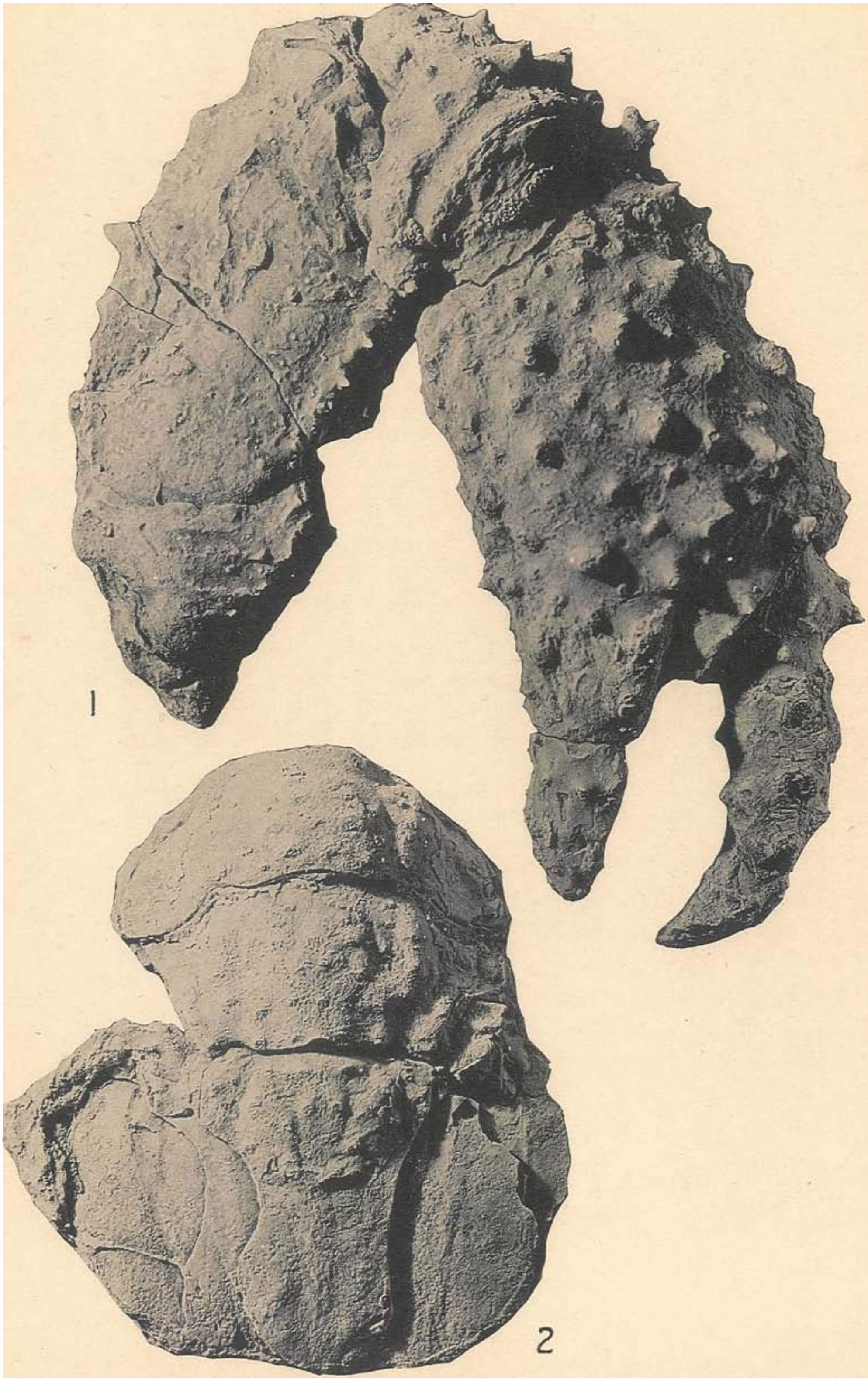
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PLATE 39

PAGE

Enoploclytia walkeri (Whitfield), x1 416

1. Left side of carapace, flattened by rock weight.

From small waterfall in Sycamore Creek valley at crossing of Houston & Texas Central and International & Great Northern railroads, 2½ miles southeast of Fort Worth, Tarrant County, Texas; basalmost stratum of Weno limestone, Washita group, Comanche series, Lower Cretaceous (upper Albian); W. S. Adkins, collector, 1919.

PLATE 40

PAGE

Homarus brittonestris Stenzel, n.sp., x2¼ 425

1. Dorsal view of complete rostrum, syntype 4.
2. Lateral view of compressed specimen, syntype 3.
3. Lateral view of compressed specimen, syntype 1.
4. Lateral view of compressed abdomen with 5 complete segments (2 to 6), syntype 2.

5–7. Upper, outer, and inner surface of right manus, syntype 5.
[D = distal, P = proximal end.]

From California Crossing, north-facing bluff on right bank of Elm Fork of Trinity River upstream from and at Chicago, Rock Island & Pacific Railroad bridge, in southwest corner of Joshua McCants survey, on O'Connor dairy land, about 10 miles northwest of Dallas, Dallas County, Texas; Britton formation of Eagle Ford group, Gulf series, Cretaceous (lower Turonian or Salmurian).

Homarus davisi Stenzel, n.sp., x1½ 427

8. Dorsal view of obliquely flattened monotype, carapace and first 4 segments of abdomen (1–4).

From California Crossing, north-facing bluff on right bank of Elm Fork of Trinity River upstream from and at Chicago, Rock Island & Pacific Railroad bridge, in southwest corner of Joshua McCants survey, on O'Connor dairy land, about 10 miles northwest of Dallas, Dallas County, Texas; Britton formation of Eagle Ford group, Gulf series, Cretaceous (lower Turonian or Salmurian).

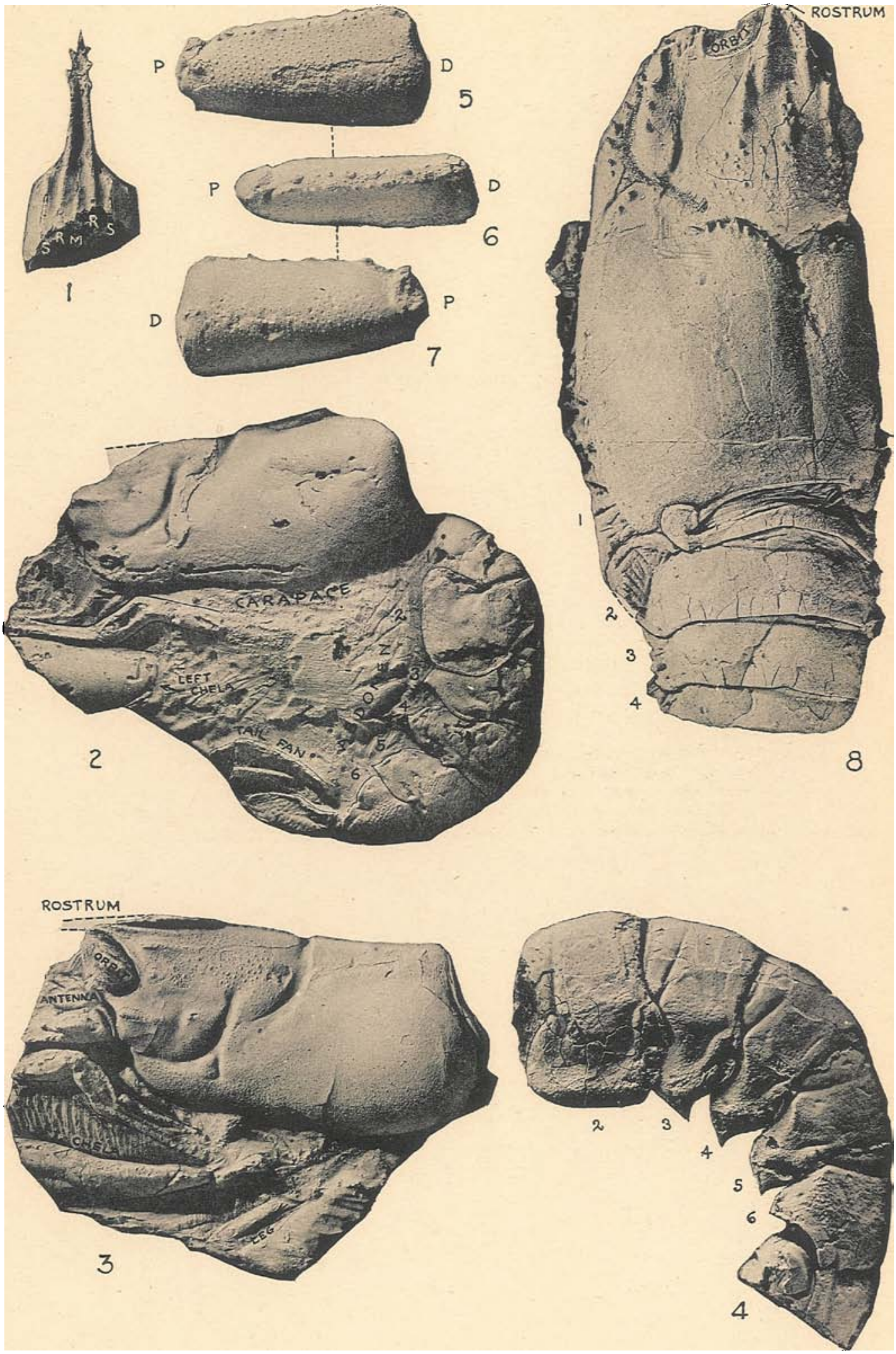
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PLATE 41

PAGE

"*Nephrops*" *americanus* Rathbun, x2¼ 429

1, 2. Outer and inner surface views of a right manus, specimen 1.
From Watauga; slopes at the head of a short, right tributary to a wide, flat-bottomed branch which is a left tributary of Big Fossil Creek; 0.51 mile east of U.S. highway No. 377 or 0.40 mile east and 0.08 mile north of Watauga schoolhouse, northern Tarrant County, Texas (Bureau of Economic Geology locality No. 219–T–4); Pawpaw shale, Washita group, Comanche series, Cretaceous (upper Albian).

3, 4. Inner and outer surface views of a left manus with stumps of the fingers, specimen 2. In figure 3 the upper margin of the manus is the bottom of the figure.

5. Inner surface view of a left manus, specimen 3.
From Watauga; gullies in pasture about 0.1 mile east and within sight of U.S. highway No. 377, Fort Worth-Denton road, opposite a Texas & Pacific Railroad trestle and 0.2 mile north of Watauga schoolhouse, northern Tarrant County, Texas (Bureau of Economic Geology locality No. 219–T–3); Pawpaw shale, Washita group, Comanche series, Cretaceous (upper Albian).

6. Inner surface view of distal end of a left manus with the fingers complete and in place. Figures 5 and 6 are complementary and provide control for reconstruction of a complete left manus, although the two specimens do not belong to the same individual. This evidence is important for generic placement and correction of the fingers; see text.
From high bluff opposite Cobb brick plant, 100 yards north of the Houston & Texas Central Railroad bridge on Sycamore Creek between Mansfield road and crossroad going east from Katy Lake; south-southeast of the center of Fort Worth, Tarrant County, Texas (collection numbers M541, G850, Texas Christian University); Pawpaw shale, Washita group, Comanche series, Cretaceous (upper Albian).

Necrocarcinus (?) ovalis Stenzel, n.sp., x2¼ 442

7–9. Dorsal, frontal, and right lateral views of carapace, monotype.
From 3½ miles west of Cedar Hill, Dallas County, Texas (Bureau of Economic Geology Coll. No. 460); Eagle Ford group, Gulf series, Cretaceous (Turonian). Collected by Mr. Q. O. Gaither and submitted by Mr. V. V. Waite, Atlantic Oil Producing Company, Dallas, Texas.

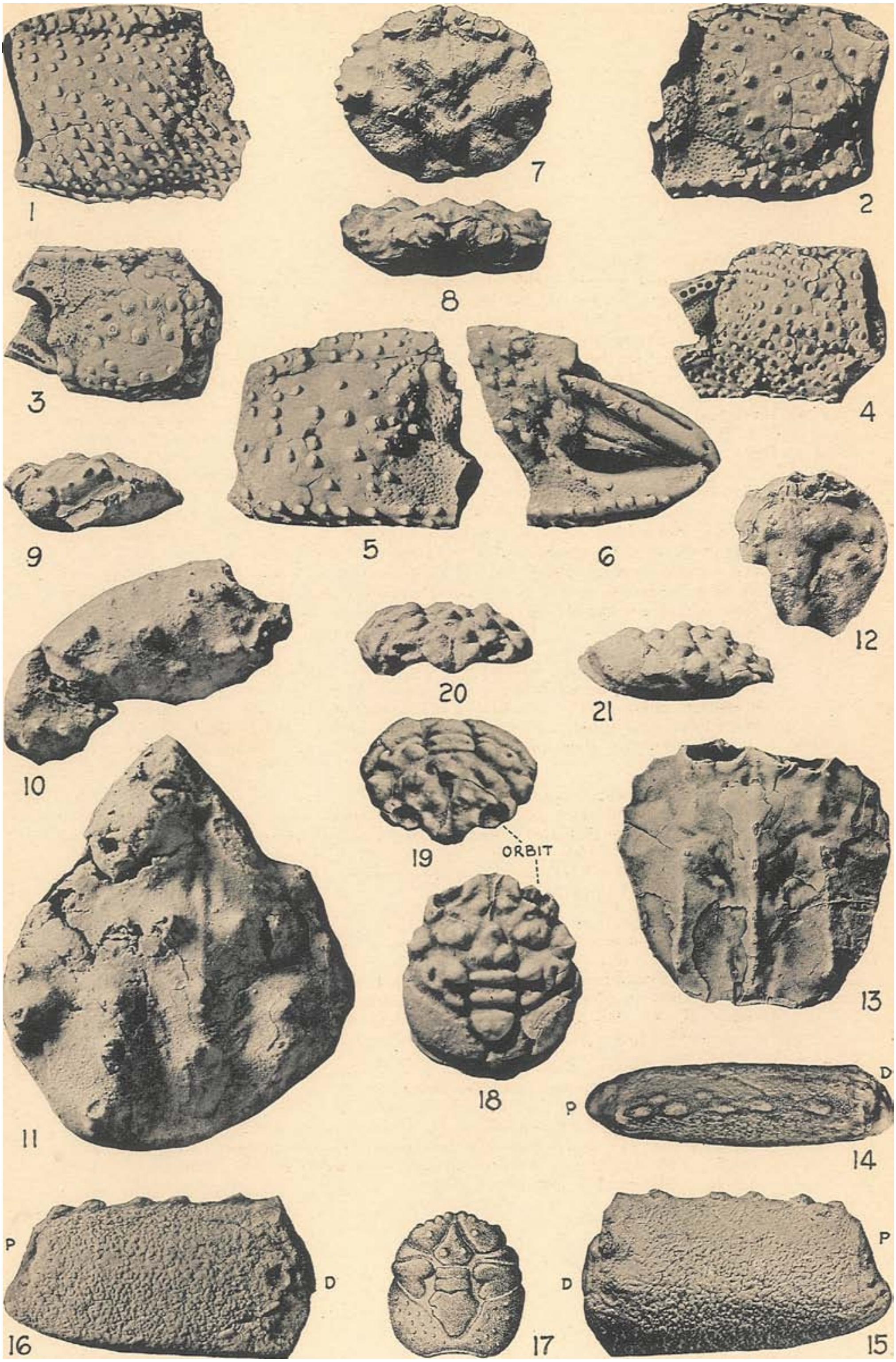
Necrocarcinus scotti Stenzel, n.sp., x5⅔ 445

10. View of outer surface of carpus and manus of left cheliped, monotype.

11. Dorsal view of carapace, monotype.
From above a muddy tank to the left of the Frisco Railroad tracks, 1 mile northeast of Denison, northeastern Grayson County, Texas (Texas Christian University Coll. No. M542, G852); Denton clay, Washita group, Comanche series, Cretaceous (upper Albian).

Necrocarcinus moseleyi Stenzel, n.sp., x2¼ 441

12. Dorsal view of incomplete carapace, monotype.
From an ant hill located in the dell between two hills, of which the northern one is cut by State highway No. 114, about 2 miles northwest of Roanoke on highway No. 114 and about 200 feet south of the highway, Denton County, Texas; Pawpaw shale, Washita group, Comanche series, Cretaceous (upper Albian). Mr. Fred T. Moseley, collector.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Necrocarcinus renfroae Stenzel, n.sp., x2¼ 443
13. Dorsal view of carapace, holotype.
From Watauga; slopes at the head of a short, right tributary to a wide, flat-bottomed branch which is a left tributary of Big Fossil Creek; 0.51 mile east of U.S. highway No. 377 or 0.40 mile east and 0.08 mile north of Watauga schoolhouse, northern Tarrant County, Texas (Bureau of Economic Geology locality No. 219–T–4); Pawpaw shale, Washita group, Comanche series, Cretaceous (upper Albian). Mrs. J. H. Renfro, collector.

Homarus travisensis Stenzel, n.sp., x2¼ 423
14–16. Views of upper margin, outer surface, and inner surface of right manus, monotype. Abbreviations used: D, distal; P, proximal end.
From old road metal pit on southwest side of Austin-Bull Creek-Anderson Mill road, on divide between Dry Creek and Shoal Creek drainage, about 8,000 feet northeast of Mount Bonnell in airline distance, Travis County, Texas; yellow clay marl of Walnut formation, Fredericksburg group, Comanche series, Cretaceous (midde Albian). Ralph H. King and George Harris, collectors.

Rathbunopon oblitum (Carter), x1⅓ 452
17. Reduced copy of type figure.
From the Cambridge greensand, Cretaceous (upper Albian); England.

Rathbunopon polyakron Stenzel, n.g., n.sp., x2¼ 450
18–21. Dorsal, oblique-frontal, frontal, and right lateral views of carapace, monotype. Abbreviations used: F, front; P, posterior of carapace; O, orbit.
From bluff on west or right bank of Shoal Creek about 900 feet south of West 34th Street bridge and northwest of the fault in northwestern Austin, Travis County, Texas; Grayson marl, Washita group, Comanche series, Cretaceous (lower Cenomanian).

PLATE 42

1. Right side view of a concretion with complete abdomen and pieces of carapace and legs, syntype 1.
2. Right side view of a concretion with nearly complete abdomen and coprolites, syntype 2.
3. Right side view of a concretion with complete abdomen and pieces of carapace and legs, syntype 3.

4–6. Successive dorsal views of an abdomen, syntype 4.

7–10. Views of lower margin, outer surface, upper margin, and inner surface of a right carpus and manus, syntype 6.

11–14. Views of upper margin, lower margin, inner surface, and outer surface of a right manus with fixed finger, syntype 7.

From California Crossing, north-facing bluff on right bank of Elm Fork of Trinity River upstream from and at Chicago, Rock Island & Pacific Railroad bridge, in southwest corner of Joshua McCants survey, on O'Connor dairy land, about 10 miles northwest of Dallas, Dallas County, Texas; Britton formation of Eagle Ford group, Gulf series, Cretaceous (lower Turonian or Salmurian).

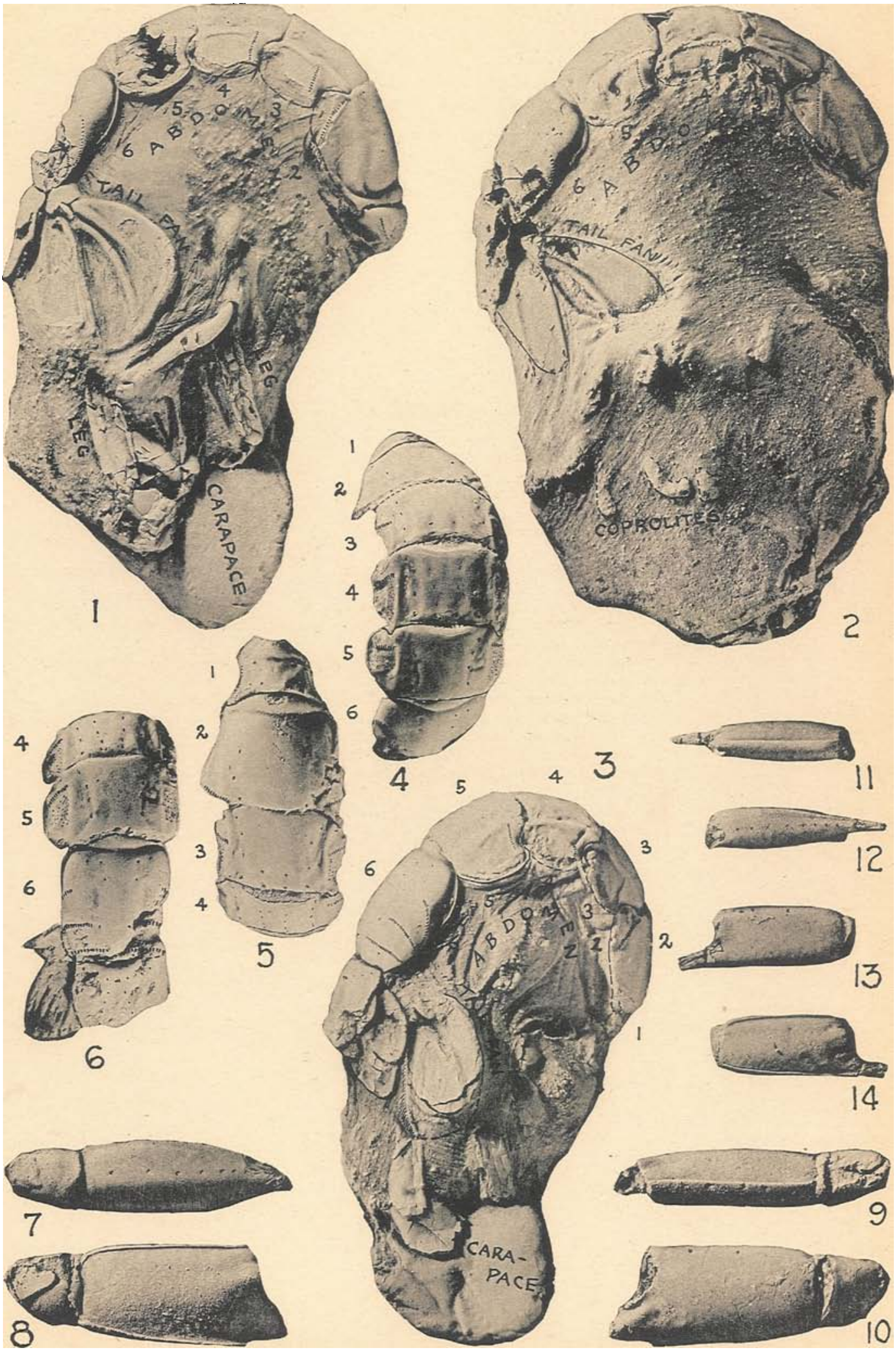
ABDOMEN
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PLATE 43

PAGE

Enoploclytia wintoni Stenzel, n.sp., monotype, x1⅓ 421

1, 2. Outside view of right and inside view of left manus.
From near Crowley, Tarrant County, Texas; Weno limestone, Washita group, Comanche series, Cretaceous (upper Albian). Norman E. Nelson, collector.

Galathea cretacea Stenzel, n.sp., monotype, x6 430

3. Dorsal view of carapace and rolled-under abdomen.
From Watauga; gullies in pasture about 0.1 mile east and within sight of U.S. highway No. 377 (Fort Worth-Denton road), opposite a Texas & Pacific Railroad trestle, and 0.2 mile north of Watauga schoolhouse, northern Tarrant County, Texas (Bureau of Economic Geology locality No. 219-T-3).
Pawpaw shale, Washita group, Comanche series, Cretaceous (upper Albian).

Galathea (?) limonitica Stenzel, n.sp., monotype, x6 431

4. Dorsal view of incomplete carapace.
From south of Fort Worth, Tarrant County, Texas.
Pawpaw shale, Washita group, Comanche series, Cretaceous (upper Albian).

Notopocorystes dichrous Stenzel, n.sp., x2 438

5. Dorsal view of carapace with complete chelipeds and parts of 3 pairs of ambulatory legs, syntype 1.
6. Ventral view of carapace with sternum, mouth parts, stumps of some legs, and appressed abdomen, syntype 3.
7. Dorsal view of carapace, syntype 3.
From California Crossing, north-facing bluff on right bank of Elm Fork of Trinity River upstream from and at Chicago, Rock Island & Pacific Railroad bridge, in southwest corner of Joshua McCants survey, on O'Connor dairy land, about 10 miles northwest of Dallas, Dallas County, Texas; Britton formation of Eagle Ford group, Gulf series, Cretaceous (lower Turonian or Salmurian).

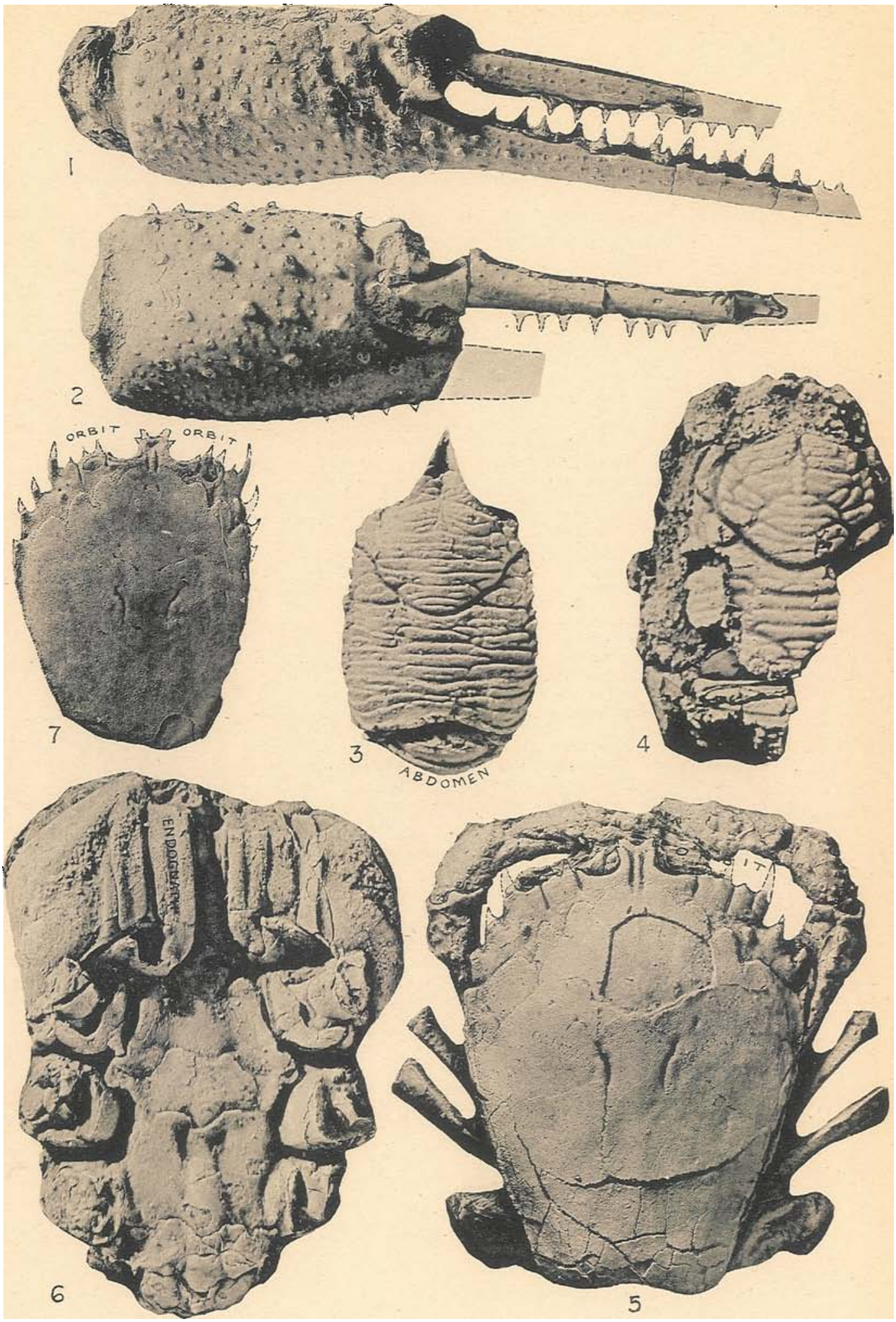

1
2
ORBIT
ORBIT
7
3
ABDOMEN
4
ENDOGNATH
6
5

PLATE 44

1. Dorsal view of carapace, partly decorticated, syntype 2, x2.
2. Dorsal view of incomplete carapace of old individual with original epidermal sculpture preserved, syntype 1, x1⅓.
3. Ventral view showing parts of the first 4 leg pairs, mouth parts, and appressed abdomen, syntype 3, x1.
4. Ventral view showing stumps of some legs, sternum, and appressed abdomen, syntype 4, x1⅓.
5. Ventral view of left anterior part of a carapace with part of left cheliped and first left ambulatory leg, syntype 5, x1⅓.
6. Outer surface view of a pair of chelae, of which the right chela is almost complete and the left represented by the fingertips. The distance between the two is as found in the matrix and is presumably the original natural one, syntype 6, x1⅓.

From California Crossing, north-facing bluff on right bank of Elm Fork of Trinity River upstream from and at Chicago, Rock Island & Pacific Railroad bridge, in southwest corner of Joshua McCants survey, on O'Connor dairy land, about 10 miles northwest of Dallas, Dallas County, Texas; Britton formation of Eagle Ford group, Gulf series, Cretaceous (lower Turonian or Salmurian).

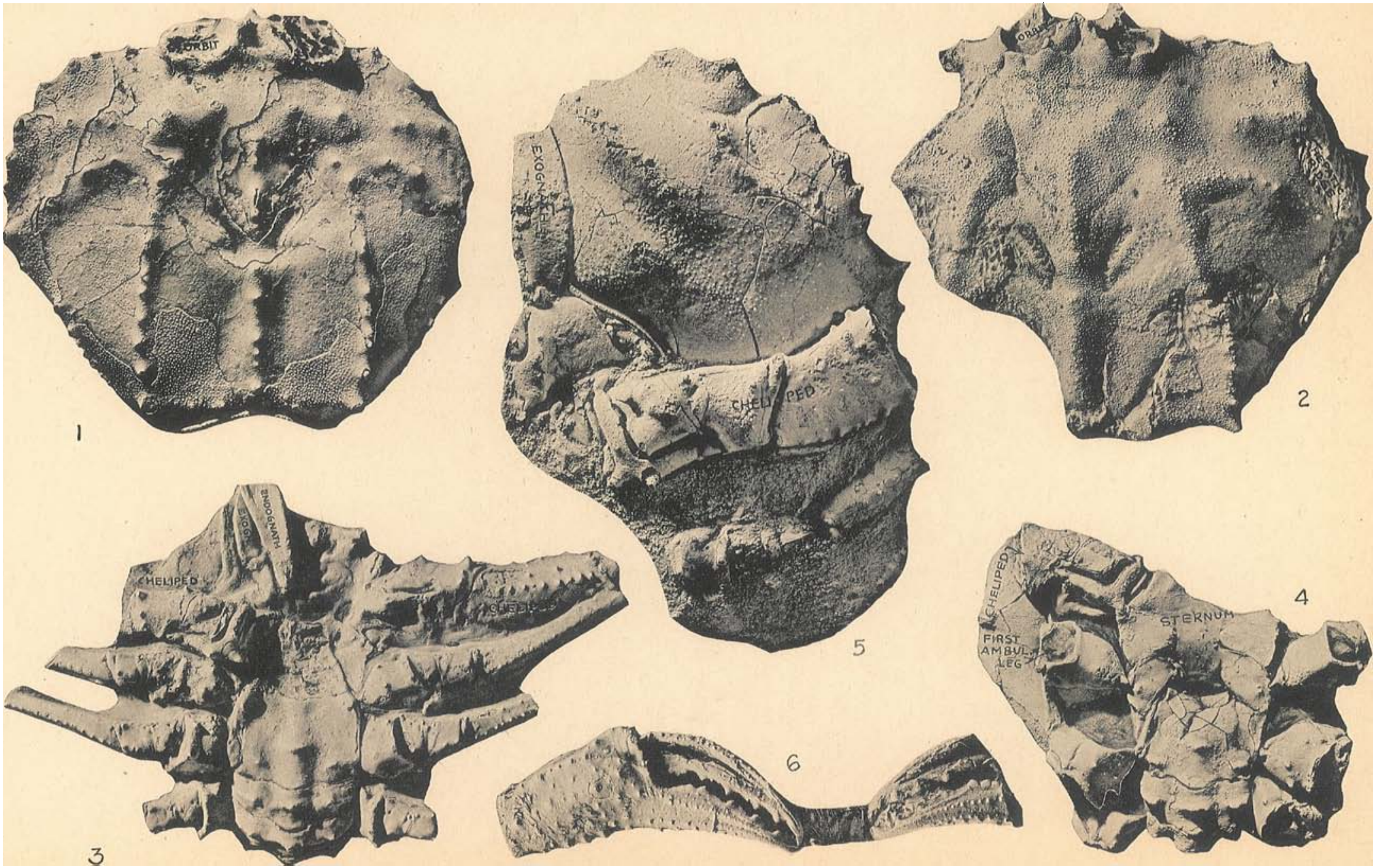

ORBIT
1
EXOGNATH
CHELIPED
5
ORBIT
2
CHELIPED
EXOGN.
ENDOGNATH
CHELIPED
3
6
CHELIPED
FIRST AMBUL. LEG
STERNUM
4

PLATE 45

PAGE

Linuparus watkinsi Stenzel, n.sp., x2 408

1. Dorsal view of carapace, syntype 1.
2. Oblique ventral view of specimen showing mandibles, parts of legs, and abdomen complete and curved under, syntype 4 (compare Pl. 34, fig. 6).

From California Crossing, north-facing bluff on right bank of Elm Fork of Trinity River upstream from and at Chicago, Rock Island & Pacific Railroad bridge, in southwest corner of Joshua McCants survey, on O'Connor dairy land, about 10 miles northwest of Dallas, Dallas County, Texas; Britton formation of Eagle Ford group, Gulf series, Cretaceous (lower Turonian or Salmurian).

Linuparus grimmeri Stenzel, n.sp., x2 406

3. Dorsal view of abdomen with segments 2 to 6, syntype 5.

From California Crossing, north-facing bluff on right bank of Elm Fork of Trinity River upstream from and at Chicago, Rock Island & Pacific Railroad bridge, in southwest corner of Joshua McCants survey, on O'Connor dairy land, about 10 miles northwest of Dallas, Dallas County, Texas; Britton formation of Eagle Ford group, Gulf series, Cretaceous (lower Turonian or Salmurian).

Astacodes maxwelli Stenzel, n.sp., x⅔ 410

4. Dorsal view of carapace with left eye preserved, syntype 5.
5. Dorsal view of specimen with right eye preserved and abdomen partly rolled under, syntype 3.
6. Right side of specimen, syntype 2.

From quarries on east side of State highway No. 188 (Roxton-High road) extending from the vicinity of Arkansas Church, 2.1 miles, to 1.1 mile north of the railway depot in Roxton, southwestern Lamar County, Texas. Roxton limestone, top part of Gober chalk tongue of Austin chalk, Gulf series, Cretaceous (Santonian).

Pagurus banderensis Rathbun, x2 435

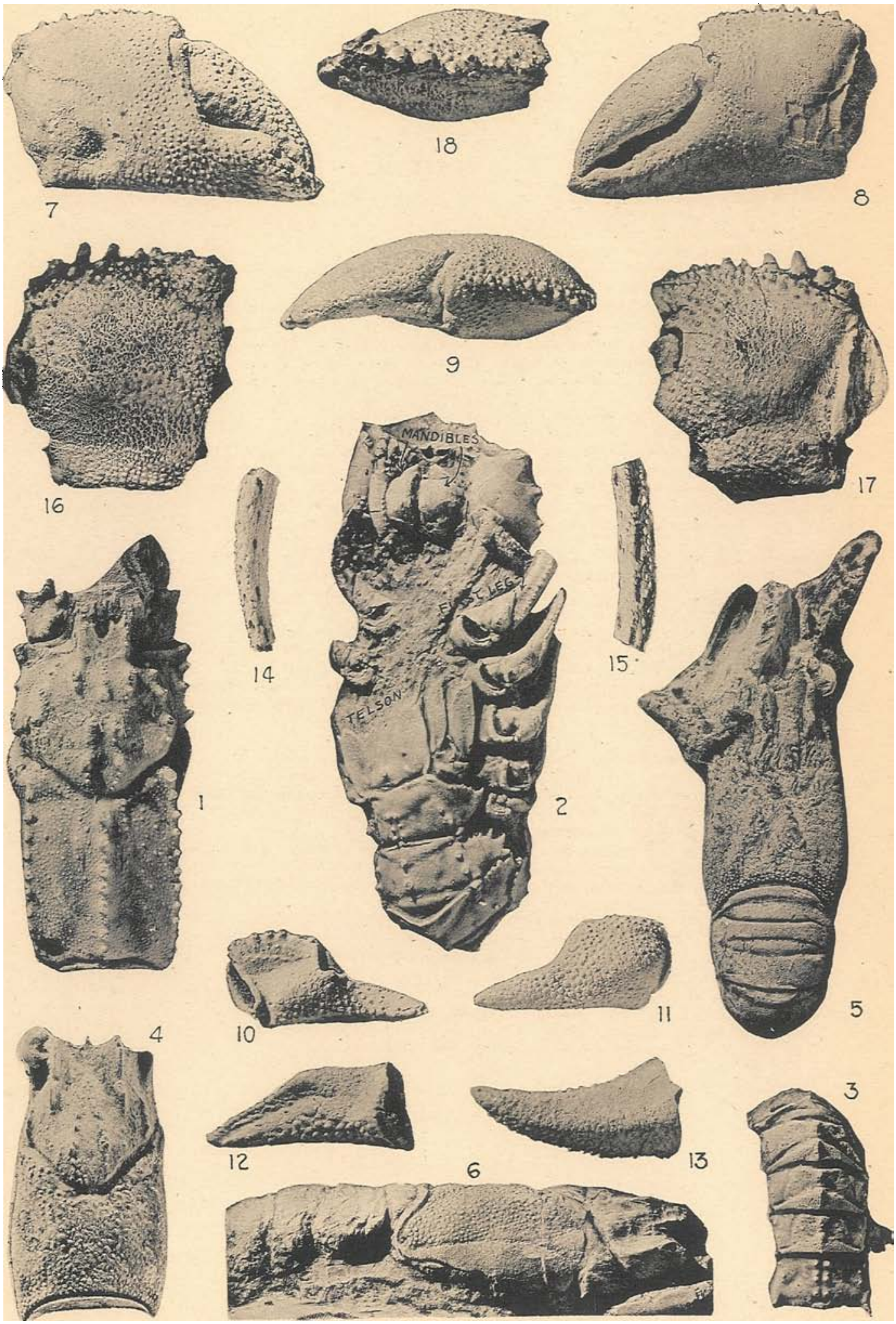
7–9. Outer, inner, and upper views of a complete right chela.
10, 11. Inner and outer views of a left chela complete except for movable finger.
12, 13. Occludent and lower views of a fixed right finger.
14, 15. Two views of a fragment of an ambulatory leg.

From State highway No. 16 (Bandera-Pipe Creek road), 2 miles east of Bandera, Bandera County, Texas.
Glen Rose formation, Comanche series, Cretaceous (lower Albian).

Pagurus travisensis Stenzel, n.sp., monotype, x2 437

16–18. Outer, inner, and upper views of right manus.

From cut on south side of road on road leading from Bull Creek valley westward to Lake Austin Park and abandoned CCC Camp MA-3-T, CO No. 1805, 0.7 mile from road fork in West Bull Creek valley, 1 mile north of Lake Austin or 3.4 miles northwest of Mount Bonnell (airline distance), northwest of Austin, Travis County, Texas. Nodular, fossiliferous limestone, basal bed of Comanche series, Cretaceous (middle Albian).


7
18
8
16
9
17
MANDIBLES
FIRST LEG
TELSON
14
15
1
2
5
4
10
11
3
12
13
6

AN AMEBELODON JAW FROM THE TEXAS PANHANDLE

Joseph T. Gregory

The curiously specialized shovel-tusked mastodons, which lived during the late Tertiary period in North America and Asia, have been made known largely through the researches of Dr. E. H. Barbour, Dr. A. Borissiak, Dr. Walter Granger, and the late Dr. H. F. Osborn. Most spectacular of these creatures, because of the close resemblance of its lower jaw symphysis and tusks to a large scoop shovel, was *Platybelodon grangeri* (Osborn), from the late Miocene Tung Gur formation of Mongolia. In North America an animal with a similar jaw has been found and named *Torynobelodon barnumbrowni* by Barbour. Another American species possessed longer and more slender tusks and has been called *Amebelodon fricki* Barbour. A smaller and somewhat older *Platybelodon*, *P. danovi* Borissiak, is known from the Tchokrak beds of Turkestan, and a few other imperfect specimens of these animals have been described from America. They are still so incompletely known that it seems well worth while to place on record for comparative purposes the description and measurements of an exceptionally well-preserved pair of lower jaws of *Amebelodon fricki* which was obtained from the Texas Panhandle by the Texas Memorial Museum.

I wish to thank Dr. E. H. Sellards, Director of the Texas Memorial Museum, for the opportunity to study this specimen, and Mr. Carl Chelf for furnishing data concerning the locality and associated fauna. The photographs were made by Mr. Louis Haring and retouched by Mr. Chester Wallace, who also prepared the cross sections.

LOCALITY

The specimen was collected by Carl Chelf, Chester Wallace, and Warren D. Mateer on the Parcell ranch, in northern Roberts County, Texas, about 7 miles south and slightly west of Notla post office, Ochiltree County. The fossils occurred in a bed of sandy bentonitic clay lying unconformably above a sand layer and below the cap rock of dolomitic sands and caliche. Associated with the *Amebelodon* jaws were specimens of a large turtle, *Teleoceras* sp., *Neohipparion* sp., and *Pliohippus* cf. *interpolatus*.

Each is represented by a single piece, so only an approximate determination of the age is possible. The *Pliohippus* tooth is unworn but broken above the base so that height of crown is not determinable. It agrees with specimens of *P. interpolatus* in size but might be a premolar of *P. fossulatus*. The *Neohipparion* lower molar is worn almost to its roots but resembles *N. eurystyle* somewhat. From the associated fauna, one only may say that the age is late Clarendonian or Hemphillian. The occurrence in Roberts County, from which up to the present only typical Hemphillian faunas have been obtained, suggests the latter age, but at present one cannot assert the absence of Clarendonian strata in that region.

Amebelodon fricki occurs in the Wray, Rhino Hill, and Feldt ranch faunas (Barbour and Hibbard, 1941, pp. 41–45), which are all Hemphillian (middle Pliocene) in age. There is no reason to doubt that the numerous other sites in Nebraska and Kansas, from which it has been obtained, and this Roberts County, Texas, site are also in Hemphillian deposits. The species is characteristic of the Hemphillian age of the Great Plains region of North America.

It may be noted that the type of *Amebelodon fricki* is from deposits said to be "Late Pliocene or Pleistocene" in age (Barbour, 1927, p. 133). The association of Columbian mammoth and *Teleoceras* in the region which he mentions, in the absence of definite proof of association in the same beds, may be taken as indicative of the presence of both Pliocene and Pleistocene strata at this

Assistance in the preparation of these materials was furnished by the personnel of Work Projects Administration Official Project No. 665-66-3-233.

locality. Inasmuch as the specimen described below agrees so perfectly with the type, I suspect that the type also may be from deposits of Hemphillian age.

DESCRIPTION

The jaw compares closely in shape and size with the type of *Amebelodon fricki*. The tusks are sheathed within the elongate symphysis to about 40 cm. from their tips. Symphysis and tusks slope downward and forward from the level of the molar teeth, the tusks curving upward gently. The upper surface of the tusks is slightly concave, the lower convex. The tusks slope downward toward the midline meeting at an angle of 70° as they emerge from the jaw. Anteriorly the angle rapidly opens to about 135° at the tip of the tusks. The curvature, combined with this inward slope, prevents the median edges of the tusks from meeting except at the tip. It seems probable that this mounting is correct, for the contacts with the undistorted bone of the jaw are extensive and close. The tusks gradually increase in width toward the roots, being 160 mm. wide at the tips and 168 mm. where they emerge from the jaw. The thickness likewise increases from 55 mm. just behind the worn portions of the tip to 57 mm. at the front of the symphysis. At their tips, the tusks show signs of abrasion and are truncated and bluntly rounded. Wear is greatest on the lower edge, which might be expected if they were used as a scoop.

During preparation of the specimen the tusks were partly opened to insert supports. The dentine was found to have well-developed dentinal tubules or rods, such as have been described from *Torynobelodon* and *Platybelodon*. The rods are long, slender, and straight, and separated by considerable intervals of smooth dentine near the root of the tusk. Toward the tip they become progressively larger, more closely spaced, and exceedingly nodular and irregular in shape, although they continue their longitudinal course.

The symphysis of the jaw is concave above, rather shallow and broad near the tip, becoming deeper and narrow posteriorly. Three cross sections are shown in figure 1. Viewed from above, the symphysis is seen to flare near its tip. Behind this it narrows, and the ridges bounding the lingual groove become high and relatively closer together. A pronounced shoulder is developed lateral to them above the space for the incisor roots. The rami of the jaw are deep and heavy. One mental foramen lies just below the anterior edge of M_2. Two small foramina occur in the narrow margin at the base of the symphysis. The principal foramen is slightly anterior to the point where the jaw begins to widen and a little above the middle of the jaw. No unusual features are presented by the ascending ramus with its low, slender coronoid process.

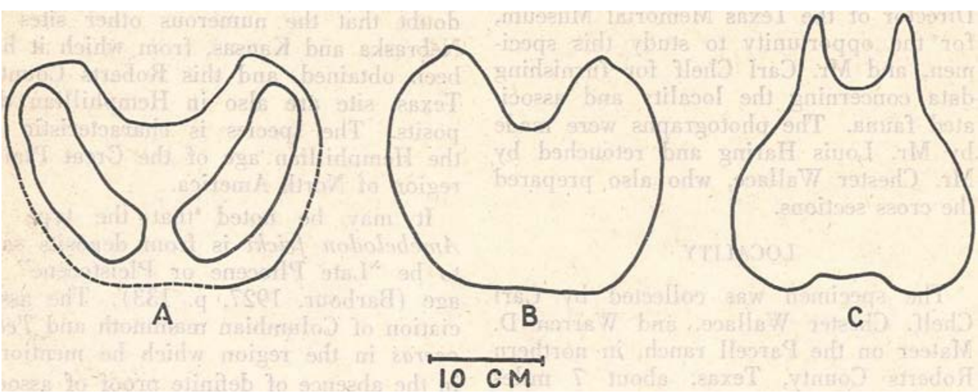


Fig. 1. Cross sections of the symphysis of the lower jaw of *Amebelodon fricki* Barbour. A, At end of tusk sheath, 16 cm. behind tip of symphysis. B, At deepest part of groove, 35 cm. behind tip. C, At narrowest point, 69 cm. behind tip.

MEASUREMENTS (IN MILLIMETERS) OF TEXAS MEMORIAL MUSEUM SPECIMEN COMPARED WITH TYPE OF *Amebelodon fricki.*

	TEXAS JAW	*A. fricki,* TYPE
Total length along midline	1835	1970
Tip incisor—condyle	1889	——
Tip symphysis — midcondylar point	1448	1475
Length symphysis	715	——
Intercondylar width (including condyles)	525	508
Length, condyle to coronoid process	215	——
Breadth across coronoid processes	432	457
Transverse diameter condyle	135	140
Depth coronoid process from angle	375	356
Width between postalveolar processes	229	——
Maximum width of symphysis (near tip)	275	——
Minimum width symphysis, behind mental foramen	203	——
Maximum depth symphysis, from groove	191	——
Width between upper ridges of **symphysis at tip**	**140**	——
Minimum width between symphyseal ridges	72	——
Width jaw across M_2, internal, in front of alveoli	103	——
Greatest thickness ramus	150	147
Depth ramus in front of M_2	222	——
Depth mandible at tip (restored below)	127	165
Depth mandible in front of M_3, outside	173	222
Depth inside mandible in front of M_3	190	——

It is evident that the specimen described is slightly smaller than the type of *A. fricki*, but the differences are so small as to be of no taxonomic significance. Large differences occur only in the depth of the mandible, which varies with age; in the depth of the symphysis, which is partly restored in the Texas specimen and hence may not be accurate; and in widths between the posterior rami of the jaws, which may be altered from their true position in the course of fossilization or preparation. The largest significant difference, that in the total lengths of the specimens, amounts to only 7.4 per cent of the dimension of the smaller specimen, which corresponds to a statistical coefficient of variability less than 2, an exceedingly low value for a skeletal dimension. The differences may be due to the slightly younger age of the animal, although it probably had attained full maturity by the time the last molar came into wear.

Two molars are preserved on each side of the jaw, the moderately worn second and nearly unworn third, which had not completely emerged from its crypt. M_2 is tetralophodont, that is, four-ridged. Trefoils are developed on both inner and outer cones. They appear to arise from the inner conelets, so far as may be determined on the worn teeth. Low but prominent anterior and posterior cingula are present.

M_3 has 5½ lophs and an anterior cingulum. The posterior cingulum is presumably present but is concealed by the jaw. The anterior portion of the tooth agrees with Osborn's description of a "trilophodont" molar, typical of his "Bunomastodontidae." Between the protolophid and metalophid are two distinct "Central Conules" which would have united with the metalophid to form trefoils in the worn tooth. The trefoil of the protolophid appears to be an expansion from its inner conelets. The third to fifth lophids have no distinct conules between them, but prominent buttresses from the lateral conelet lead inward toward the base. The fifth crest is indistinctly divided into inner and outer segments; it is followed by a tall posterior cusp. The ridges of both molars, especially the posterior, narrow rapidly upwards so that the width at the crest is scarcely half that at the base of the crown.

MEASUREMENTS OF TEETH, IN MILLIMETERS

	TEXAS SPECIMEN			*A. fricki,* TYPE		
	LENGTH	WIDTH	INDEX	LENGTH	WIDTH	INDEX
M_2	165	88.7	54	——	——	——
M_3	231±	90	39	229	89	39

Height cusps of M_3

Texas specimen: 53 mm., inside, second crest.
Type specimen (worn): "25–32 mm."

It may not be amiss to point out that the dimensions of the teeth, which we are accustomed to regard as less variable than other parts of the skeleton, agree even more closely with the type of *A. fricki* than do those of the jaw, which were compared above. In view of this close agreement there can be little question of the correctness of the reference of this specimen to Barbour's species.

DISCUSSION

An examination of Volume I of Osborn's monograph "Proboscidea" shows that he placed increasing importance upon the type of trefoil formation in the molars of the trilophodont and allied mastodons, until in his final classification he placed in a separate family, the Serridentidae, those forms in which the trefoil spurs arise from ectoconelets of lower and entoconelets of upper molars, mesoconelets tend to disappear, crests divide by binary fission into 4 to 8 conelets, central conules are absent, and centers of valleys remain open. The remaining genera, comprising the Bunomastodontidae and Humboldtidae of Osborn's classification, have the valleys between the lophs closed by "Central Conules" and trefoil spurs developing from the mesoconelets. Numerous parallelisms between the genera of these families are recorded. Both the Serridentidae and Bunomastodontidae are supposed to have developed the shovel-tusked adaptation, *Platybelodon* and *Torynobelodon* being referred to the former (subfamily Platybelodontinae), whereas *Amebelodon* is placed with the latter (subfamily Amebelodontinae).

It is difficult to say whether there were few or many parallel phyla of mastodonts living during the Tertiary. But the hypothesis of relatively few stocks which differed in certain adaptive features is a far simpler basis upon which to erect a classification than the parallel development of closely similar morphologic features and adaptations in several distinct lines. This is particularly so when the existence of these "phyla" can be detected only by the presence of rather small constant differences, whose fundamental importance is, after all, not demonstrable. Osborn recognized three distinct families and 11 subfamily groups among the "trilophodont" type of mastodonts. I believe that a much simplified arrangement would adequately portray our knowledge of the group.

The separation of the shovel-tusked mastodonts into two groups with different molar structures rests upon no basis whatever. *Platybelodon* is said to have partly serridentine molar construction (Osborn, 1936, p. 459). The previously known specimens of *Amebelodon* have all had the molars too far worn (or, in *A. sinclari*, no cheek teeth) to show which mode of trefoil formation was present. Hence their assignment to the "Bunomastodontidae" was entirely arbitrary. In the specimen just described, one can find traces of both types of trefoils. Central conules are well developed in the first valley of M_3 but not more posteriorly. A slight tendency toward formation of serrate ridges may be seen, but it is not pronounced. It too could well be characterized as "partly serridentine." Altogether the conditions described strengthen a suspicion which I have developed from examination of other trilophodont mastodonts that there may not be such a fundamental structural difference between the serridentine and trilophodont molar types, and that the earlier classification of the "bunomastodont" proboscideans into a single family is nearer the truth. Some of the teeth referred by Osborn to the Serridentidae appear at least equally close to the zygolophodont Mastodontidae. Even if Osborn's classification stands on this point, however, reference of the Amebelodontinae to the Serridentidae will require more evidence than a "partially serridentine" pattern of M_3.

Besides the difference in molar structure, the Amebelodontinae are supposed to differ further from the Platybelodontinae in the absence of the dentinal rod structure of the tusks. Osborn (1936, p. 715) states that the dentinal rods have been observed in *Platybelodon grangeri, Torynobelodon loomisi, T. barnumbrowni,* and *Platybelodon* sp., and that they are not present in either *Amebelodon fricki* or *A. sinclairi.* The additional evidence concerning the structure of *Amebelodon* furnished by the specimen described above casts doubt upon the validity of this separation. The presence of dentinal rods in its tusks appears to be good evidence of affinity with *Platybelodon* and *Torynobelodon*. The absence of these structures from the type of *A. fricki* is remarkable, if actually so, and may indicate that they are not constant within the group. Nor can the presence of four ridge crests in the second molar of *Platybelodon* be considered a "striking contrast" (Osborn, 1936, p. 459) to *Amebelodon*, since it too is tetralophodont. Again the distinction was drawn upon characters which were not shown by any of the described specimens.

No reason remains for keeping the Platybelodontinae and Amebelodontinae distinct. The shovel-tusked mastodonts form a well-defined adaptive group characterized by the enlargement of the lower tusks into a shovel-like scoop. Abraded ends of these tusks attest the usefulness of this structure, presumably for scooping up aquatic plants on which the animals fed. There is no valid evidence that this adaptation developed more than once. The group, therefore, falls within a single family and forms one subfamily, the Amebelodontinae. The name Platybelodontinae must be relegated to synonymy. Without expressing an unreserved opinion upon the relationships of the amebelodonts to other mastodonts, I submit the following definition of the Amebelodontinae, which I regard as a subfamily of the Trilophodontidae, using that family in a wide sense to include all the bunodont or trefoil-toothed mastodonts.

Subfamily AMEBELODONTINAE

A subfamily of late Tertiary bunodont Mastodontoidea (Trilophodontidae) in which the lower jaw was moderately elongated and bore widened, flattened, incisor tusks which were parallel and close to one another or touching, the combined tusks forming a shovel-like instrument. Dentine of lower tusks with characteristic rod-like structure. Upper tusks short. Second molar in known genera with 4 lophs; third molar with 5 or 6 lophs.[1] Double trefoils present on cheek teeth.

Range, Miocene, Asia; Pliocene, North America.

Genus AMEBELODON Barbour

Torynobelodon Barbour.

Range: Miocene, Asia: Pliocene, North America.

Genus PLATYBELODON Borissiak

Range: Miocene, Asia; Pliocene, North America.

Torynobelodon was based upon *T. loomisi* Barbour, described from a fragment of a lower tusk from a site near the type locality of *Amebelodon fricki*. Its characters are:

1. Concave above and below.
2. Curved strongly longitudinally so that tusk could be used more as a dredge or scoop than that of *Amebelodon*.
3. Worn tip (which does not separate it in any way from the rest of the group).
4. Presence of dentinal rods, first recognized in this specimen but probably characteristic of the subfamily.

The only important difference from *A. fricki* is the biconcave cross section, a character of dubious value.

A second species described by Barbour as *T. barnumbrowni* closely resembles the Asiatic *Platybelodon* and was subsequently referred to that genus by Barbour (1929). Osborn, in the Proboscidea monograph (pp. 470–472, 743), places it again in *Torynobelodon*, however, for reasons which are not apparent. I am inclined to regard it as *Platybelodon*. The close agreement between *Platybelodon danovi*, *P. grangeri*, and *P. barnumbrowni* in shape of the mandible and proportions of the lower tusks seems sufficient grounds for uniting them in a single genus.

The genus *Torynobelodon* thus rests solely upon its type, *Torynobelodon loomisi*, which, insofar as may be deduced from a broken tusk, was nearer in general proportions to the longer tusked

[1]Osborn (1936, p. 459) gives the complete ridge formula as: $D_p2\ \frac{?2}{2}$; $D_p3\ \frac{3}{3}$; $D_p4\ \frac{3\frac{1}{2}\text{–}4}{3\frac{1}{2}\text{–}4}$; $M1\ \frac{3\text{–}3\frac{1}{2}}{3\text{–}3\frac{1}{2}}$; $M2\ \frac{4}{4}$; $M3\ \frac{5\frac{1}{3}}{6\frac{1}{4}}$

Amebelodon and when better known will probably be found close to *Amebelodon fricki* in most of its characters. I tentatively refer it to the same genus.

Osborn regarded *Phiomia osborni* Matsumoto as ancestral to the shovel-tusked *Amebelodon fricki* Barbour and therefore placed *Phiomia* in the subfamily Amebelodontine (1936, p. 236).

The characters of *Phiomia* which Osborn cites as indicative of Amebelodontine affinity, namely, progressive elongation of the grinding teeth, progressive development of central conules destined to become trefoils, and progressive elongation of the facial region (1936, pp. 237–238), are without exception characters of the Trilophodontidae as contrasted with the Mastodontidae. It is true that the evolutionary trends within *Phiomia* are in the direction of *Amebelodon fricki*, but they are equally in the direction of the other long-jawed mastodonts. Only the scoop-shaped tusks of *Phiomia* are particularly suggestive of *Amebelodon*, and these also appear to be forerunners of the narrower, somewhat flattened, short tusks of *Trilophodon* (cf. Osborn, 1936, fig. 224, A, 3, p. 273). It should be noted that the milk tusks of *Trilophodon* are slightly concave above and remotely serrate at the end, both of which characters are reminiscent of *Phiomia* incisors (Osborn, 1936, p. 253, fig. 192B).

To include *Phiomia* in the Amebelodontinae would mean broadening the definition of that subfamily to include primitive trilophodonts.

The characteristic dentinal tubules and extreme elongation or shovel-like modification of the tusks, which set the amebelodonts apart from the remaining groups of Tertiary mastodonts, could no longer be used to define the subfamily. Moreover, *Phiomia* is close to the ancestry not only of the amebelodonts but also to that of the trilophodonts, tetralophodonts, serridentines (Osborn, 1936, p. 382, denies this) and very probably the rhynchotheres and brevirostrines. Therefore, it should not be placed in a subfamily (the Amebelodontinae) created for a specialized branch of the trilophodont group. Either it should be returned to the Palaeomastodontidae, resurrecting a horizontal classification in which that family is ancestral to both of the later families of mastodonts, or it should be placed in a primitive subfamily of the Trilophodontidae. As it has been shown (Matsumoto, 1924, pp. 55–57) that *Palaeomastodon* and *Phiomia* differ in details which foreshadow respectively the characteristic molar strutures of the later true mastodons (Mastodontidae) and the bunodont or trefoil-toothed mastodonts (Trilophodontidae), the latter alternative is more desirable.

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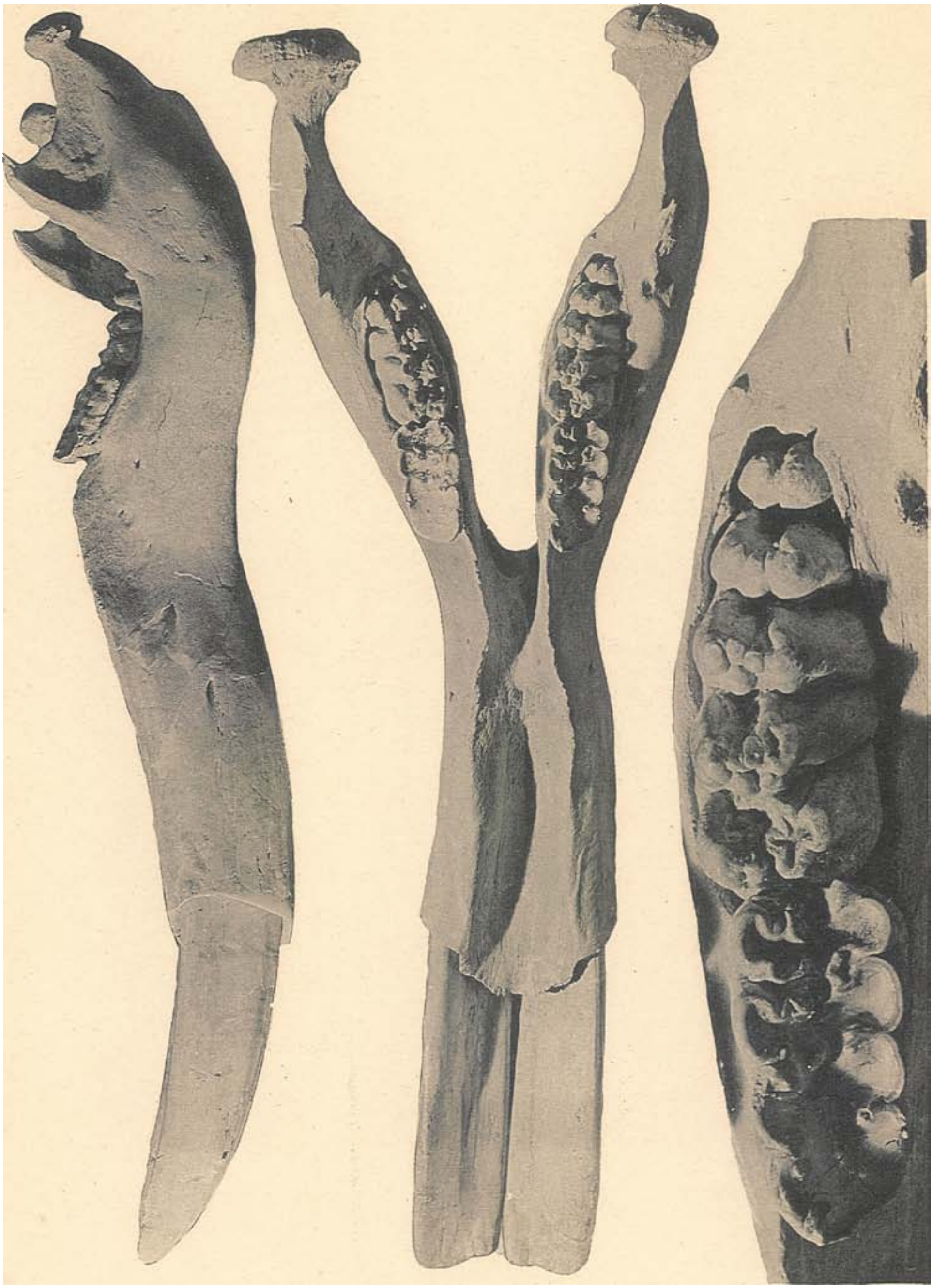
PLATE 46

Amebelodon fricki Barbour. Specimen in Texas Memorial Museum, Austin.
Above, left side view of lower jaw, x0.091.
Center, occlusal view of lower jaw, x0.094.
Below, left $\overline{M2}$–$\overline{M3}$; occlusal view, x0.34.



Map of High Plains region of west Texas. Plains margin is shown by hachured line. The encircled numerals indicate Pleistocene vertebrate fossil localities.

QUATERNARY OF THE TEXAS HIGH PLAINS

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Field studies of Quaternary deposits and land features of the High Plains of west and northwest Texas have been carried on by the Bureau of Economic Geology during parts of the years 1940 to 1944 inclusive. At the beginning of this work during 1940–1941, detailed studies of the Blanco beds of Crosby County resulted in conclusive evidence that these deposits were laid down in a lake basin rather than in an aggrading stream valley as interpreted by earlier workers (Gidley, 1903; Baker, 1915; Matthew, 1924). Recognition of a lacustrine origin for the Blanco beds led to a search for and discovery of other ancient filled lakes and to a study of the larger modern playa lake basins of the south and central plains. Differences in the age of lake deposits were determined on paleontologic evidence supported by observation on the character of the sediments and on the extent of basin filling. It became apparent that basins similar to those occupied by modern playas have been forming and filling on the Texas plains throughout most if not all of Quaternary time, and that the lake deposits if properly interpreted and related to the main stages of canyon cutting, valley filling, and deposition of the eolian sand sheets might establish a Quaternary chronology unexcelled outside of the glaciated regions.

The work has progressed far enough to permit a general discussion of the High Plains of Texas and New Mexico, with description of some of the Quaternary features and types of deposits. A great deal of both field and laboratory work remains to be done, and collections of vertebrate fossils are greatly needed, before the geologic record can be fully interpreted. Acknowledgment is made to Dr. E. H. Sellards, Director of the Bureau of Economic Geology, with whom the writers have frequently consulted.

GENERAL DESCRIPTION

The part of the High Plains which lies in western Texas and eastern New Mexico occupies an area of roughly 50,000 square miles.' That part of the region lying south of the Canadian River valley, known as the Staked Plains or Llano Estacado, is essentially a plateau, being bounded on the north, east, and west by prominent escarpments rising from stream-eroded lower lands and passing southward without sharp physiographic break to the Edwards Plateau. North of the Canadian River valley the plains are continuous with the High Plains of western Oklahoma, Kansas, and Nebraska. The High Plains are a land feature of construction, having been formed by a widespread sheet of late Tertiary and Quaternary continental deposits laid down over an eroded, low-relief surface of Permian, Triassic, and Cretaceous rocks. The surface features of the southern High Plains as well as the development, or at least the extensive modification, of the larger canyons, and the bounding escarpments, are the result of Quaternary erosion and deposition.

Topography and drainage.—The plains surface is remarkably flat and, except for the Canadian River valley and shorter canyons projecting inward from the margins, is generally devoid of prominent topographic features. The surface slope is southeastward, averaging in Texas 8 to 10 feet per mile. Near the western margin of the plains, the slope becomes considerably steeper, particularly in northeastern New Mexico where the surface is a dip slope on broad lava flows extending eastward from the Capulin volcanic district. Minor features of relief common to the plains area are shallow playa lakes, sand dunes, and small stream valleys.

Canadian River, which is entrenched in a deep valley across the Texas Panhandle, is the only well-developed drainage system of the High Plains. Long shallow valleys of intermittent streams, which form the headward reaches of Red, Brazos, and Colorado rivers and extend at widely-spaced intervals almost across the plains, provide a feeble drainage for limited areas immediately adjacent to the valleys. Surface waters accumulating in these valleys ordinarily flow for only a short distance before being lost by seepage and evaporation. In rare periods of excessive rainfall, however, considerable volumes of flood waters are carried off the plains. Over most of the plains area the surface run-off is concentrated as ephemeral lakes in numerous basins or depressions. The drainage area of the individual basins ranges from only a few acres for the smaller basins to more than 100 square miles for some of the largest.

Pleistocene and Recent deposits are much more widespread on the plains than has been generally recognized, previous studies having been devoted primarily to older strata of the region. The main types of deposits are (1) lake or pond deposits; (2) stream valley deposits; and (3) wind deposits.

PLAINS BASINS

Lake and pond deposits of Quaternary age occur in old filled basins, the surface features of which have been largely or entirely obliterated, and as partial filling of the numerous playa basins now existing on the plains. The older basins are known in comparatively small numbers, as they are recognized only from exposures of their sediments along the dissected margin of the plains. Both the older and later stages of lake deposits can best be interpreted by considering first the physical features and the origin of the partly filled basins existing in the region at the present time.

Partly Filled Basins

Playa basins in great numbers and of various sizes are irregularly distributed over the entire southern High Plains except in areas where they have been obliterated by recent dissection or by windblown sands. The basins range in depth from a few feet to about 150 feet and in maximum diameter from 200 feet or less to 8 or 10 miles. The smaller basins, those less than 1 mile in diameter and less than 50 feet in depth, are by far the most numerous. In ground plan the basins are gently dished, and the walls have either gentle or steep slopes depending upon the character of the formation in which the basins are formed. The floors of the larger basins are broad flat plains which may be modified to some extent by wind-deposited dunes and ridges and by one or more large saline playas entrenched from 20 to 30 feet below the general level of the floor plain. The walls of the larger basins usually form steep slopes or bluffs on the west side, with more gentle, erosion- and dune-modified slopes on the other sides. The actual basin margins are in many places obscured by recent wind-blown sands.

The smaller playa basins commonly are known as "dry lakes" or "sinks" and the saline playas of the larger basins as "alkali lakes." The saline playas, being bottomed on or near the water table and supported by large drainage areas, contain shallow surface waters during all but the driest periods. Ponds or lakes bottomed well above the water table survive for shorter periods. In most of the larger playas the loss of water is principally a result of evaporation, whereas in the smaller basins, bottomed above the water table, both evaporation and seepage result in their rapid dessication. None of the basins have outlets except along the stream valleys and near the edge of the plains where a few are in the early stages of dissection.

Origin.—Heretofore the most generally accepted conception of the origin of the larger, partly filled basins of the High Plains has been that they are the surficial reflection of collapsed subterranean caverns within the salt and other soluble rocks of the underlying Permian formations. This hypothesis has been advanced by Baker (1915) and Patton (1935) as a satisfactory explanation of the removal of large volumes of material represented by the basins and the highly saline waters of the "alkali lakes." Under this hypothesis the saline waters were considered to have originated in underlying Permian rocks and to have risen under artesian head through the collapsed zone to the playa surfaces. Some of the larger playas, such as Yellow and Illusion lakes in Lamb and Hockley counties, were thought to have formed within segments of abandoned stream valleys. Such "stream valleys," or extensive linear topographic depressions, of which the Portales Valley of eastern New Mexico is the best-known example, have also been considered to be slump troughs (Price, 1944) and limestone synclinal valleys (Bryan, 1938). The playa basins here discussed should not be confused with the more extensive "valleys" in which some of the basins have formed. The smaller basins have been explained as "sink holes" formed by solution of calcareous rocks at shallow depth, as blowouts formed by wind action, and as depressions caused by local compaction of sediments.

The present writers, after examining various basins and lake deposits, are unable to accept the previously proposed theories as adequate explanation for the origin of the larger playa basins. It is true that many or most of the smaller basins have no preserved or exposed features indicative of their origin. However, in a considerable number of localities the origin of the basin is clearly evident. Subsidence and deflation are the principal causes of basin formation of which there is direct evidence. Of these, deflation is believed to be by far the most important. Other factors such as wave action and solution have undoubtedly contributed to some extent in the development of nearly all of the basins. Subsidence and deflation are more fully discussed in the following paragraphs.

Subsidence.—Subsidence in pre-Quaternary rocks beneath small basins, now filled or partly filled with Quaternary sediments, occurs along the north side and below the narrows of Tule Canyon in Briscoe County, on both sides of Mulberry Canyon northwest of Goodnight in Armstrong County, along a small creek 2 miles south of Higgins in Lipscomb County, and in a few other areas. However, partly filled basins are nearly or quite as abundant in areas where exposed pre-Quaternary rocks show no slumping whatever, as they are in the more limited areas where slumping is known to have taken place, and it is therefore evident that causes other than slumping have been responsible for the formation of many of the basins.

Some true sink holes formed by solution of Cretaceous limestones lying at or near the surface occur in the southern part of the plains and in adjacent parts of the Edwards Plateau. Such sinks have been observed at several places south of Douro in Ector County, near the edge of the escarpment known as Blue Mountain in northwestern Ector County, and along North Concho Draw in northeastern Glasscock County. The sinks are only a few feet in depth and are recognized by their exposed rim rocks and dislocated blocks of limestone within the fill. It may be assumed that other shallow basins which do not have exposed bed rock rims have had a similar origin within that part of the plains where fairly thick limestones or caliche beds underlie the surface deposits. However, Cretaceous limestones underlie only a relatively small part of the plains area, and other shallow-lying soluble rocks, such as caliche, are not present in sufficient thickness to account for any but the quite shallow depressions.

Small sunken blocks up to 12 or 15 feet in diameter and 4 to 5 feet deep have developed in recent years along a weak east-trending surface fracture on the McGeehee ranch on the south side of Mulberry Canyon in Armstrong County (fig. 1). A steep monoclinal flexure in underlying Tertiary rocks, and trending with the surface fracture, is exposed in both walls of a narrow canyon crossing the fracture trace. The fracture along which the small sinks are developed appears to have originated along the axis of the flexure. Similar sunken blocks have

Fig. 1. Small sink holes recently developed along a fracture zone, Armstrong County.

been observed in a poorly developed drainage 1 mile southeast of Happy in Swisher County. Some of the playa basins may owe their incipient development to enlargement of sunken blocks along fractures, having subsequently been greatly modified and further enlarged by wind action or other forces.

Within the exposed areas of country rock in and immediately surrounding the larger basins containing saline playas no evidence of faulting or marked slumping was observed, but on the contrary the Cretaceous and Triassic strata are almost flat, dipping only at about the normal rate for the region. At Guthrie Lake, about 3 miles south and west of Tahoka in Lynn County, a thin bed of Cretaceous limestone forms a nearly flat floor over a considerable part of the playa bed and, as shallow test pits have shown, the same limestone extends beneath a thin veneer of fill over another considerable part of the playa. No places were observed where either the older or later stages of lake deposits have been fractured, slumped, or otherwise affected by secondary adjustment of collapsed materials. The apparent absence of disturbance in the position of the lake sediments and of the country rock surrounding and underlying these large basins indicates that the basins did not originate by subsidence, or that subsidence was either so gentle as to be indistinguishable within the exposed areas or so localized in the form of sinks as to be nowhere evident.

Deflation.—The most frequently observed direct evidence bearing on the origin of the plains basins is ridges of wind-deposited saliferous silt, sand, and clay bordering the east sides of many basins. These ridges consist of material obviously derived from the playa floors during dry intervals and conform closely to the shape of the playa from which they were formed. (See fig. 2.) The ridges are present on only a small percentage of the smaller "dry lake" playas where they rise from 3 to 20 feet or more above the general plains level but are present on almost all of the saline playas within the larger basins. The ridges on some of the larger playas, as at Yellow Lake in Lamb County and Shafter Lake in Andrews County, rise 75 feet or more above the level of the playa floor but usually do not rise to the level of the surrounding plains.

Some of the basins have only one well-developed dune ridge. Some others, however, have more than one such ridge. The large basin known as Shafter Lake in Andrews County has a succession of dune ridges, the outer ridges having successively broader arcs and higher elevations. The outer ridges appear to have been formed from broader deflation surfaces of the basin floor and at earlier times than the inner ridge, which was derived from the more localized area of the basin floor now occupied by Shafter Lake.

The amount of material preserved in the dune ridges derived from deflation of the playa basins is sufficient to account for only a part of the space of the depressions, but considerable quantities of deflated material must have been carried far beyond the ridges and deposited outside the basins. The fact that most of the saline playas are bottomed on or near the local water table, the base level of wind erosion, indicates that deflation was the primary factor in the formation of the saline playas. The initial excavation and subsequent stages of deepening of the saline playas and consequent formation of their bordering dune ridges can almost surely be assigned to more arid substages of the Recent epoch when deepening by wind action was made possible by a lowering water table. Lateral expansion of the playas proceeds during relatively humid substages after deepening has ceased at the water table. Lateral enlargement of the playas is now taking place and is effected by the combination of wave action and deflation. The playa bluffs are reduced by wave erosion and gulleying during occasional seasons of heavy rainfall when waters accumulate to a depth of 10 or more feet in some of the playas. As the waters lower, the freshly eroded materials become exposed and are attacked by the wind, and the finer particles are removed. Deflation at the present time is almost entirely confined to the marginal beaches and to the fans of influent streams, the central part of the large playas being

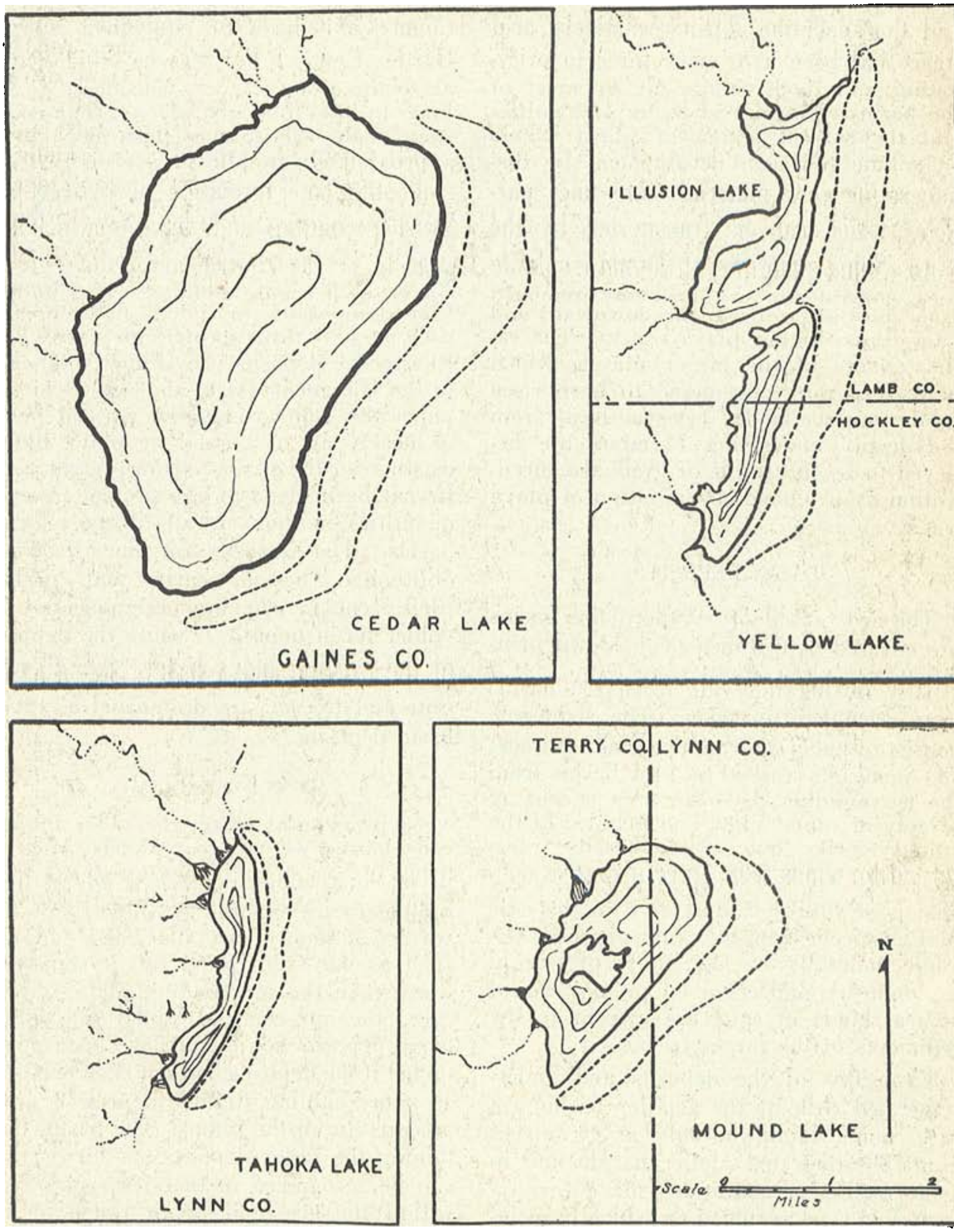

Fig.2. Outline map of some of the principal saline playas of the plains. Marginal dunes indicated by dashed lines. Base from aerial photographs.

usually covered by shallow water or a thin crust of efflorescent salts beneath which the sediments are permanently wet and therefore stabilized against wind erosion. None of the larger playas examined are now being deepened by deflationary action, but, on the contrary, recent fill is accumulating in the deeper parts of the playas. Lateral enlargement is to some extent counteracted by wind-deposited benches against the eastern side of the playas.

In conclusion, field evidence indicates that while subsidence or slumping has been responsible for, or a contributing factor in, the formation of some plains basins, this explanation has been overextended, and that deflation during relatively arid stages has been a primary force in originating and modifying many or most of the basins. Erosion by waves and gullies and the solvent action of playa waters contribute to basin development by disintegrating rock materials into finer particles which can be transported by the wind. Some quantities of the more soluble rock constituents are probably removed from most of the basins by downward and lateral percolating playa waters. The saline waters of the larger playas, which heretofore were considered to have risen to the surface under artesian head from the deeply underlying Permian, are believed to be the result of gradual concentration by prolonged evaporation of playa waters.

BASIN DEPOSITS

The bed rock floors of the plains basins are covered by sediments laid down principally during intervals when the basins were occupied by lakes. The sediments consist of material from two main sources: (1) materials washed into the basins from the surrounding drainage area consisting largely of sands, clay, and pebbles of the country rock; and (2) materials transported by winds from foreign sources consisting of fine rock dust and, in the case of Pleistocene deposits, volcanic ash. Organic materials are commonly present in the deposits, and chemical precipitates of several kinds of salts are present in the sediments of the larger basins.

Exposures of the deposits and underlying bed rock of the smaller basins are rare, being found in only a few places along the dissected plains margin and in some artificial excavations made for impounding stock water. Consequently, principal attention has been given to the sediments of the larger and deeper modern basins, which are much more extensively developed and are usually exposed in long wave-cut bluffs along the border of their saline playas, and to the older dissected filled basins.

Quaternary basin deposits on the southern plains range from earliest Pleistocene to Recent in age. The oldest deposits recognized are the Blanco beds of Crosby County and beds of equivalent age in Hartley County. For reasons subsequently given these deposits are considered to belong to the first glacial, or Nebraskan, stage of the Pleistocene. Basin deposits of approximately middle Pleistocene age include the Tule formation of Briscoe and Swisher counties and deposits which appear to be the equivalent of the Tule in Garza and Lynn counties. The middle Pleistocene deposits cannot, at the present time, be assigned to a definite stage. Late Pleistocene deposits provisionally referred to the Wisconsin stage, and named in this paper the Tahoka clay, are present in all or nearly all of the larger playa basins existing on the plains at the present time. Recent basin deposits are present in some quantities in most or all of the existing basins. The deposits of the filled and obliterated basins, early and middle Pleistocene in age, are designated as the "older basin deposits," while the deposits of the existing playa basins, late Pleistocene and Recent, are designated as "later basin deposits."

Older Basin Deposits

As previously stated, the older Pleistocene basins were so completely filled as to be unrecognizable except where their sediments are exposed by dissection. The surface of some of the older basin deposits, such as the Tule formation, is somewhat lower than the surrounding plains. However, the presence of underlying older basin deposits could not have been determined if the deposits had not been exposed, as many similar slightly depressed areas are present on the plains. The basins containing the older deposits, so far as they can be recognized in their exposures, are within the size and depth range of the larger, partly filled, more modern basins and are believed to owe their origin to the same causes. Any ridges of deflated materials which may have accumulated on the borders of the older basins have not been preserved. Inasmuch as the relatively young dune ridges of the Recent playas have suffered considerable modification by erosion, it is unlikely that ridges of the much older basins could have survived in recognizable form. Some of the principal older lake deposits now known are the Blanco beds of Crosby County, deposits exposed along Rita Blanca Creek in Hartley County, the Tule formation or Rock Creek beds along Tule and Rock creeks in Briscoe and Swisher counties, and deposits on a branch of Double Mountain Fork of Brazos River and on Spring Creek in Garza and Lynn counties.

Blanco beds.—The Blanco beds are exposed in two localized areas along Blanco River, or White River as it is alternately known. The most extensive exposures are along the upper canyon walls in the vicinity of the juncture of Crawfish Draw with Blanco Canyon 10 miles north of Crosbyton. The second and somewhat smaller exposed area is along the east wall of Blanco Canyon 6 miles northeast of Crosbyton. The two deposits are recognized as Blanco on the basis of their faunas and their lithologic similarities. At the head of a small reentrant canyon 3 miles southeast of Crosbyton is a small exposure of beds of similar appearance to the Blanco, but as no fossils have been found, the age of the deposits cannot be ascertained. No discernible connection exists between the different areas. The Blanco beds are unconformably underlain by reddish-brown sands and clays of the middle Pliocene (fig. 3) and are overlain by a widespread sheet of surface sands of probably eolian origin.

The Blanco beds consist mainly of well-bedded, light gray, calcareous sands and clays with some fresh-water limestones, tufa, diatomite, and coarse gravels. The finer grained materials make up the main body of the deposits but grade marginally to coarser sand and gravel. The following section is representative of the main body of exposed beds.

Section No. 1. Measured on west wall of Blanco Canyon, 3500 feet south of the Mt. Blanco–Cone road and near the mouth of Crawfish Canyon, Crosby County, Texas.

	Thickness *Feet*
10. Bentonitic clay, greenish gray, sandy in upper part	10.0
9. Sands, gray to light greenish gray, containing calcareous nodules	4.7
8. Diatomaceous earth. light gray; varies in thickness from 1 foot to more than 5 feet; at this section	1.0
7. Bentonitic clay, sandy	9.4

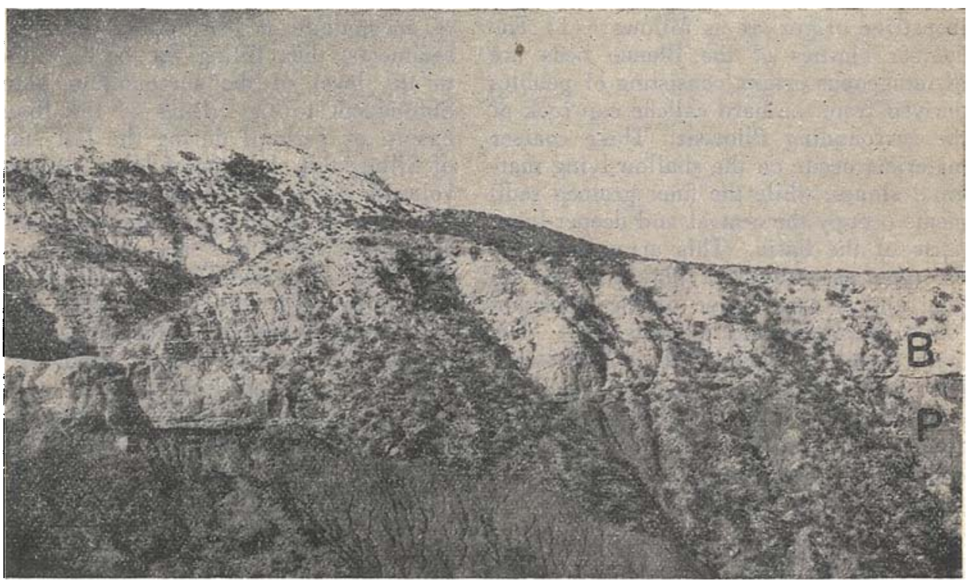

Fig. 3. Contact between Blanco beds and underlying reddish-brown Pliocene at the south side of Mt. Blanco, Crosby County, Texas. B, Blanco. P, Pliocene.

	Thickness *Feet*
6. Caliche, gray, jointed	6.8
5. Bentonitic clay, calcareous and sandy	6.2
4. Fresh-water limestone, thin flaggy beds, reef-like tufa masses locally present	6.0
3. Clay, gray, calcareous	2.0
2. Sand, light greenish gray, massive	12.5
1. Clay, light tan to greenish	2.0
Total	60.7

In this and six other sections, which were measured at intervals over an outcrop distance of about 1.5 miles, the number of recognized beds is from ten to twelve, and the total thickness ranges from 56 to 74 feet. Most of the beds shown in section No. 1 can be recognized in the other sections, although changes in thickness and facies of the individual beds occur along the outcrop. In the marginal areas the several beds pass to a sand and pebble section which thins and wedges out.

The Blanco beds are believed to be lacustrine deposits laid down in broad shallow basins rather than deposits of a large stream valley, as was interpreted by Gidley (1903) and other earlier writers. The main lines of evidence pointing to a lacustrine origin are as follows: (1) The coarser clastics of the Blanco beds are of indigenous origin, consisting of pebbles derived from the hard caliche cap rock of the surrounding Pliocene. These coarser materials occur on the shallow-lying marginal slopes, while the finer grained sediments occupy the central and deeper-lying parts of the basin. This arrangement is the same as in existing playas of the region and is the reverse of the condition found in stream-laid deposits. (2) The main body of exposed beds is well stratified (figs. 3 and 4), some of the beds being traceable across most of the exposed areas. (3) The types of sediments, particularly the bentonitic clays, fresh-water limestones, and the more localized beds of diatomite are indicative of quiet water deposition. (4) No evidence exists along Blanco Canyon or its tributaries of a connecting filled valley segment between the two areas of Blanco beds or of an extension of such a valley either above or below these areas.

Fig. 4. Basal massive sandstone (S) of the Blanco beds overlain by platy fresh-water limestone (L) at locality 10 miles north of Crosbyton, Crosby County, Texas.

The Blanco beds must have been deposited during a relatively humid cycle of considerable duration, as it is only in such conditions that permanent or nearly permanent lakes could have been maintained in the shallow basins long enough to accumulate at least 60 to 70 feet of sediments, thus filling the basins almost to the level of the surrounding plains. Subsequent to the filling of the Blanco basins, or perhaps during the last stages of filling, thin deposits of loess, sand, and volcanic ash were laid down, which were later eroded and largely removed by wind action. A widespread sand sheet 20 to 30 feet thick of probable eolian origin was laid down over the surrounding plains and across the eroded surface of the basin deposits. The wind-eroded remnants of unaltered ash and loess as well as the overlying, probably eolian sands indicate more arid conditions following the Blanco stage.

Inasmuch as the Blanco beds unconformably overlie deposits of middle Pliocene age and are disconformably overlain by a sheet of eolian sand, the age of the Blanco is based primarily upon evidence afforded by the vertebrate fossils. The Blancan fossil assemblage (localities 15 and 16 of the list of vertebrate localities) first known from the Blanco beds of Crosby County, Texas, is characterized by certain short range genera such as *Borophagus*, *Gigantocamelus*, and *Hippotigris (Plesippus)* which are known only in the Blancan. Within the assemblage, however, are longer range genera including *Camelops*, *Tanupolama*, and *Platygonus*, which first appear in the Blancan and which survive through most or all of the remaining Pleistocene. The fauna also contains surviving typical Pliocene genera, such as *Nannippus* and *Rhynchotherium*, which do not survive the Blancan. The presence of these Pliocene forms in the early collections from the Blanco appears to have been the basis upon which the original assignment of a Pliocene age was made. The typical Pleistocene elements of the fauna had not been found or were not recognized until more extensive collections, made during 1940–1941, were studied by Meade.[1] The Pleistocene age assignment of the Blanco is based upon Meade's study which reveals the Pleistocene affinities of the fauna. The less abundant Pliocene elements, the short-range genera known only in the Blancan, and the typical Pleistocene genera constitute a fossil assemblage which indicates an early, perhaps earliest, Pleistocene age. This, together with the evidence that the deposits were formed in a humid climate, which would be expected to correspond with a glacial rather than with an interglacial stage, indicates that the Blanco beds are of Nebraskan age. The eolian deposits overlying the Blanco beds may have been deposited in part or entirely during the succeeding Aftonian interglacial stage.

Rita Blanca deposits.—Lacustrine deposits which are in part equivalent to the Blanco beds are exposed along Rita Blanca Creek and its tributaries about 8 miles west of Channing in Hartley County. The exposed areas are too limited to enable a determination of the extent of the deposit, and as the basal contact is nowhere exposed, the total thickness is unknown.

The lowermost exposed strata, which can be seen on the northeast side of Rita Blanca Creek along the Channing-Romero road, consist of 30 feet or more of dark, distinctly laminated clays containing abundant plant remains and some small fossil fish. Some sand beds and thin uniform layers of fresh-water dolomite are interbedded with the shales. Locally the shales are highly gypsiferous. Overlying the laminated clays is a section, 50 feet or more in thickness, consisting mainly of sands, bentonitic clays, and thin-bedded calcareous sandstone. A small Blancan fauna has been collected from sand members in both the lower and upper parts of this section, and numerous tracks of two kinds of camels were found locally in some of the calcareous sand beds. (See locality 2 of the list of vertebrate localities.)

The lower laminated shales were evidently laid down in a permanent or nearly permanent lake, while the upper and more sandy section appears to have been deposited in shallow waters subject to intervals of partial or complete dessication. The well-preserved camel tracks were probably made while the animals were wading in shallow water in search of aquatic plants.

Post-Blancan Pleistocene deposits up to 40 feet in thickness and consisting of unconsolidated sands, clays, and volcanic ash overlie the Blancan deposits on a divide between Rita Blanca Creek and a small tributary stream, 8 miles west of Channing. The post-Blancan age of these deposits is determined on the basis of a partial mammoth skeleton found in one of the sand beds at a locality about 0.3 mile north of the Channing-Romero road. The mammoth is a characteristic post-Blancan Pleistocene form but does not occur in the Blancan. The volcanic ash, which is the uppermost preserved member of these deposits, is quite pure, well bedded, and up to 14 feet in thickness. The ash and other post-Blancan lake sediments accumulated within a basin only partially filled during Blancan time or within a re-excavated area in the Blancan deposits.

Tule formation.—Pleistocene lake deposits which are extensively exposed along Tule Creek in Briscoe and Swisher coun-

[1]Meade, G. E., The Blanco fauna. Univ. Texas Pub. 4401, pp. 509–556, 1944 [1945].

ties were named the Tule formation by Cummins (1893) and were later described by Gidley (1903) under the name of Rock Creek beds. Gidley considered the deposits to have formed in a stream valley, basing his interpretation upon local occurrences of cross-bedded sands and gravels and upon the presence of land animals in some of the deposits. Recent studies carried on by the writers show the Tule formation to be a lake deposit within a large basin which can be fairly accurately outlined on the east, north, and south sides. The lake basin has a north-south width near its east end of at least 6 or 7 miles and extends for a somewhat greater distance in an east-west direction along both sides of Tule Creek.

The Tule formation consists mainly of well-bedded, gray, unconsolidated sands and greenish-tan, bentonitic clays. Thin, continuous beds of fresh-water limestone usually consisting of several very thin and uniform flaggy layers occur at two or more horizons over a part of the deposit, and coarse gravel or pebble lenses are commonly present along the margins of the basin. Beds of unaltered volcanic ash are locally present in the deposit. The Tule formation attains a thickness of 100 feet or more along Rock Creek about one-half mile northeast of the Ashel Cross ranch headquarters in western Briscoe County, but the average thickness of exposed sections is not more than 70 or 80 feet. Toward the margins of the basin the deposit thins and lenses out. As in the case of the Blanco beds, the clays and finer grained sands make up the main body of sediments in the central and deeper parts of the basin, while coarser sands and gravels are usually along the marginal areas. Section No. 2 is representative of the central part of the Tule formation.

Section No. 2. Measured 9.3 miles west of Silverton, Briscoe County, Texas.

	Thickness Feet
12. Surface soil and sand	2.5
11. Sands, thin bedded, with thin layers of brown clay and occasional lentils of gravel	17.0
10. Clay, grayish tan with thin light gray ashy bands, conchoidal fracture, occasional crystals of selenite	6.8
9. Sands, with thin alternating bands of sandy clay	6.0
8. Clay, greenish yellow, easily weathered	3.0
7. Sands, gray, containing thin beds of sandy clay and a thin bed of platy limestone near top	10.0
6. Clay, brownish tan, conchoidal fracture, selenite locally abundant	21.0
5. Limestone, white, thin platy beds	0.3
4. Sandy clay and sand (partly covered), gray, thin partings of brown waxy clay and small amounts of selenite	12.6
3. Pack sand, gray, occasional gravel lentils at base	13.0
2. Sandy clay, gray to greenish gray	7.0
1. Pack sand and some gravel, thin clay seams	15.0
Total	114.2

Triassic.

The gravels and some of the sands must have been carried into the basin from the surrounding area by influent streams and sheet wash. The bentonitic clays presumably are the alteration product of volcanic ash which accumulated in the basin at different times during the process of filling. Some of the sands were probably also carried into the basin by the wind. The thin fresh-water limestones and dolomites, here as in the other basin deposits of the plains, may represent deposition caused by partial dessication of lake waters resulting in oversaturation and precipitation from solution of calcium and magnesium compounds.

The Tule deposits did not fill the basin to the level of the surrounding plains, the surface of the Tule being some 30 to 40 feet below the general plains level. Further filling may have been prevented by climatic changes in which the lake could no longer exist, or, more probably, by draining of the lake by headward erosion of Tule Canyon which has subsequently dissected large areas of the deposits.

The vertebrate fauna of the Tule formation includes such typical Pleistocene forms as mammoth, *Equus*, *Canis*, and *Camelops*. (See locality 6 of the list of vertebrate localities.) The fauna does not contain the early Pleistocene Blancan short-range genera nor does it contain the

Bison which is characteristically present in this region within deposits known to be of late Pleistocene age. This indicates an intermediate Pleistocene age for the Tule formation.

Spring Creek deposits.—Lacustrine deposits believed to be equivalent to the Tule formation occur along Double Mountain Fork of Brazos River and a tributary stream known as Spring Creek in western Garza and eastern Lynn counties. The Spring Creek deposits are similar to the Tule formation in lithology and degree of basin filling in respect to the plains surface. The vertebrate fossils (locality 21 of the list of vertebrate localities) which have been collected from the Spring Creek deposits indicate that the deposits are equivalent to the Tule formation. The deposits have not yet been studied sufficiently to permit a more detailed discussion.

In addition to the deposits discussed above, some other older lake deposits are known but have not been adequately studied. One of these deposits is exposed in Yellowhouse Canyon, north of Slaton in Lubbock County. (See locality 14 in list of vertebrate localities.)

Later Basin Deposits

The later basin deposits occur as partial filling in the playa basins still existing on the plains surface. They include late Pleistocene lacustrine deposits and Recent deposits of eolian and lacustrine origin and some playa-bordering alluvium.

Tahoka clay.—The oldest deposit definitely recognized within the modern playa basins is present in all of the larger of these playa basins on the Texas plains that have been examined by the writers. The surface of this deposit makes up the broad floor plain, one of the characteristic features of these basins. The deposit is here named the Tahoka clay for the town of Tahoka in Lynn County which lies near Tahoka Lake, Mound Lake, and other playas around which the deposit is typically developed and well exposed.

The Tahoka clay consists mainly of bluish-gray calcareous and gypsiferous clays and gray sands which grade marginally to coarser sands and gravels. Thin, discontinuous beds and small lentils of fresh-water limestone are locally present in the basinward facies of the deposit. The principal variation noticed in the composition of the Tahoka is a marked difference in the ratio of clay to sand in the several basins of the group, as well as in different parts of a continuous exposure of any single basin. The following section is representative of the more sandy phase of the deposit:

Section No. 3. Measured on southwest side of large playa 2 miles north of Morita, Howard County, Texas.

	Thickness *Feet*
3. Bluish-gray, bentonitic clay containing some silt and locally quite gypsiferous	6.5
2. Unconsolidated sand with some silt and clay	15.5
1. Coarse sand and gravel, resting on Triassic clay	3.0
Total	25.0

The following section is representative of the more clayey parts of the deposit.

Section No. 4. Measured at I. D. Walker clay pit on west bluff of Rich Lake, Lynn County, Texas.

	Thickness *Feet*
6. Gray, unconsolidated sands, with thin soil zone at top	4.0
5. Greenish-brown clay	5.0
4. White, fresh-water limestone containing numerous casts and shells of small bivalves; bed is irregular in thickness, about	0.8
3. Gray, calcareous clay, with small limestone lentils	8.0
2. White fresh-water limestone, containing small bivalves	0.5
1. Bluish-gray calcareous clay, sandy in lower part, to base of bluff at playa water level	7.5
Total measured thickness	25.8

The thickness of the Tahoka measured at the several saline playas ranges from 21 feet at Soda Lake in Ward County to as much as 35 feet at Shafter Lake in Andrews County and Cedar Lake in Gaines County. None of the measurements are thought to represent the maximum thickness, as exposures are limited to the playa bluffs which are typically developed at or near the western margin of the basin where the deposit is probably thinner than in the central unexposed area.

The Tahoka clay rests unconformably on older strata. In all but one or two of the larger saline playas (see map, Pl. 47) Triassic shales or Cretaceous limestones and shales are exposed beneath the Tahoka at some parts of the western sides of the playas. The contact between the Tahoka and the older rocks dips at a low angle toward the central basin so that the base of the Tahoka passes within a short distance below the floor level of the present playas. Around the margin of the basins the Tahoka in places overlaps older Quaternary or Upper Tertiary strata which are resting upon Triassic or Cretaceous. Disconformably overlying the Tahoka are local developments of dune and playa deposits which will be described in succeeding paragraphs.

Extent and correlation.—The Tahoka clay, as here interpreted, occurs on the

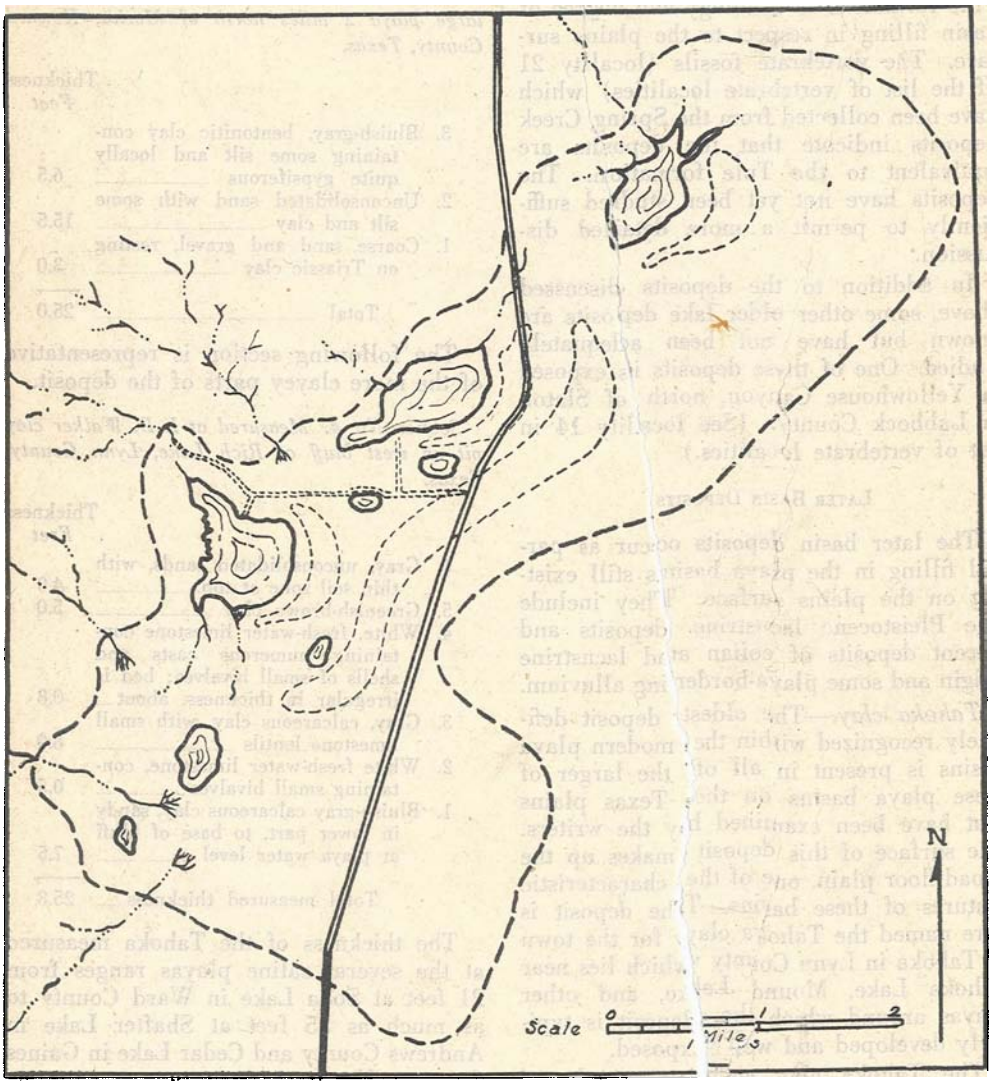

Fig. 5. Outline map of basin and playas in Bailey County, Texas. Approximate margins of basin indicated by heavy dashed line. Marginal dunes indicated by light dashed lines. Base made from aerial photograph.

High Plains of Texas and eastern New Mexico as a group of isolated deposits varying in extent according to the size of the basin or valley in which it was deposited. Some of the larger individual deposits, such as occur in the large basin in Hockley and Lamb counties, Texas, in which Yellow Lake and Illusion Lake playas are developed, or the extensive deposit in Roosevelt County of eastern New Mexico surrounding Laguna Salada playa, may extend over 50 or more square miles. The general distribution of the main occurrences now recognized is indicated by the playas developed in the Tahoka. (See Pl. 47.) A basin containing several playas formed in the Tahoka fill is shown in figure 5, and a detailed areal map is shown in figure 6.

Correlation of the separate deposits is based principally upon the following observations: (1) The Tahoka clay occupies a similar position and is similarly developed as to thickness and extent in each of the larger basins examined. (2) The several deposits are closely similar in general appearance, lithology, and degree of consolidation. (3) The deposits were laid down in permanent lakes which stood at least 20 to 30 feet above the floors of the present playas. This indicates a relatively humid climate of long duration which almost certainly would have prevailed at the same time over the entire region here

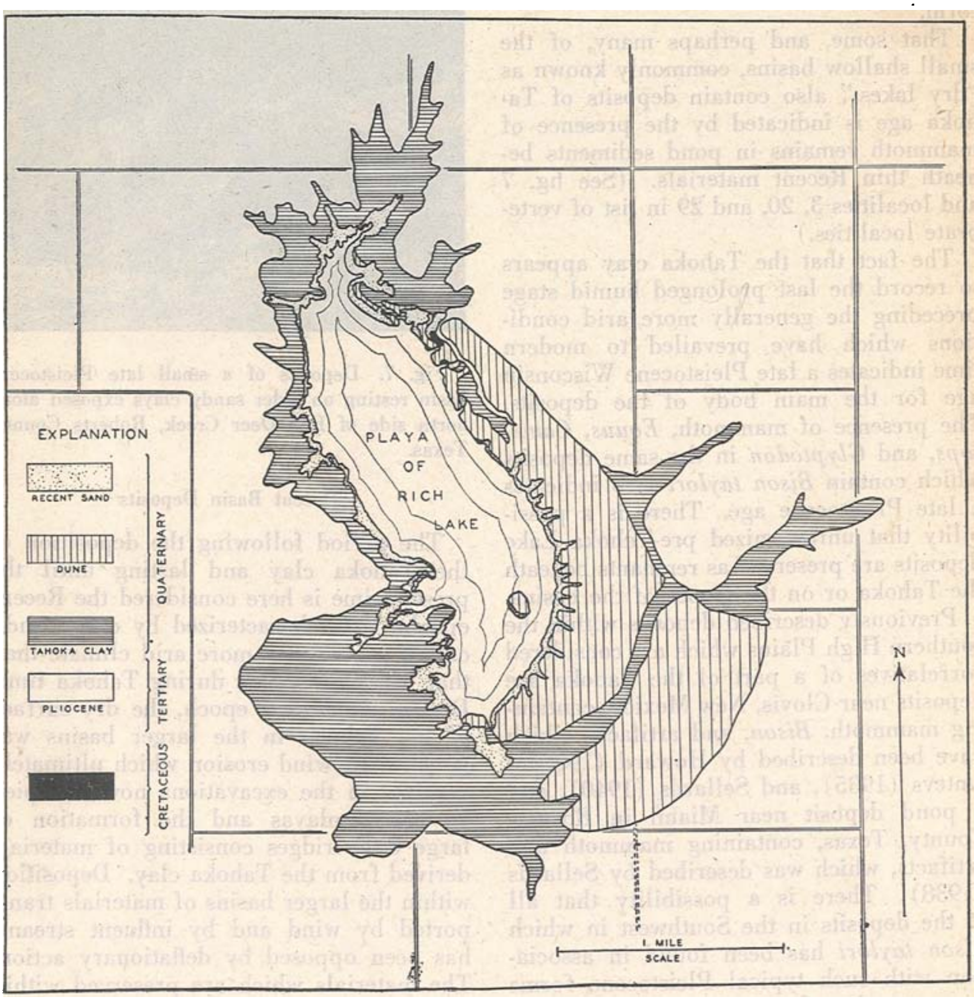

Fig. 6. Geologic map of Rich Lake, Terry County, Texas.

considered. (4) The saline playas, the large clay-silt dune ridges resulting from deflation of the playas, and sand dune deposits which have formed during relatively arid conditions of the Recent epoch are similarly developed in and on most of the larger deposits of the Tahoka. (5) Vertebrate fossils are found in the Tahoka at Silver Lake in Cochran County, Monument Lake in Bailey County, Tahoka Lake in Lynn County, Cedar Lake in Gaines County, and Shafter Lake in Andrews County. (See localities 7, 10, 18, 22, 23, and 24 in list of vertebrate localities.) The fossils alone do not serve to distinguish Tahoka from earlier Pleistocene deposits except in those assemblages containing *Bison taylori,* a late Pleistocene form.

That some, and perhaps many, of the small shallow basins, commonly known as "dry lakes," also contain deposits of Tahoka age is indicated by the presence of mammoth remains in pond sediments beneath thin Recent materials. (See fig. 7 and localities 3, 20, and 29 in list of vertebrate localities.)

The fact that the Tahoka clay appears to record the last prolonged humid stage preceding the generally more arid conditions which have prevailed to modern time indicates a late Pleistocene Wisconsin age for the main body of the deposits. The presence of mammoth, *Equus, Camelops,* and *Glyptodon* in the same deposits which contain *Bison taylori* also indicates a late Pleistocene age. There is a possibility that unrecognized pre-Tahoka Lake deposits are preserved as remnants beneath the Tahoka or on the slopes of the basins.

Previously described deposits within the southern High Plains which are considered correlatives of a part of the Tahoka are deposits near Clovis, New Mexico, containing mammoth, *Bison,* and artifacts, which have been described by Howard (1935a), Antevs (1935), and Sellards (1940), and a pond deposit near Miami in Roberts County, Texas, containing mammoth and artifacts, which was described by Sellards (1938). There is a possibility that all of the deposits in the Southwest in which *Bison taylori* has been found in association with such typical Pleistocene forms as mammoth and *Equus* are of Tahoka age.

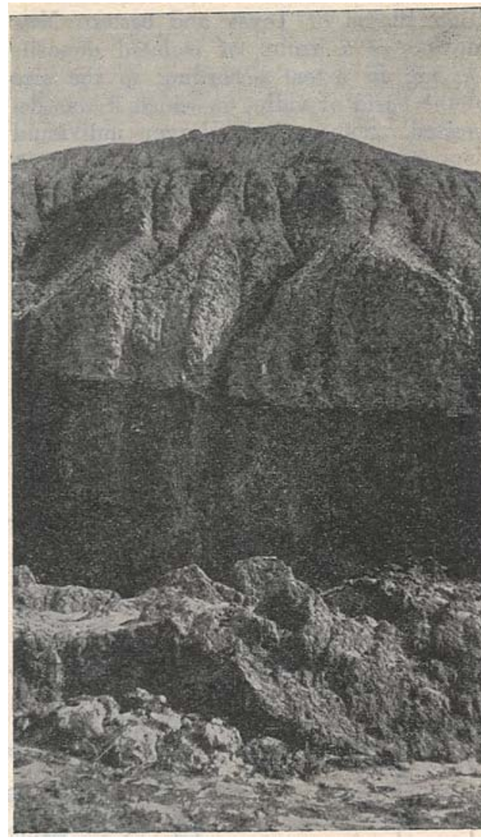

Fig. 7. Deposits of a small late Pleistocene basin resting on older sandy clays exposed along north side of Red Deer Creek, Roberts County, Texas.

Recent Basin Deposits

The period following the deposition of the Tahoka clay and lasting until the present time is here considered the Recent epoch. It is characterized by events indicating a generally more arid climate than that which prevailed during Tahoka time. During the Recent epoch, the dry surface of the Tahoka in the larger basins was attacked by wind erosion which ultimately resulted in the excavations now occupied by saline playas and the formation of large dune ridges consisting of materials derived from the Tahoka clay. Deposition within the larger basins of materials transported by wind and by influent streams has been opposed by deflationary action. The materials which are preserved within the playas include those which became stabilized against wind activity by falling within the permanently wet zone and those too coarse for wind transport.

Insofar as they can be interpreted from present knowledge, the principal post-Tahoka events affecting the larger basins occurred in the following succession (fig. 8): (1) Formation of dune ridges on or near some of the eastern basin margins from shallow deflation of the drying Tahoka Lake floors; (2) development by intensified and more localized deflation of playas and their bordering dune ridges; (3) partial filling of the playas and areal enlargement by wave action apparently during a minor substage of relative humidity; (4) renewed deflation of playas to a level below the present water table with partial destruction of previous fill and formation of low benches of wind-transported sediment against the playa side of the bordering dune ridges; (5) modern playa filling within vertical limits of permanently wet zone, continued lateral enlargement of playas by wave action, and some deflation.

Although the dominant climatic condition of the Recent epoch has been one of relative aridity, substages of increased aridity and increased humidity are indicated by the geologic events listed above. The immediate past and the present time are believed to be within a substage of relative humidity. This belief is based on the observations that all of the saline playas are now enlarging their areas by wave action on their marginal bluffs and are at many places drowning and enlarging the mouths of influent drainages. Also a rising local water table is indicated in most of the playas by permanently wet modern fill of at least several feet in thickness. Deflation, which excavated the playas to the level of the floors on which the modern sediments are resting, must have taken place during a drier substage when the water table was lower than at present. The somewhat older playa fill, remnants of which now form low marginal benches against higher bluffs of Tahoka clay, also represents a minor cycle of increased humidity. The substages of increased aridity are indicated by deflation resulting in formation of playas and the large dune ridges.

The time duration of the several indicated substages of the Recent is unknown. The best approach at dating the different deposits is probably by archeological methods such as employed by Roberts (1942) in dating cultural objects at San Jon, New Mexico. Extensive camp sites are found within some of the basins, particularly on the dune ridges bordering the saline playas. On one such camp site on the marginal dune of Silver Lake in Hockley County, the writers collected representative artifacts including pottery and projectile points which were examined by Kelley. According to Mr. Kelley[2] the artifacts are approximately equivalent in age to the Chupadero culture and indicate that the camp was occupied during the 14th or 15th Century. Inasmuch as the abundant camp site objects occur within the upper few inches of soil on the ridge crest,

[2]Kelley, J. Charles, Personal communication.

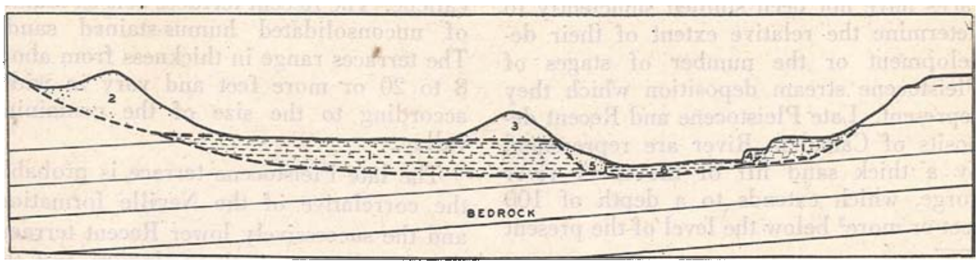

Fig. 8. Idealized cross section illustrating principal features and deposits of larger basins. 1, Tahoka clay. 2, Outer dune ridge, present in some basins. 3, Clay-silt dune on margin of saline playas. 4, Shelf of post-Tahoka playa fill. 5, Bench consisting of material deflated from playa. 6, Saliferous muds of modern playas. 7, Bed rock (Triassic, Cretaceous, Pliocene, or older Pleistocene).

it is evident that very little material has been added to the dunes since the camps were occupied. The playas and their marginal dunes, which represent a substage of aridity, may be considered to have formed previous to the 14th or 15th Century.

Summary of Conclusions on Basins and Their Deposits

(1) Deflation originates and enlarges playa basins in the High Plains during stages of aridity.

(2) Lake deposits form in the basins during humid stages and develop in thickness and extent proportional to the duration and intensity of the humid stage.

(3) The Blanco beds of Crosby County and the Rita Blanca deposits of Hartley County are considered to be of Nebraskan age.

(4) The Tule formation of Briscoe and Swisher counties and the Spring Creek deposits of Garza and Lynn counties are considered of middle Pleistocene age.

(5) The Tahoka clay is of Wisconsin age and was deposited during a humid climate.

(6) Older Pleistocene lake deposits similarly represent humid stage deposition and are considered to have formed during glacial stages.

STREAM DEPOSITS

Quaternary stream deposits occur within all of the stream valleys crossing the Texas plains. The oldest deposits are the higher sand and gravel terraces of Canadian River such as can be seen north of the town of Canadian along U. S. highway No. 60 in northern Hemphill County. The older terraces have not been studied sufficiently to determine the relative extent of their development or the number of stages of Pleistocene stream deposition which they represent. Late Pleistocene and Recent deposits of Canadian River are represented by a thick sand fill of the inner river gorge, which extends to a depth of 100 feet or more[3] below the level of the present channel, and by low terraces which border the river flood plain. The two lowest terraces along the river and its tributary valleys are of Recent age.

The long shallow valleys such as Tule Creek, Running Water Creek, Double Mountain Fork, and Mustang Draw, which form the upper reaches of Red, Brazos, and Colorado rivers, contain late Pleistocene and Recent deposits. In their course across the plains, these valleys are usually from 400 feet to one-fourth of a mile wide and are entrenched from 20 to 50 feet below the level of the surrounding plains. The floors of the valleys are covered by unterraced and usually unchanneled valley fill, the lower part of which consists mainly of gray, partially consolidated sands and gravels and is late Pleistocene in age. The upper part of the fill consists mainly of unconsolidated humic-stained sand and clay and is of Recent age. The thickness of the fill has been determined in only a few artificial excavations where it averages about 20 feet. The Recent part of the fill is usually less than 5 feet thick.

Near the eastern margin of the plains the streams enter deeply entrenched canyons in which the valley fill includes three recognizable terraces. The highest of these terraces is the downstream extension of the late Pleistocene part of the unterraced valley fill above the canyons. The two successively lower and narrower terraces (fig. 9) are equivalent to the unterraced Recent fill above the canyons in the same streams and to the low Recent terraces of Canadian River. The late Pleistocene terrace consists mainly of gray sands and caliche gravels, somewhat cemented by caliche. The Recent terraces consist mainly of unconsolidated humus-stained sands. The terraces range in thickness from about 8 to 20 or more feet and vary in width according to the size of the containing valley.

The late Pleistocene terrace is probably the correlative of the Neville formation, and the successively lower Recent terraces the correlatives of the Calamity and the

[3]On the authority of Mr. O. R. Morse, Civil Engineer for the Fort Worth and Denver Railroad Company, soundings were made through a thickness of 120 feet of sand filling in Canadian River bed at the crossing of the Fort Worth and Denver railroad at Tascosa in Oldham County, and a thickness of about 108 feet of sand filling was found at the Santa Fe railroad bridge north of Amarillo in Potter County. A similar thickness of fill has also been reported at the crossing of U. S. highway No. 60 at Canadian in Hemphill County.

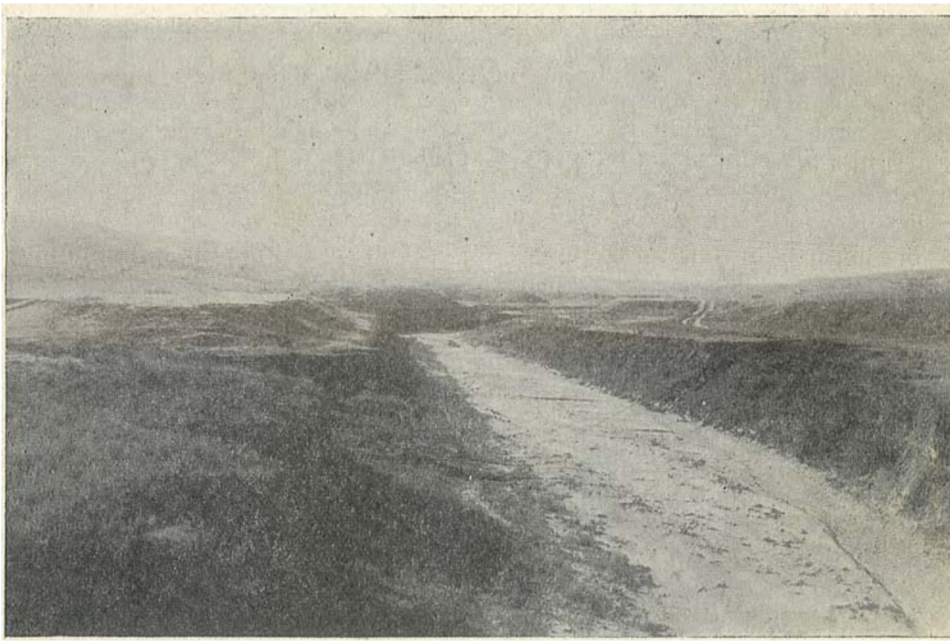

Fig. 9. Recent terraces on tributary of Canadian River along State highway No. 152, 10 miles east of Borger, Carson County, Texas.

Kokernot (Albritton and Bryan, 1939). The three terraces may also correlate, from oldest to youngest, with the Jeddito formation, Tsegi formation, and Naha formation of the Jeddito Valley area of Arizona which were described by Hack (1942).

The age of the late Pleistocene deposit in both its terraced and unterraced portions is recognized by its stratigraphic relation to the succeeding Recent deposits and by the presence in it of *Equus*, mammoth, *Camelops*, and *Bison*. The localities from which some or all of these fossils have been found are given in the list of vertebrate localities and include localities 5, 8, 9, 13, and 32. The Recent terraces are recognized by position, by the presence of *Bison bison* and by the absence of Pleistocene forms.

The stage of erosion during which the long shallow valleys were extended across the plains, probably the same stage during which the inner filled gorge of Canadian River was formed, was either much more prolonged or more intense than subsequent Recent stages of erosion during which valley excavation did not extend upstream beyond the heads of the canyons. The development of the valleys must have taken place in a period of increasing humidity when large volumes of water enabled the streams to erode and extend their valleys across the comparatively flat plains surface.

Accumulations of valley fill must have started almost concurrently with a decline in humidity when diminishing flow of water through the valleys could no longer erode the valley floors or maintain the previously established grades. The late Pleistocene and Recent deposits which cover the valley floors clearly show that deposition has been dominant and erosion subordinate since late Pleistocene time within the parts of the valleys which lie above the canyons. Development of the valleys and formation of the late Pleistocene fill are believed to have taken place during the Wisconsin stage of the Pleistocene and to be of the same age as the Tahoka clay. The Wisconsin age of the deposits, as has been stated, is indicated by vertebrate fossils and by their stratigraphic position in respect to Recent deposits; and the fact that this fill is the first deposit to accumulate within the valley indicates that no great difference in age exists between the deposits and the containing valley. The valley is therefore thought to belong to an earlier part of the Wisconsin.

Three minor stages of Recent valley cutting are apparent within the canyons extending into the eastern part of the plains where the stream gradients are greatly steepened. The stages of cutting are represented by successively smaller and deeper valleys. The lowest and smallest of these minor valleys is the present channel or gulley which is now cutting rapidly headward and laterally. The other two minor valleys are filled and form the two Recent terraces. None of these minor valleys extended headward beyond the steeper gradients at the heads of the canyons.

Late Pleistocene and Recent erosional features and deposits are similarly developed in stream valleys throughout the plains region, as well as in adjoining regions of the Southwest. The valleys and tributaries characteristically contain late Pleistocene and Recent fills. The fill may be terraced along parts of the valley having relatively steep gradients and unterraced where the gradient is comparatively flat. Where the fill is terraced, one Pleistocene and two Recent terraces are generally present. An actively eroding channel or gully is now extending headward in all or nearly all of the valleys. As has been pointed out by Albritton and Bryan (1939) and others, climate is the only factor which could have influenced stream action in similar ways and at the same times throughout such a large area. It may be concluded, therefore, that each degradational stage indicates a period of increased humidity, and each aggradational stage a period of increased aridity over the entire plains region.

EOLIAN DEPOSITS

Quaternary eolian and Recent fluviatile-eolian deposits are far more widespread over the plains region than the lacustrine and stream deposits. The surface deposits which cover most of the plains to an average thickness of 20 to 40 feet are largely of eolian origin as they mantle irregularities on the older rocks and are too widespread to have been distributed by other than wind action. These deposits consist of well-compacted sands and dust-size particles and contain a large amount of secondary caliche. They exhibit a mature flattish surface except where indented by streams and playas.

Inasmuch as these sands have not been found to contain fossils, their approximate age can be determined in only a few places where their relation to deposits of known age can be established. The sand sheet which overlaps the Blanco beds is believed to be of early Pleistocene age, perhaps Aftonian. This sand contains a large amount of caliche, particularly in its lower part, which is indicative of considerable age, and numerous playa basins partly filled by late Pleistocene or Recent sediments have formed on the sand. At several places, as in Ector and Crane counties, pond deposits containing late Pleistocene vertebrate fossils overlie definite eolian sands. Eolian sand deposits have probably formed on the plains surface during all or most of the Pleistocene, particularly in the more arid stages.

One or more widespread eolian sand sheets were laid down during the Recent epoch over much of the southern and western parts of the plains. The Recent age of these sands is recognized by their preserved dune-form topography and by their disconformable relation to underlying deposits of late Pleistocene age.

The Recent sands were derived partly from reworking of underlying older sands, the exposed surface of which can be seen in some of the deeper modern blow-outs in Ector, Crane, Ward, and Winkler counties. Some of the sands have been derived from the terraces and channel of Canadian River and from channel and fan deposits of short intermittent streams. The process of fluviatile-eolian sand deposition is still operating in the extreme northwestern part of the Texas Panhandle, in the vicinity of Texline, and elsewhere on the western side of the plains. Short east-flowing valleys which are well entrenched on the steeper sloping western part of the plains become wider and shallower downstream as the gradient flattens until they gradually lose their identity as channels. Occasional flooding causes the streams to deposit wide sand fans on the flattened gradient. The sand is then reworked and further transported by winds.

Reworking of the older Recent sands and to some extent their underlying deposits is still taking place in relatively very localized areas, such as in the long belt of active dunes which is crossed by U. S. highway No. 80 in the vicinity of Monahans in Ward County and in several local areas in the vicinity of Muleshoe in Bailey County. The active dunes are within larger areas of somewhat older, well-preserved dunes now anchored or partly anchored by vegetation. These dunes, in turn, lie within or marginal to much more extensive areas of well-vegetated and modified low dunes belonging, at least in part, to an earlier stage of the Recent. The sands of these older modified dunes have a characteristic reddish-orange color caused by films of iron hydroxide on the sand grains. The later sands in being reworked have lost the iron hydroxide film by attrition and are of a light gray color. The widespread earlier Recent sands indicate a substage of relatively great aridity, while the smaller areas of more Recent and modern sands, and the well-vegetated surface of the earlier sands, indicate a present substage of increased humidity.

LIST OF PLEISTOCENE VERTEBRATE LOCALITIES

The following list is a record of the localities in which recognizable Pleistocene fossils have been found. Each locality corresponds to the numbered localities on the map (Pl. 47). In the faunal list, the word mammoth has been used in preference to a generic name because generic identification of fragmentary remains was uncertain in many cases. The name of the institution following the faunal list indicates place of storage of the specimens. Some of the principal references are given for the well-known localities.

Locality No. 1—Dallam County

On south bluff of Perico Creek, 7.5 miles east and 2 miles south of Texline. Specimen collected by Mr. W. S. Wilson of Texline. Locality examined by the writers in 1944.

Horizon.—Late Pleistocene.

General description.—The fossil came from a bed of semi-consolidated, reddish-brown sand which is overlain by recent wind-blown sands now almost obscuring the outcrop.

Fauna.—An incomplete mandible of *Panthera atrox.* West Texas Museum, Lubbock, Texas.

Locality No. 2—Hartley County

Several localities on the Collin ranch along Rita Blanca Creek and some of its tributaries and north of the Channing-Romero road, 8 miles west of Channing. Locality examined by the writers in 1942 and 1943.

Horizon.—Deposits of two different ages are recognized within this basin. The oldest is Blancan, the other post-Blancan Pleistocene in age.

General description.—The Blancan fossils are in at least two horizons in a section of clays and calcareous sands. Some of the clays also contain small fossil fish and insects. Two or more thin sandstone members at and near the lower vertebrate horizon locally contain numerous tracks of two kinds of camels. The post-Blancan deposits consist mainly of sands and volcanic ash. A partial mammoth skeleton was found in the sands overlying the Blancan deposits.

Fauna.—Blancan stage: *Gigantocamelus* and *Stegomastodon.* Post-Blancan stage: mammoth. West Texas Museum, Lubbock, Texas.

Locality No. 3—Roberts County

On north side of Red Deer Canyon, 5 miles west and 4 miles north of Miami. Reference: Sellards (1938).

Horizon.—Late Pleistocene.

General description.—Fossils were found at shallow depth in a small filled pond. Parts of five or more individual mammoths were recognized.

Fauna.—Mammoth. Texas Memorial Museum, Austin, Texas.

Locality No. 4—Randall County

On east side of Cita Canyon, about 15 miles east and south of Canyon. Reference: Johnston (1938).

Horizon.—Early Pleistocene, Blancan.

General description.—Fossils found in unconsolidated sands and in calcareous, cemented sands near top of canyon wall.

Fauna.—See list given by Johnston (1938). Panhandle Plains Historical Museum, Canyon, Texas.

Locality No. 5—Swisher County

On North Tule Creek, 5 miles north of Tulia, and 300 feet west of U. S. highway No. 87. Locality examined by the writers in 1944.

Horizon.—Late Pleistocene, Wisconsin.

General description.—The fossils occur in a partially cemented, sandy gravel which is overlain by from 2 to 6 feet of later sands. The valley fill is well exposed in a large excavation made for obtaining road material.

Fauna.—Mammoth, *Bison, Camelops, Canis.*

Locality No. 6—Swisher and Briscoe Counties

Tule formation (Rock Creek beds). Several localities along Tule Creek in eastern Swisher County and along Tule and Rock creeks in western Briscoe County. References: Cope (1893), Cummins (1893-b), Gidley (1903), Hay (1924), Lull (1915), Matthew (1924), Troxell (1915), Wood and Wood (1933), Wood et al. (1941).

Horizon.—Middle Pleistocene.

General description.—The principal locality from which vertebrate fossils have been collected is on the Mayfield ranch on Rock Creek, 0.2 mile north of State highway No. 86. The fossils are in a sand bed near the top of the Tule formation.

Fauna.—See faunal lists given by Cope (1893-b), Gidley (1903), Matthew (1924), and Troxell (1915).

Locality No. 7—Bailey County

On west side of Monument Lake, 2 miles west and 2 miles north of Baileyboro. Locality examined by the writers in 1942.

Horizon.—Late Pleistocene, Wisconsin.

General description.—Fossils were found in the marginal facies of the Tahoka clay in exposures on the southwest side of the playa.

Fauna.—Mammoth, *Equus, Bison.*

Locality No. 8—Hale County

On White River, 0.5 mile west of Plainview. Locality examined by the writers in 1944.

Horizon.—Late Pleistocene, Wisconsin.

General description.—Fossils occur in a gray sandy clay, overlain by about 6 feet of pack sand. The bison bones at this locality constitute a "bone bed." They are exposed along a distance of about 75 feet and in places reach a thickness of about 2 feet. The bone bed is exposed on the north side of a pit dug for road material.

Fauna.—Mammoth, *Bison.*

Locality No. 9—Hale County

On Double Mountain Fork of Brazos River, 2.4 miles west of Abernathy. Locally known as Goeth gravel pit. Locality examined by the writers in 1944.

Horizon.—Late Pleistocene, Wisconsin.

General description.—The fossils occur in gray indurated sands and gravel overlain by 3 to 5 feet of humus-stained later sands. The deposit is valley fill.

Fauna.—Mammoth. Department of Geology, Texas Technological College, Lubbock, Texas.

Locality No. 10—Hockley County

On southeast side of Silver Lake, 2 miles south and 0.2 mile east of the northwest corner of Hockley County. Locality examined by the writers in 1942.

Horizon.—Tahoka clay, Wisconsin.

General description.—The bison bones occur in the upper part of the Tahoka clay as a "bone bed" which averages about a foot in thickness and is exposed for a horizontal distance of about a hundred feet.

Fauna.—*Bison.*

Locality No. 11—Hockley County

Hines' gravel pit, 6.3 miles west and 1.5 miles north of Witharral. Several excavations locally known as Johnson's gravel pits lie 0.5 mile to the southeast. Locality examined by the writers in 1943.

Horizon.—Late Pleistocene, Wisconsin.

General description.—The basal part of the deposit consists of cross-bedded siliceous gravels and reworked Cretaceous shells. Above the gravels is a lake or pond deposit of gray sand and clay with numerous small fresh-water gastropod and pelecypod shells. These gravel pits lie within the present drainage area of Yellow Lake, which is 3.5 miles to the northwest.

Fauna.—Mammoth, *Equus, Camelops, Bison.* West Texas Museum, Lubbock, Texas.

Locality No. 12—Lubbock County

On Yellowhouse Canyon, northwest of Lubbock, 1.5 miles northwest of the junction of the railroad and College Avenue. Locality examined by the writers in 1942.

Horizon.—Pleistocene.

General description.—There are lake deposits of two distinct ages here. The older deposit, probably the equivalent of the Tule formation, consists of stratified light gray sands and clays and is exposed in the dissected wall of the canyon. The more recent deposit, probably of Wisconsin age, consists principally of gray sands and clays. It was formed within the present valley of Yellowhouse Canyon and lies topographically lower than the main body of the older deposits.

Fauna.—Older deposits: mammoth, *Equus, Camelops*; younger deposits: *Bison.*

Locality No. 13—Lubbock County

On Yellowhouse Canyon, near dam across the eastern lake at Buffalo Lakes, 8 miles southeast of Lubbock. Locality examined by the writers in 1944.

Horizon.—Late Pleistocene, Wisconsin.

General description.—A terrace deposit consisting of light gray sands with interbedded thin clay lenses. Fresh-water gastropods and Unios are abundant.

Fauna.—*Holmesina?, Equus,* mammoth. Bureau of Economic Geology, The University of Texas, Austin, Texas.

Locality No. 14—Lubbock County

On north side of Yellowhouse Canyon, 4.5 miles north and east of Slaton. Locality examined by the writers in 1942 and 1943. Reference: Meade (1942).

Horizon.—Middle Pleistocene, probably equivalent to the Tule formation.

General description.—This locality has been designated the Slaton quarry. A large number of fossils have already been collected. The main deposit lies within the canyon, well below the plains level, and consists of stratified light gray sands and bentonitic clays with numerous fresh-water gastropods and small bivalves. Remnants of the lake deposits occur above the cap rock on both sides of the canyon, indicating that this basin was essentially filled before its dissection by Yellowhouse Canyon.

Fauna.—Mammoth, *Equus, Camelops, Tanupolama, Capromeryx, Cynomys, Neofiber,* carnivore.

Localities Nos. 15 and 16—Crosby County

Blanco beds. Locality No. 15, along Crawfish Draw and White River, 10 miles north of Crosbyton. Locality No. 16, on east side of White River, 6 miles northeast of Crosbyton. References: Baker (1915), Cope (1893-a, b), Cummins (1890, 1891, 1892, 1893), Gidley (1903), Matthew (1924, 1925), Osborn (1903, 1936).

Horizon.—Early Pleistocene, Nebraskan.

General description.—See references and this paper, pages 491–493.

Fauna.—See faunal lists given by Cope (1893-a, b), Gidley (1903), and Matthew (1924).

Locality No. 17—Crosby County

On north side of Double Mountain Fork of Brazos River, 14.5 miles south of Lorenzo. Locality examined by the writers in 1943.

Horizon.—Pleistocene.

General description.—A small lake deposit consisting of gray sands and clays.

Fauna.—*Equus.*

Locality No. 18—Lynn County

On south end of Tahoka Lake, 4.5 miles north and 2.8 miles east of Tahoka. Locality examined by the writers in 1943.

Horizon.—Tahoka clay, Wisconsin.

General description.—The fossils occur in the upper part of the Tahoka clay.

Fauna.—*Bison.*

Locality No. 19—Garza County

Just below the plains escarpment, 4 miles east and 0.3 mile south of Southland. Locality examined by the writers in 1943.

Horizon.—Late Pleistocene, probably Wisconsin.

General description.—A small deposit of lake clays and sands.

Fauna.—*Bison.*

Locality No. 20—Garza County

At edge of plains escarpment, 2.5 miles east and 1.5 miles north of Graham Chapel. Locality examined by the writers in 1943.

Horizon.—Late Pleistocene, Wisconsin.

General description.—A small, partially filled basin, now in the early stages of dissection by gullies.

Fauna.—Mammoth, *Bison.*

Locality No. 21—Garza County

Spring Creek deposits. Along Double Mountain Fork of Brazos River and along Spring Creek, 5 miles south and 3 miles west of Graham Chapel. Locality examined by the writers in 1942 and 1943.

Horizon.—Middle Pleistocene, probably equivalent to the Tule formation.

General description.—The fossils were found in a sand member near the base of the Spring Creek basin deposits.

Fauna.—Mammoth, *Mylodon, Equus, Camelops.* Bureau of Economic Geology, The University of Texas, Austin, Texas.

Locality No. 22—Gaines County

On west side of Cedar Lake, 8.8 miles south and 15.5 miles east of Seagraves. Locality examined by the writers in 1943 and 1944.

Horizon.—Tahoka clay, Wisconsin.

General description.—Fossils were found in the marginal facies of the Tahoka clay.

Fauna.—Mammoth, *Equus.*

Locality No. 23—Andrews County

On north side of Shafter Lake, 4.5 miles west along the Eunice road from State highway No. 51 north of Andrews. Locality examined by the writers in 1942.

Horizon.—Tahoka clay, Wisconsin.

General description.—The fossils occur in two horizons. The lower horizon is slightly above the contact of the fill with the older brown sands. The fossils in this horizon are fragmentary and badly etched by alkaline waters. The upper horizon is about 20 feet above the present lake floor and consists of two layers, a well-compacted green sand and a light gray sandy clay, in both of which fossils are found.

Fauna.—Mammoth, *Equus.* Bureau of Economic Geology, The University of Texas, Austin, Texas.

Locality No. 24—Andrews County

On northwest side of Shafter Lake, about 1 mile from Locality No. 23. Locality examined by the writers in 1942.

Horizon.—Tahoka clay, Wisconsin.

General description.—Fossils occur in a gray sandy and gravel layer about 6 feet above the present lake floor.

Fauna.—Mammoth, *Glyptodon, Equus,* turtle. Bureau of Economic Geology, The University of Texas, Austin, Texas.

Locality No. 25—Howard County

On Wild Horse Creek, 6 miles east and 2.3 miles north of Fairview. Locality examined by the writers in 1939 and 1942.

Horizon.—Late Pleistocene and Recent.

General description.—The valley of Wild Horse Creek contains a broad and relatively thick Quaternary fill, separable into three well-defined units on the basis of lithology and by the unconformities separating them. The lowest and oldest unit is composed of gray clays, gray to light greenish-gray sands and gravels, well compacted to semi-consolidated by calcium carbonate.

This horizon is further characterized by the presence of numerous small gastropods and bivalves and by mammoth and *Equus* remains. The middle unit of the valley fill unconformably overlies the older fill and is more restricted in extent. It consists of ponded materials of dark ash-gray sandy clays and darker clays containing humic materials. The thickness is from 0 to about 18 feet. It contains numerous *Bison* bones, possibly other animals, and artifacts. This unit is overlain unconformably by the upper unit.

The upper unit, consisting chiefly of unconsolidated sands and gravels, is distinguishable from the other units by lack of compaction, reddish-brown to dark gray color, relative position, paucity of invertebrate fossils, and apparently complete absence of vertebrate fossils. The thickness varies greatly but in places attains 30 feet.

Fauna.—Mammoth, *Equus*, *Bison.*

Locality No. 26—Howard County

Two and one-half miles east of Coahoma. Locality examined by the writers in 1939.

Horizon.—Late Pleistocene.

General description.—A valley fill consisting of light gray sand and gravels. The thickness of the deposit is not known. The fossils were obtained from 4 to 5 feet below the surface of the ground. A partial mammoth skeleton was collected here.

Fauna.—Mammoth, *Equus*, *Cynomys*. Bureau of Economic Geology, The University of Texas, Austin, Texas.

Locality No. 27—Howard County

On north side of Beals Creek, adjacent to railroad spur, at west edge of Big Spring. Locality examined by the writers in 1940.

Horizon.—Pleistocene.

General description.—The deposit consists of stream-deposited, siliceous and calcareous gravels, which contained a mammoth skull, and ponded light gray, sandy clays with numerous small gastropods.

Fauna.—Mammoth. Bureau of Economic Geology, The University of Texas, Austin, Texas.

Locality No. 28—Howard County

On Beals Creek, 1 mile south and 1.5 miles east of the Cosden refinery east of Big Spring. Locality examined by the writers in 1939 and 1944.

Horizon.—Pleistocene.

General description.—Resting unconformably upon the Triassic is a deposit of siliceous and calcareous gravels up to 30 feet in thickness in which fossil vertebrates are found. Overlying the gravel is a deposit of reddish-brown, semi-consolidated sand with caliche nodules and concretions which attains a thickness of about 40 feet.

Fauna.—Mammoth, *Equus*, *Tanupolama*. Bureau of Economic Geology, The University of Texas, Austin, Texas.

Locality No. 29—Ector County

About 500 feet east of State highway No. 51, 1 mile south of the Ector-Andrews County line. Locality examined by the writers in 1942.

Horizon.—Late Pleistocene, probably Wisconsin.

General description.—The fossils found consisted of fragmentary bones and teeth scattered over earth dumps from an artificial pond or "tank" which had been excavated to a depth of about 7 feet within a partly filled small lake basin. The sediments are dark humic-stained sandy clays typical of the fill in shallow basins on the plains.

Fauna.—Mammoth, *Equus.*

Locality No. 30—Ector County

About 3 miles north of Sand Hills on U. S. highway No. 80, in the southwest corner of Ector County, in an area of active dune development. Locality examined by the writers in 1942.

Horizon.—Late Pleistocene, probably Wisconsin.

General description.—Vertebrate fossils are found in gray, calcareous sands which also contain pond snails and some fossilized stems of aquatic plants. These sands are exposed in the bottoms of several of the larger and deeper blow-outs.

Fauna.—Mammoth, *Equus.*

Locality No. 31—Ector County

Ten miles southwest of Odessa in and near the Odessa meteor crater. Locality examined and specimens collected by E. H. Sellards, R. W. Miller, and G. L. Evans in 1940.

Horizon.—Late Pleistocene.

General description.—Fossils were found in dark silt in an exploratory shaft 8 by 12 feet near the center of the Odessa meteor crater and in two excavations within similar fill located about 200 and 700 feet respectively northwest of the crater. The fossils were not confined to a definite horizon but were scattered irregularly from 8 to 16 feet below the surface.

Fauna.—*Equus.* This genus is represented by several partial jaws, isolated teeth, and limb bones. Bureau of Economic Geology, The University of Texas, Austin, Texas.

Locality No. 32—Midland County

On Mustang Draw, 5 miles south and 0.3 mile west of Stanton. Locality examined by G. L. Evans in 1941.

Horizon.—Late Pleistocene.

General description.—The fossils occur in a small gravel pit in clayey sand, 8 feet beneath the surface and immediately above a bed of coarse gravel. The deposit appears to be confined within the narrow valley of Mustang Draw.

Fauna.—Mammoth. A number of limb bones, isolated teeth, and a piece of tusk are known. Some of the specimens are stored in the city museum at Midland, Texas.

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THE BLANCO FAUNA

Grayson E. Meade

INTRODUCTION

The present paper describes several collections of vertebrate fossils from the Blanco beds of Crosby County, Texas. The principal collection is one made during the spring and summer of 1941, when the Bureau of Economic Geology, through the State-wide Paleontologic-Mineralogic Survey, made collections of fossil vertebrates from the Blanco beds for the purpose of obtaining additional information on the paleontology and geology of this classic locality. The material was collected by Work Projects No. 15995, under the supervision of Mr. Richmond Bronaugh. The specimens were prepared by Work Projects Administration Official Project No. 665–66–3–233. A few Blanco specimens in the collection of the West Texas Museum at Lubbock are included, as well as some additional material collected by Glen L. Evans, Carl Chelf, and the writer in the summer of 1943. During the progress of all the field work, particular attention was paid to the stratigraphic occurrence of the fossils. At each of the major fossil sites a section was measured from the bottom to the top of the Blanco beds in order that the exact horizons in which the fossils occurred could be determined.

Nearly all the known members of the Blanco fauna are included in these collections. Several genera, namely, *Procastoroides*, *Hypolagus*, *Panthera*, *Camelops*, *Gigantocamelus*, *Tanupolama*, and *Capromeryx*, described in this paper have not been reported previously from the Blanco. A comparison of this fauna with the upper Pliocene and lower Pleistocene faunas of North America indicates a lowermost Pleistocene age for the Blanco fauna.

The writer wishes to express particular gratitude to Dr. E. H. Sellards for the privilege of studying the collection of Blanco fossils, for assistance in carrying on this work at the Bureau of Economic Geology, and for permission to transport many of the fossils to Lubbock for study. Sincere thanks are due Dr. Everett C. Olson for critically reading the manuscript and for offering many valuable suggestions. The writer is indebted to Mr. Glen L. Evans for valuable discussions and many important suggestions. Dr. Paul O. McGrew has aided with many helpful suggestions and by reading of the manuscript. The department of zoology of the Chicago Natural History Museum has helped by generously allowing their collection of recent felid material to be studied. Appreciation is expressed to Mr. J. S. Bridwell and to Mr. R. B. Smith for their coöperation and for permission to collect the fossils on their respective ranches.

DESCRIPTION OF LOCALITY

The Blanco beds lie near the eastern edge of the Llano Estacado in Crosby County, Texas (fig. 1). The principal exposures occur on the canyon slopes of Crawfish Draw about 2 miles west and north of its confluence with White River, on the J. S. Bridwell and R. B. Smith ranches 10 miles north of Crosbyton, Texas (see fig. 2). Most of the fossils were found in the exposures on the north side of Crawfish Draw, west of the Crosbyton-Floydada road, and south of Mount Blanco. Six miles northeast of Crosbyton, on both sides of the public road, is another more limited exposure of the Blanco beds where a few fossils were collected. Between these two localities, on the east side of White River and east of Mount Blanco, is an exposure of Blanco beds traversed by the Cone-Mount Blanco road.

Matthew (1924b) calls attention to an exposure of supposed Blanco beds 2½ miles southeast of Crosbyton in a small tributary on the west side of Blanco Canyon. He reports that no fossils were found at this locality. In 1942, Glen L. Evans and the writer visited this locality and searched for fossils but failed to find any. Matthew also mentions a smaller outcrop of beds similar in lithology to the Blanco about 20 miles south of Crosbyton near where the main road to Post comes down off the plains. He reported that no

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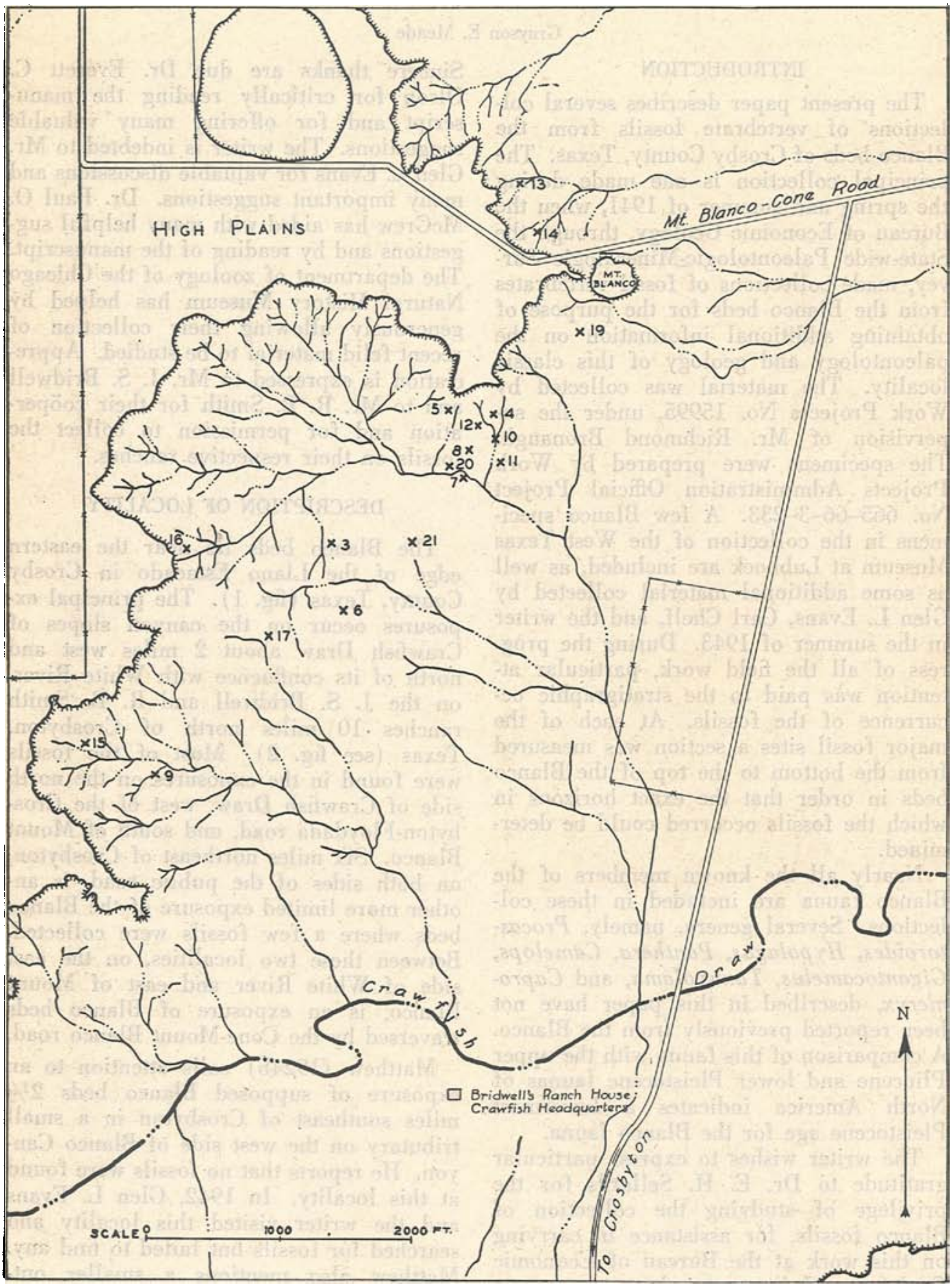

Fig. 1. Map showing location of the major collecting sites in the Blanco beds, Crosby County, Texas.

fossils were found here either. This area also was examined by Evans and the writer, who failed to find any exposures that could definitely be correlated with the Blanco.

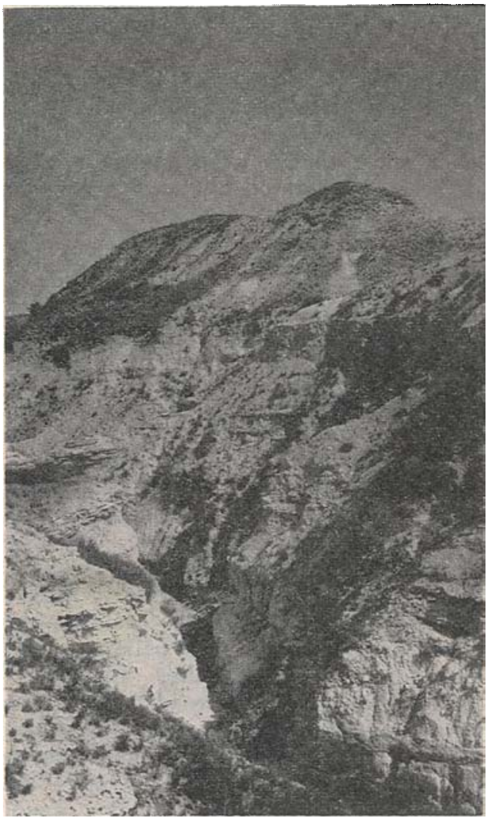

Fig. 2. Exposure in the Blanco beds on the J. S. Bridwell ranch, Crosby County, Texas. Basal contact is beneath gray sandstone seen in bottom of picture. Photograph by Glen L. Evans, June, 1941.

PREVIOUS WORK IN THE BLANCO BEDS

In the winter of 1889–90, Mr. W. F. Cummins discovered the first vertebrate fossils from the Blanco beds. Cummins wrote (1890, p. 190) that: "Overlying and resting unconformably upon the Dockum Beds are beds of red clay, white sandy clays, white clays, and a hardened clayey limestone, fronting to the eastward and forming bold escarpments 200 feet high. These beds constitute the staked plains. Because of the extensive presentation of these strata in Blanco Canyon, Dickens County, I have given them the name of Blanco Canyon beds." The only fossils that he found in these beds "were some of the larger mammals and a species of turtle." He did not have sufficient data to enable him to place the Blanco Canyon beds in their proper geologic position but indicated that they were of "—much more recent date than Cretaceous—."

It is apparent from the description of the beds that Cummins was applying the name Blanco Canyon Beds to all the post-Cretaceous deposits of the Staked Plains.

In 1891 Cummins further discussed the Blanco Canyon Beds and included a section made about 1 mile south of Mount Blanco. In 1892 he changed the name of the Blanco Canyon Beds to Blanco Beds, because the double name was undesirable and because the beds were also found far from Blanco Canyon.

By this time he had traveled entirely around the Staked Plains and believed that over nearly all the Staked Plains area the upper strata belonged to the Blanco beds. To explain the origin of these widespread deposits he assumed a great inland "sea" covering approximately the area of the present Staked Plains. The lower part of the Blanco was thought to thicken to the northwest and the upper limestone bed[1] was found to be of about the same thickness wherever observed. Thus a lacustrine origin was assumed for the Blanco beds.

The first attempt to place the Blanco beds definitely in their proper geologic position was made by Cummins. He believed them to be equivalent to the White River beds.[2]

Some of the fossils which Cummins had collected were sent to Cope for identification. On the basis of these fossils Cope believed the Blanco beds to be intermediate between Loup Fork and the *Equus* beds. Later in the year Cope accompanied Cummins in a more thorough exploration of the Staked Plains, and additional fossils were collected from the Blanco beds.

The following year (1893) Cummins further discussed the Blanco beds: "This

[1]The omnipresent caliche zone of the Staked Plains and many other territories in the Southwest.

[2]Reported by Cummins (1891) to be equivalent to the Green River beds but meaning the White River beds; a mistake which he rectified the following year (1892).

formation constitutes the eastern scarp of the Staked Plains from the Double Mountain Fork of the Brazos on the south to Paloduro Canyon on the north." He also considered some exposures near Miami in Roberts County, Texas, as a part of the Blanco beds.

The American Museum sent an expedition, under the leadership of Dr. Gidley, to the Staked Plains for three consecutive summers from 1899 to 1901. The party did not reach the Mount Blanco area the first season, but in the following two seasons made large collections from the Blanco which added materially to the knowledge of its fauna.

Gidley (1903b) concluded that the Blanco beds were true Pliocene but of limited extent, occurring in the vicinity of Mount Blanco, and traceable for 15 to 20 miles eastward to the edge of the plains. He showed that Cummins's interpretation of the Blanco beds in Roberts County was based upon the erroneous identification of some horse teeth. It also became evident to him that in the vicinity of Mount Blanco, the bottom 32 feet of Cummins's section included beds of reddish clay and red clay which were older than the Blanco.

He disagreed with Cummins's interpretation of the origin of the Blanco sediments, believing them to be fluviatile and not lacustrine. Gidley (1903b, p. 625) states: "It is thus seen that the Blanco beds, at Mount Blanco, like the Rock Creek beds, apparently occupy a comparatively narrow valley or basin formed for their deposition by ancient erosion of the older beds. Like the Rock Creek beds also they extend a long distance in one direction, being traceable south-eastward for fifteen or twenty miles to the edge of the Plains. Though the deposits differ in character from those of the Rock Creek beds and the fauna indicates an earlier age, here, as at Tule Canyon, there is a total absence of any proof of a lake origin for these beds and many evidences of river or stream deposition.

"The occasional beds of diatomaceous earth are easily accounted for by supposing that there were in this ancient valley occasional ponds filled with clear water, enduring for various periods of time, partially or totally isolated from the stream that ran through the valley, such as exist at the present time in the West, especially in the Sand-hills country of northwestern Nebraska and southern South Dakota."

Baker (1915) briefly discussed the Blanco beds with respect to their origin. He believed them to be probably a stream deposit and to occupy a comparatively narrow valley or basin formed for their deposition by erosion of the older beds.

In 1924, Matthew and Simpson collected vertebrate fossils from the Blanco beds. Matthew prepared a report on the fauna and geology of the Panhandle area of Texas; a part of this report was devoted to his observations on the Blanco. Matthew also showed that the Blanco beds were of limited extent and mentioned four separate localities. These are essentially the same as the localities now known to exist, which have already been mentioned in "Description of Locality." Matthew, however, considered these localities to be only the fossiliferous portion of the Blanco. He believed the upper portion of the Blanco to be interdigitated with and contemporaneous with the upper part of the Panhandle clays. Thus he assumed a wider distribution for the Blanco than Gidley had previously shown.

Matthew also believed the Blanco to be fluviatile in origin. "We believe all of these to be stream-valley fillings,—" "—The Blanco beds were deposited in a broad and shallow slowly aggrading stream valley with a slow-flowing, probably intermittent stream of about the type of the present Blanco Creek. The valley would be partly occupied then as now by abandoned stream channels forming ponds and muckholes—."

This interpretation of a fluviatile origin for the Blanco has generally been accepted without question by subsequent workers. Evans and Meade (1945), however, have shown that this interpretation is untenable, and that the deposits were laid down in a basin rather than in a stream bed.

THE BLANCAN STAGE

Osborn (1936, p. 675) thought that the "Blanco formation" included more than one specific stage and that it probably represented a long period of geologic time. This assumption apparently was based principally upon the advanced

Stegomastodon texanus, from the upper levels of the Blanco, compared with the more primitive *S. successor* from the lower levels of the Blanco.

Faunal assemblages here regarded as Blancan in age include the Blanco, Hagerman, Coso Mountains, Benson, Sand Draw, Broadwater, Cita Canyon, and Rexroad. It becomes a matter of some importance then whether the Blanco represents one or more than one specific stage. If more than one stage is represented in the Blanco, it is probable that other Blancan assemblages also represent more than one specific stage.

The number of stages represented by the Blanco of Texas may be determined by both the paleontologic and the geologic evidence. The paleontological evidence is discussed later under "Unity of Fauna." To examine the geologic evidence, it is necessary to return to the mode of origin of these deposits.

Evans and Meade (1945) have demonstrated that the Blanco deposits occupy basins or depressions within the Tertiary beds. At some time subsequent to the formation of the basins they began to be filled with lacustrine deposits. There is no indication that this cycle of basin filling was interrupted at any time from its beginning until the basin was essentially filled, because there are no unconformities which can be traced for any distance across the basin. Minor breaks in sedimentation are in evidence in the entire section, but these appear to indicate fluctuations in the water level and temporary rejuvenations of the influent drainages. The alternating sands and clays, however, may represent relative changes in the rate of accumulation of the deposits. Many of the clays are bentonitic, probably representing an alteration of volcanic ash which fell into the basin. This would indicate a fairly rapid accumulation of individual clay beds. The almost pure diatomite and the limestone layers indicate periods of considerable duration when there was permanent water beyond the point to which clastic sediments from the shores were carried.

The old "Blanco Basin" then contained permanent water part of the time, and probably for periods of considerable duration. It served as a watering place for the animals from its origin until the basin was filled with sediments, or until it was dissected and drained by the headward erosion of White River. Its geologic history probably is included within one major climatic cycle.[3] Minor climatic cycles either left no imprint, or they may be recorded by the local unconformities which are present. If the assumption is correct that Blanco time is included in a single major climatic cycle, then the fauna preserved in these deposits also represents a specific stage, and not several stages.

MANNER OF ACCUMULATION OF FOSSILS

The lacustrine origin of the Blanco sediments does not materially alter the previous conceptions of the environmental conditions and the accumulation of the fossils in a "stream-valley filling." Matthew (1924b) said of the Blanco that: "We believe all of these to be stream-valley fillings, accumulated not after the Panhandle clays were deposited and eroded, but simultaneously with the upper part of the Panhandle. The latter we regard as plains deposits, perhaps partly accumulated by occasional wide flooding from the streams, but chiefly due to the slow but steady accumulation of dust on a sodded prairie surface with imperfect drainage and scattered playa lakes—in fact just such a surface as exists at the present time, only with the streams little below the general level instead of being in deep canyons. The utter barrenness of the Panhandle clays is due to the very slow accumulation, so slow that skeletons and bones were completely disintegrated and destroyed by weathering before they were buried deep enough for preservation. The Blanco beds were deposited in a broad and shallow slowly aggrading stream valley with a slow-flowing, probably intermittent stream of about the type of the present Blanco creek. The valley would be partly occupied then as now by abandoned stream channels forming ponds and muckholes in which animals would be most frequently caught and buried whole, the stream channel beds proper,

[3]A major climatic cycle as used here denotes a predominately humid or arid climate of considerable duration. During Blanco time the climate was relatively humid, for only under such conditions could permanent or nearly permanent lakes have been maintained.

mostly sandy, being likely to have any remains of animals pretty well broken up and disarticulated before they were permanently buried. The several articulated skeletons that have been found in the Blanco, were preserved in white clays; the fragmentary material is chiefly from sandy clays and sands."

The inferred presence of ponds and muckholes would offer essentially the same conditions for the entrapment and preservation of animals as would a shallow lake. The sands, however, do not represent stream channel beds, and the fact that most of the Blanco fossils were disarticulated and many broken before permanent burial cannot be explained as a result of stream action.

The present occurrence of fossils in the Blanco beds is mostly confined to the marginal areas of the basin. It is not known whether or not the central part of the basin contained fossils, as that part has been removed by erosion. However, in similar basin deposits on the west Texas plains, nearly all of the fossils occur in the marginal areas. In those basin deposits where the central part is present and exposed by erosion, few if any fossils are to be found. It may be assumed that the animals did not venture out into the deeper water in the central part of the basin: that they were caught, or died, and were buried in the marginal areas. Here the bones would be subject to some transportation by wave action of the water, and by intermittent streams which entered the basin.

The predatory animals must also assume their share of responsibility for the destruction and dispersal of many of the bones. Many of the smaller animals may have been completely devoured, which perhaps partially explains the paucity of such forms in the Blanco. However, it is far more likely that the rarity of small forms is the result of careless collecting. A few small forms are present in the Blanco and more are sure to be found. Certainly the sedimentary conditions that prevailed during much of Blancan time must have been nearly at an optimum for the preservation of the large and small animals alike.

The depredations of the carnivores must be assumed to have taken place either in the shallow water of the lake margins or on the shore bordering the lake. In feeding upon the herbivores they would necessarily have scattered the bones over a probable distance of several yards. Bones left lying close to the water's edge may have been subsequently washed into the lake by intermittent streams which entered the basin.

An illustration of the concentration of disarticulated bones which may have accumulated in such a manner is shown by the camel bones in Site No. 11. Here the deposit of *Gigantocamelus* remains (fig. 3) may represent a herd of camels which ventured into the shallow waters of the ancient lake and were trapped or were overcome by carnivores at the edge of the water. In one small area were found the partial and complete skulls and jaws of about eighteen individuals. An abundance

Fig. 3. *Gigantocamelus* bones at Site No. 11, Crosby County, Texas. The fossils are near the bottom of the basal sand of the Blanco beds. Photograph by Glen L. Evans.

of limbs, vertebrae, ribs, and the like were found also, but there were practically no articulated bones.

The bones would also be subjected to trampling and a certain amount of scattering by the larger animals wading in the marginal parts of the lake in search of vegetation growing in the shallow water. That the camels, horses, peccaries, and probably the mastodons did just that may be illustrated by the action of modern horses and cattle which wade considerable distances out into the ponds and lakes to obtain vegetation or to escape flies and other insects. On numerous occasions horses and cattle have been seen far out in shallow ponds and lakes feeding upon the vegetation, and on one occasion a pig was seen enjoying an early morning swim, fully a hundred yards from the shore, and in water over 3 feet deep.

The field party of the Bureau of Economic Geology did not find any articulated skeletons but did find several articulated camel skulls and jaws and a number of articulated leg bones. The articulated horse skeletons found by Matthew were preserved in white clays. Presumably these represent individuals that were buried sufficiently far out in the basin to escape those processes which would have tended to scatter the bones. Even in the marginal deposits one cannot imagine that at least some individuals were not buried in their entirety. But the fact that most of the fossils are disarticulated, and many are broken, would indicate that most of the animals which were caught in the lake had been subjected to trampling by their contemporaries, or their bones had been scattered by carnivores, by wave action, or by intermittent waters entering the lake.

FAUNA

Blanco Faunal List

Cope (1893), Gidley (1903), and Matthew (1924) have recorded the fauna of the Blanco. The following is a revised faunal list of the Blanco beds.

Reptilia

Testudo turgida Cope
Testudo pertenuis Cope
Testudo campester Hay

Aves

Creccoides osbornii Shufeldt

Mammalia

Procastoroides sp.
Hypolagus sp.
Canimartes cumminsii Cope
Borophagus diversidens Cope
Panthera palaeoonca, n. sp.
Stegomastodon successor Cope
Rhynchotherium falconeri Osborn
Serbelodon (?) praecursor Cope
Megalonyx leptostomus Cope
Glyptotherium texanum Osborn
Hippotigris simplicidens (Cope)
Nannippus phlegon (Cope)
Platygonus bicalcaratus Cope
Platygonus texanus Gidley
Camelops cf. kansanus Leidy
Gigantocamelus spatula (Cope)
Tanupolama blancoensis, n. sp.
Leptotylopus percelsus Matthew
Capromeryx sp.

Unity of the Fauna

Osborn (1936) believed that the Blanco included more than one specific stage and that it represented a long period of time. The evidence does not substantiate this view. On the contrary, it indicates that the Blanco represents but a single age. The geologic evidence has already been cited. The fauna shows no evidence of more than one age, nor does it indicate any great lapse of time from the beginning of Blanco deposition to the end. There is no discernible difference among individuals of the same species which occur in the lower levels as compared with those that occur in the higher levels of the Blanco deposits. In the mammalian group, with the possible exception of *Stegomastodon*, *Platygonus* is the only genus at present represented by more than one species. Here it might be expected that one species would be confined to the lower levels and one species confined to the upper levels, particularly if a considerable lapse of time is alloted to the Blanco. If such were the case it would be indicative that the one species had been descended from the other. However, such is not the case, and the two species of *Platygonus* occur together in the lower and in the upper levels. Similarly, there is no vertical zonation of the stegomastodons; both the "advanced" and "primitive" forms occur together from the lower to the uppermost fossiliferous horizons.

Stirton and VanderHoof (1933) suggested the possibility that "*Plesippus cumminsii*" came from the beds underlying the Blanco. This possibility is unlikely as "*P. cumminsii*" is probably a synonym of "*P. simplicidens*" which is a characteristic Blancan form. Evans and the writer have carefully searched these underlying beds and have found a number of fossils, all indicative of middle Pliocene age, including the genera *Neohipparion* and *Astrohippus*. None of the forms from the underlying beds occur in the Blanco, nor do any known Blancan forms occur in the underlying beds. Inasmuch as the Blanco deposits consist in part of sediments reworked from the Pliocene beds, it is possible that reworked Pliocene fossils have been introduced. This possibility, however, is remote because of the preservation and comparative paucity of fossils in the adjacent Pliocene beds.

Correlation of Faunal Elements

In the correlation of mammalian faunas the entire faunal assemblage should be considered. In any given assemblage, there are certain genera which are more useful in correlations than others because of their shorter geologic range, greater geographic distribution, more rapid evolution, or greater abundance as fossils. Before a fauna can be considered as a whole, however, each representative of that fauna should be viewed with respect to its relative diagnostic importance to the entire fauna. Thus the correlation of the Blanco fauna is preceded by a correlation of its faunal elements in which are discussed the principal occurrences and the geologic range of the Blanco genera. This information on each genus provides a basis for the correlation of the Blanco fauna.

Procastoroides is known from the Broadwater, Rexroad, Sand Draw, and the Blanco. This genus is a typical member of the Blancan faunas, and so far as is now known its range is limited to the Blancan age.

Hypolagus ranged from the middle Miocene to the Blancan. The single tooth of this genus from the Blanco is specifically indeterminable. In view of the extensive range of the genus, the specimen is not diagnostic in correlations.

Canimartes is not well enough known to be of value in the present correlation.

Borophagus occurs in the Coso Mountains fauna, as well as in the Tehama, Hagerman, and the Blanco. It is one of the genera limited to the Blancan of North America.

Panthera is the only felid material represented in the Blanco. The geologic range and the relationships of late Pliocene and Pleistocene felids, however, are too inadequately known to permit accurate correlations based on this group.

Proboscideans are well represented in the Blanco. *Stegomastodon* is a characteristic Pleistocene genus. It is the most common proboscidean in the Blanco. Osborn (1936) considers *S. primitivus* from the first interglacial as more primitive than *S. successor* from the Blanco, and the type of *S. mirificus* from the second glacial as more primitive than *S. texanus* from the Blanco. Lugn and Schultz (1934) determined the horizon of the "*Stegomastodon primitivus* quarry" as probably Aftonian, or the first interglacial stage. They determined the horizon of *S. mirificus* to be Kansan or second glacial stage. With respect to these proboscideans Osborn (1936) said: "Inasmuch as three types of *Stegomastodon*, namely, *S. successor*, *S. texanus*, and *S. arizonae*, definitely belong in the Upper to Uppermost Pliocene, it is obvious that the geologic age of both *S. primitivus* and of *S. mirificus* demands further investigation."

The demands for "further investigation" have resulted in: (1) The definite assignment of the Curtis, the locality of the type of *S. arizonae*, to the lower Pleistocene; (2) the retention of an Aftonian age assignment for the *S. primitivus* quarry; and (3) the correlation of the *Stegomastodon* quarry with the Sand Draw by McGrew.

If *Stegomastodon primitivus* and *S. mirificus* are more primitive than the Blanco species as Osborn believed, there remains little reason for continuing to consider the latter as upper Pliocene mastodons. The writer can see no logical alternative to the view that the Blanco stegomastodons are true Pleistocene forms.

Rhynchotherium and *Serbelodon* are characteristic Pliocene genera. Their presence along with the characteristic Pleistocene genera of the Blanco indicates that they are survivors from an earlier period. The latter genus carries no weight in the problem since the generic reference is doubtful. Osborn considered *Rhynchotherium falconeri*, from the Blanco, as the most advanced species of the genus, and one can readily admit of the probability that this species lived into the early Pleistocene. McGrew (1944) has suggested that certain primitive proboscideans did not range as far northward as Broadwater or Sand Draw. This supposition is given support by the presence of *Rhynchotherium* in the Blanco and its absence in more northerly deposits of equivalent age. *R. francisi* is of doubtful geologic occurrence as well as of questionable generic reference. The specimen comes from Brazos River, Burleson County, Texas. The county is in a region of Eocene rocks, not late Tertiary. Inasmuch as the specimen comes from Brazos River, it is probable that it is from a Pleistocene alluvial terrace and not from the Pliocene. If this is correct, and the tooth is correctly referred to *Rhynchotherium*, it offers additional evidence of the range of this genus into the Pleistocene.

The absence of mammoths in the Blanco might be argued as evidence against its Pleistocene age if the first appearance of mammoths coincides with the beginning of the Pleistocene in North America. Their absence in the Broadwater and the Sand Draw and other faunas thought to be of lower Pleistocene age is fairly conclusive evidence that the mammoths did not reach North America until some time after the beginning of the Pleistocene.

Megalonyx leptostomus is the only species of sloth known from the Blanco. The genus is reported from other Blancan deposits. It probably makes its first appearance in this country in the middle Pliocene. Its geologic range extends into the Pleistocene. The sloth material from the Blanco appears to be inconclusive, at present, in correlations and age determination of the beds.

Glyptotherium texanum represents the only Pliocene occurrence of this group of edentates, if the Blanco is considered to be of Pliocene age. Glyptodonts are typical members of the Pleistocene faunas. The evidence may be inconclusive, but the presence of glyptodonts is decidedly more suggestive of a Pleistocene than of a Pliocene age.

Hippotigris is limited to the North American Blancan.

Nannippus phlegon apparently represents the last and most progressive species of the genus. The genus is a survivor from earlier periods and lived longer in the South than in the far West or North (McGrew, 1944.) This species is limited to the North American Blancan.

Platygonus is another characteristic Pleistocene genus with a wide geographic range. Gazin (1938) pointed out that the only material definitely referable to the genus *Platygonus* occurring in pre-Pleistocene deposits was that from the Coso Mountains, Benson, Hagerman, and the Blanco. If, as is compatible with the evidence, these faunas are considered to be of lower Pleistocene age, then there remains no valid occurrence of the genus in the Pliocene.

Gigantocamelus is known to occur in only four localities: the Broadwater and Sand Draw quarries of Nebraska, the Blanco, and the Rita Blanca deposits in Hartley County, Texas. The genus is most certainly characteristic of the Blancan and, so far as known, is confined to this age.

Tanupolama occurs in the McKittrick and Rancho La Brea tar pits and in the Pleistocene deposits of Florida, Hay Springs, Broadwater, Coso Mountains, and Blanco. Gidley (1922) reported a *Lama* from the Curtis of San Pedro Valley, which in all probability is *Tanupolama*. The genus is one of the most characteristic Pleistocene forms, and there are no valid occurrences in pre-Blancan deposits.

Leptotylopus is known only from the Blanco.

Capromeryx is a characteristic Pleistocene genus. It doubtfully occurs in the Pliocene.

Correlation of the Blanco Fauna

The Blanco fauna may be correlated with the Broadwater, Rexroad, Hagerman, San Joaquin, Benson, Coso Mountains, Sand Draw, Tehama, and Cita Canyon.

The age of the Blanco beds was not determined by Cummins except that in 1890 he stated that they were much more recent than the Cretaceous, and in 1892 that they were the equivalent of the White River. Cope (1892a) believed the deposits to be intermediate between the *Equus* beds and the Loup Fork. Gidley (1903b) considered the age to be middle Pliocene and Matthew (1924b) also thought the Blanco to be of middle Pliocene age. More recently the age has been generally accepted as upper Pliocene. Gazin (1936) observed that the upper Pliocene Hagerman horizon was not far removed from the Blanco and that the differences between the two faunas might be only of geographic significance.

J. R. Schultz (1938) correlated the Blanco with the San Timoteo, Hagerman, Coso Mountains, and Tehama. He had sufficient faunal evidence to indicate that many of the Blancan faunas were more recent than upper Pliocene and considered them as transitional from upper Pliocene to Pleistocene.

Johnston (1938) called attention to the close relationship between the Cita Canyon fauna and that of the Blanco.

Hibbard (1938) considered the Rexroad to have its closest relationships with the Blanco and that it was as old as or older than the Blanco. Later, in 1941, he stated that the Rexroad, Blanco, Benson, and Hagerman faunas were of approximately the same age.

McGrew (1944) regarded the Sand Draw quarry as Pleistocene in age on the basis of geological, invertebrate, and vertebrate evidence and presented adequate reasons for considering the Blancan as lower Pleistocene.

There has never been any conclusive evidence that the Blanco fauna was of Pliocene age. Previous to the discovery of several new genera, which are discussed in the present paper, there likewise has been no conclusive evidence to show that the Blanco was younger than Pliocene.

The Blanco fauna is characterized by certain short range genera such as *Procastoroides*, *Borophagus*, *Gigantocamelus*, and *Hippotigris*, which are known only in the Blancan; by *Nannippus* and *Rhynchotherium*, typical Pliocene genera which are unknown in post-Blancan deposits; and by several long-range genera including *Camelops*, *Tanupolama*, *Capromeryx*, and *Platygonus*, which appear first in the Blanco and which survive through most or all of the remaining Pleistocene. The fauna as a whole is obviously much more closely allied to the Pleistocene faunas than to any known Pliocene fauna. There can be no disagreement on the advisability of dating a fauna on the basis of its most recent elements, rather than on the basis of those which may have survived from an earlier age. If this is done, the evidence is in favor of an early Pleistocene rather than a Pliocene age for the Blanco. The writer believes that the combined weight of the newly discovered forms in the Blanco and the evidence presented by J. R. Schultz and by McGrew is sufficient proof that the Blancan is of Pleistocene and not upper Pliocene age.

McGrew has indicated a time gap between Hemphillian and Blancan ages. There are many indications in this region that such a time gap does exist. There is a considerable faunal break between the middle Pliocene Hemphill and the Blanco, and as yet there are no known faunas that fill this hiatus. Middle Pliocene is the latest definitely known Pliocene to occur in west Texas, and nearly everywhere the upper part of these beds is characterized by a development af caliche, which varies from a few feet up to 30 feet in thickness. This represents a prolonged period of aridity, relatively dryer than the present climate, and a time when there were exceptionally few, if any, deposits accumulating in this area. It is not possible at present to determine how great a time span this caliche development may represent. But it is significant that the deposition of the Blanco sediments did not commence until after the formation of some of the caliche. Climatic changes were responsible for the cessation of caliche development and the initiation of a new cycle of sedimentation. The climatic changes that occurred at the beginning of the Pleistocene may correlate with the changed climatic conditions in this area. With one or two exceptions, all the known basin deposits on the plains are of Blanco age or younger. It seems probable that the alternating climatic conditions of the Pleistocene were favorable for the formation and the filling of basins, since dozens of Pleistocene basin deposits are known.

On geologic evidence alone, the age of the Blanco would be difficult if not impossible to determine. The Blanco beds lie upon the middle Pliocene and are overlain by wind blown sands of Pleistocene age. The following geologic facts, however, are significant: The Blanco beds were deposited during a relatively humid stage of considerable duration, under conditions totally unlike those of the upper Pliocene. The Blanco beds were deposited during a glacial stage rather than during a relatively arid interglacial stage. The Blanco stage probably was of greater duration than the middle Pleistocene Tule, or the late Pleistocene Tahoka, because of the greater thickness of lacustrine deposits in the Blanco and because the Blanco basin was more completely filled than were the known middle and late Pleistocene basins. Thus the geological evidence is indicative of an early Pleistocene age for the Blanco. The paleontological evidence indicates an early or earliest Pleistocene age. Accordingly the Blanco is considered to be of Nebraskan age.[4]

[4]The Sand Draw, an equivalent of the Blanco, was considered by McGrew (1944) to be of Aftonian age. Further work on the problem has convinced him (oral communication) that the Sand Draw, as well as the Broadwater, is probably of Nebraskan age instead. The term Blancan, then, should no longer be used as a provincial age for the upper Pliocene, but for the lower Pleistocene Nebraskan. Possibly the Blancan should include both the Nebraskan and Aftonian faunas. The upper limit of the Blancan may provisionally be placed at the top of the Aftonian, inasmuch as it is doubtful whether Nebraskan and Aftonian faunas can be differentiated. Post-Aftonian faunas are far too distinctive ever to be included in the Blancan.

Fossil Sites in the Blanco Beds

The positions of the fossil sites worked by the field party of the Bureau of Economic Geology are plotted on figure 1. Sites No. 1 and 2 did not yield any identifiable fossils; consequently they are not listed in the following tabulation. Sites No. 13 and 14 are on the R. B. Smith ranch on the slopes of the first reëntrant on the north side of the Cone-Mt. Blanco road and east of a large pond on the surface of the plains and near the escarpment. All the other sites are on lands owned by J. S. Bridwell and lie between Mt. Blanco and the mouth of Crawfish Draw on the west side of White River, with the exception of Site No. 22 which is on the east side of White River and several miles southeast of the other sites.

DESCRIPTION OF FAUNA

Class REPTILIA

Order TESTUDINATA

Family TESTUDINIDAE

TESTUDO sp.

Referred specimens.—Several individuals with nearly complete carapace and plastron, and numerous individual fragments.

Discussion.—Much of the turtle material has not been prepared. The specimens are undoubtedly referable to the known Blanco species, but specific identification has not been made.

Site No.	Locality and Horizon	Principal Genera
3	East side of Crawfish Draw, 19 feet above basal contact with red Tertiary clay	Nannippus Hippotigris
4	350 yds. S. 75 yds. E. of gate near Mt. Blanco, 35 feet above basal contact	Platygonus bicalcaratus Platygonus texanus Megalonyx Stegomastodon
5	350 yds. S. 20° E. of gate near Mt. Blanco, 35 feet above basal contact	Stegomastodon
6	Approximately 875 yds. due north of Crawfish ranch house, on S. side of canyon, underlying diatomite bed, 28 feet above basal contact	Hippotigris Platygonus bicalcaratus Platygonus texanus Procastoroides Tanupolama Capromeryx
7	On north side of steep bluff capped by reefy limestone, 75 yds. SW. of Site No. 8, at basal contact	Rhynchotherium

Site No.	Locality and Horizon	Principal Genera
8	60 yds. W. of Site No. 11, 35 feet above basal contact	Platygonus bicalcaratus Platygonus texanus Stegomastodon Camelops
9	650 yds. NW. of Crawfish ranch house, on S. side of draw, 17 feet above basal contact, in gray sand lens immediately above "flaggy limestone" member	Platygonus bicalcaratus Hippotigris Borophagus Leptotylopus
10	35 yds. S. of Site No. 4, mostly at basal contact	Gigantocamelus
11	60 yds. E. of Site No. 8, on S. point of ridge, mostly at basal contact	Gigantocamelus Camelops *Tanupolama* Panthera
12	25 yds. W. of Site No. 10, 35 feet above basal contact	Stegomastodon
13	150 yds. NW. of Mt. Blanco, on S. side of small draw on the R. B. Smith ranch, 38 feet above basal contact	Platygonus bicalcaratus Platygonus texanus Glyptotherium
14	100 yds. NW. of Mt. Blanco, within 30 feet of the Cone-Mt. Blanco road, 38 feet above basal contact	Glyptotherium Stegomastodon
15	50 yds. W. of Site No. 9, NW. of Crawfish ranch house, on N. side of draw, in same horizon as Site No. 9	Stegomastodon Hippotigris
16	25 yds. NW. of Site No. 17, on W. side of draw, 50 feet above basal contact	Stegomastodon Megalonyx Hippotigris
17	50 yds. W. of Site No. 6, S. side of canyon wall, in upper part of basal massive sand	Platygonus texanus
18	120 yds. S. 10° W. of Site No. 21, on S. side of draw, in basal sand at lower contact	Stegomastodon
19	100 yds. SW. of Mt. Blanco, on the S. side of the draw, at basal contact	Stegomastodon Camelops
20	35 yds. N. 20° W. of Site No. 7, on N. side of draw, 12 feet above basal contact	Hippotigris Testudo
21	200 yds. S. 30° W. of Site No. 7, 43 feet above basal contact	Stegomastodon
22	Approximately 875 yds. W. of Calvin Smith's house which is located 8 miles NE. of Crosbyton, near the middle of the Blanco section	Hippotigris Nannippus

Class MAMMALIA

Order RODENTIA

Family CASTORIDAE

PROCASTOROIDES sp.

Referred specimen.—Univ. Texas No. 31176–65, a right lower incisor.

Discussion.—The material is insufficient for specific identification. The incisor measures 6 mm. in width. It represents a small or immature individual, or a species somewhat smaller than those already described. Barbour and Schultz (1937) noted a considerable range of size in the Broadwater specimens. This size variation was also observed by Hibbard (1941) in the Rexroad specimens.

Order LAGOMORPHA

Family LEPORIDAE

HYPOLAGUS sp.

Referred specimen.—West Texas Museum No. 437, a superior cheek tooth.

Discussion.—This is the only leporid remains in the Blanco collection. Little can be said of the tooth except that the medial lingual folds are strongly crenulated. The antero-posterior diameter of the tooth measures 2.6 mm. The transverse diameter measures 4.8 mm.

Order CARNIVORA

Family CANIDAE

BOROPHAGUS DIVERSIDENS Cope

Pl. 48, fig. 4

Referred specimens.—Univ. Texas No. 31179–39, a portion of the right maxillary with the carnassial tooth and the roots of the first molar; No. 31176–64, a right calcaneum.

Discussion.—The carnassial tooth is heavily worn, but it exhibits the characters of the genus in the massiveness of the tooth and in the absence of a parastyle. The antero-posterior diameter of the tooth is 28.3 mm. and the transverse diameter is 13.4 mm.

The calcaneum is slightly larger than the one which Cope referred to *Felis hillanus.* It is considerably larger, however, than the calcaneum of *Osteoborus.* The maximum length measures 55 mm.

VanderHoof (1936) considered Cope's paratypes of *Borophagus diversidens* as forms close to *Canis dirus* and not representing the genus *Borophagus.* He has also suggested that Cope's *Felis hillanus* is not *Borophagus,* but probably *Osteoborus.* There is no material in the present collection referable to *Osteoborus* or *Canis,* and their presence in the Blanco cannot further be substantiated. That *Canis* should appear as part of the Blanco fauna may be expected, but it appears doubtful that the typical middle Pliocene *Osteoborus* actually occurs in the Blanco.

Family FELIDAE

PANTHERA PALAEOONCA, n.sp.

Pl. 48, figs. 1, 2; Pl. 49

Holotype.—Univ. Texas No. 31181–192, nearly complete skull and mandible. Skull rather badly crushed.

Referred specimen.—Univ. Texas No. 31176–63, a partial right superior carnassial tooth.

Locality and horizon.—Blanco beds, Crosby County, Texas. The type is from the head of Blanco Canyon, 10 miles north of Crosbyton, on the J. S. Bridwell ranch, Univ. Texas locality No. 31181, Site No. 11. The material from this site was excavated from the base of the Blanco beds near the contact between them and the underlying Tertiary red sands and clays. The referred specimen is from Univ. Texas locality No. 31176, Site No. 6.

Diagnosis.—A jaguar, differing from the living species *Panthera onca* in having longer carnassials, both absolutely and relatively, and in having longer and more slender superior canines.

Description.—The skull is somewhat damaged. The left zygomatic arch is incomplete, and the saggital and occipital crests are missing. Some of the incisors are damaged, and the protocone of the right carnassial is absent. Parts missing on one side of the skull are usually present on the other so that a fairly accurate picture of the skull may be obtained.

The dorsal outline of the skull is convex with the highest portion apparently over the orbits. The checked and broken bones of the skull do not permit, for the most part, a discussion of the elements in relation to each other, or a detailed comparison with the bones of other species.

The mandible lacks the posterior region of the left side and the tip of the coronoid process of the right side. The incisors, canine, and posterior portion of the carnassial of the left side are missing. The second and third premolars are also missing, but these were probably lost during the life of the animal because the alveoli are completely filled with bone and the surface is roughened and pitted. The alveolus for the left canine appears too small to have housed the tooth, and it also was probably lost before the death of the animal.

Except for the teeth, there appear to be no significant differences in the construction of either the skull or the mandible beyond what easily falls within the range of individual variation of *Panthera onca.*

Discussion.—Merriam and Stock (1932) have shown that there is a great variation in size among the jaguars. The measurements of the skull and jaw of the Blanco specimen indicate a cat of about average jaguar size. The superior and inferior carnassials, however, exceed in length those of the recent jaguar.

Ratio diagrams were made using six characters measurable on the fossil and living species. For these comparisons eight specimens of the modern puma were used, five specimens of the modern jaguar, four specimens of the modern lion, and three specimens of the modern tiger. These results are shown in figure 4.

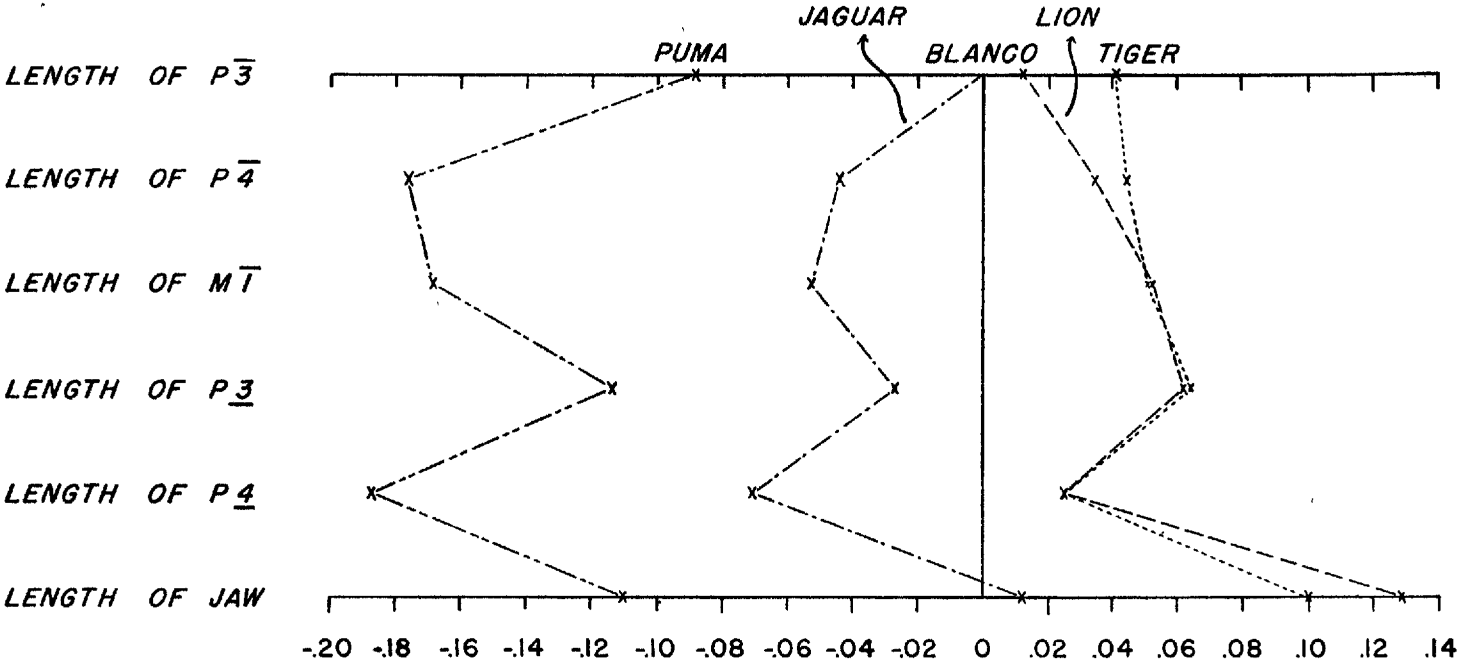

Fig. 4. Ratio diagram of mean values in skull and jaw dimensions in several specimens each of the puma, jaguar, lion, and tiger. In the diagram, Blanco refers to the Blanco specimen *Panthera palaeoonca*.

The proportions of P/4, M/1, and P4/ to the length of the jaw, compared to *Panthera onca*, are significantly different as analyzed statistically. The differences are shown in the following table:

Variate	*Panthera onca* N = 6 Mean	σ'	d of *Panthera palaeoonca* from *Panthera onca* mean	d/σ'
P/4 Length of jaw	12.3	.38	1.8	4.73
M/1 Length of jaw	12.5	.76	2.6	3.42
P 4/ Length of jaw	17.1	1.10	4.3	3.91

M/3 of *S. successor* is described as having five complete ridge-crests, the pentalophid consisting of two half-cones without trefoils and the hexalophid consisting of two primitive conelets. The type jaw of *S. successor* does not have a completely errupted M/3, and all the other material from the Blanco referred to this species by Osborn consisted of immature individuals. The teeth of these individuals might have presented quite a different appearance if they had been fully adult. The teeth in the present collection clearly demonstrate that the posterior ridges and cones not only become progressively larger with advancing age of the individual, but that posterior accessory conelets and cones are added as well, during and after eruption of the tooth.

In the collections of the West Texas Museum there is a complete mandible, No. 392, and a maxillary containing a complete M 2–3/ of *Stegomastodon successor.* These were collected several years ago by Dr. M. A. Stainbrook. There can be no doubt that these belong to the same individual because the mandible was found with the teeth up, and the maxillary with the teeth down, directly over the jaw. Remains of the skull and the tusks were found in place but were so badly weathered that it was impracticable to collect them. In these specimens the first three ridge-crests show wear, a stage of wear beyond that of the type jaw. Accordingly the hexalophid is considerably more developed than in the type. It consists of two cones almost as large as the cones of the pentalophid, but not quite so high. There is no evidence of accessory cones posterior to the pentalophid, but the posterior part of the tooth is still buried in the jaw, so this cannot definitely be determined.

In M 3/ the hexaloph is composed of two prominent cones, widely spaced and with two small inconspicuous cones or

Order PROBOSCIDEA

Family SERRIDENTIDAE

RHYNCHOTHERIUM FALCONERI Osborn

Referred specimens.—Univ. Texas Nos. 31177-1 and 31177-23; each a third molar.

Discussion.—These teeth seem clearly referable to *Rhynchotherium falconeri.* They differ from the type mainly in the better developed fifth ridge, which consists of three cones instead of two as in the type specimen.

Included in the collection are three other molar teeth which can only doubtfully be referred to this genus, but certainly not to this species. Each represents a third molar. The ridges resemble those of *Rhynchotherium* in that they are more wedge-shaped than the ridges of *Stegomastodon,* which give a general appearance of rounded cones. Each tooth consists of five ridges, the last, however, being rudimentary as in *Rhynchotherium.* They are reminiscent of *Stegomastodon* in that the valleys between the ridges are filled with accessory cones, although they are not as numerous as in most specimens of *Stegomastodon.* Undoubtedly more complete material will clear up the relationships of these doubtful teeth.

Family HUMBOLTIDAE

STEGOMASTODON SUCCESSOR Cope

Pl. 50, figs. 1–4

Referred specimens.—Several partial skulls and mandibles and about forty isolated teeth.

Discussion.—Three species of *Stegomastodon* are listed from the Blanco: *S. successor*, *S. texanus,* and *S. mirificus.*

conelets between. The heptaloph is composed of four low, inconspicuous conelets almost in a transverse row.

Osborn has not referred any superior teeth to *S. successor* but assumed that the ridge-crest formula for M 3/ of this species was 5½ because (1936, p. 682): "the inferior molars of *Stegomastodon* are much more progressive than the superior molars. . . ." Therefore, since the ridge-crest formula of M/3 is + 5½, the formula of the superior M 3/ could not have been more than that of the inferior molar. His belief that the inferior molars possessed from a fraction to one more ridge-crest than the superior molars is not borne out by the evidence of the associated superior and inferior molars of specimen No. 392, nor is it substantiated in the case of the superior and inferior teeth of *S. primitivus*. The ridge-crest formula for M 3/ of *S. successor*, as shown by No. 392 and other specimens, should be at least 6½ instead of 5½. It is also somewhat misleading in the case of M/3, to consider it a + 5½ crested tooth. The first fractional ridge-crest, the plus ridge-crest, is the pro-protolophid. This occurs on all unworn teeth, but it completely disappears because of attrition with the posterior end of M/2 as the tooth is progressively worn and moved forward in the jaw. There should at least be consistency in giving this fractional ridge-crest credit for being present in all teeth, or not consider it at all.

The characters of the hexaloph and heptaloph of M 3/ of several specimens of *Stegomastodon successor* are summarized in the following table:

M 3/ of *Stegomastodon texanus* consists of a low rudimentary sixth crest consisting of from four to five conelets and a rudiment of the heptaloph. The above table demonstrates that in a series of only six specimens the hexaloph may vary from four to two cones, all having a rudiment of the heptaloph. In fact, No. 31171–25 may be considered to have a rudimentary octaloph. The mandible, No. 392, is 5½ crested and should be referred to *S. successor*. The maxillary, in which M 3/ is 6½ crested, however, belongs to the same individual. Osborn gives the ridge-crest formula of *S. texanus* as M 3/ 5½–6. All the specimens listed in the above table are specifically indistinct from No. 392. The differences are due to individual variation.

Apparently Osborn estimated the ridge-crest formula for M 3/ of *S. successor* to be 5½ on the basis of the ridge-crests of his other species. He does not refer any superior molars to this species. The large number of teeth in the present collection preclude the probability that the superior molars of *S. successor* are not included in the collection.

M/3 of the type jaw of *S. texanus* consists of a heptalophid of three cones and an octalophid of two cones. M/3 of the paratype jaws of *S. texanus* consists of a hexalophid of two prominent cones and a depressed heptalophid.

No. 31178–8, an M/3, possesses a hexalophid of two cones, with an intermediate anterior cone, and a depressed heptalophid of two cones. No. 31171–19, an M/3, possesses a hexalophid of two cones and a heptalophid of two double cones.

M 3/ No.	Hexaloph	Heptaloph
392	Four cones. (Two prominent cones; two intermediate conelets.)	Four low conelets.
31171–8	Right molar: Three cones. (Two prominent cones, one anterior intermediate conelet.)	Right molar: No distinct conelets.
	Left molar: Four cones. (Two prominent cones, one anterior and one posterior intermediate conelet.)	Left molar: Four low conelets.
31171–25	Three cones. (Two prominent cones; one prominent median cone between pentaloph and hexaloph.)	Six conelets. (Arranged in two transverse ridges of three conelets each.)
31171–27	Two cones.	Four conelets. (Two prominent conelets, one low intermediate conelet and one posterior conelet.)
31198–1	Two cones.	Two appressed cones.
31178–19	Two cones.	Three conelets. (Two prominent conelets; one small median posterior conelet.)

No. 31171–13, an M/3 has a hexalophid of three cones and a heptalophid of three low cones.

Osborn considered *S. texanus* to occur in the middle and upper levels of the Blanco; *S. successor* to occur in the lower levels. This vertical distribution is not borne out by the present collection. Specimens ordinarily referable to *S. texanus* and *S. successor* occur at any level in the Blanco. No. 392, for instance, occurs well toward the top of the Blanco; the lower teeth are referable to *S. successor* and the superior teeth referable to *S. texanus*. One can only draw the conclusion that *S. texanus* and *S. successor* are not distinct species but only individual variants of one species.

It is not possible at the present time, nor advisable without first-hand information to be gained by a comparison of the actual specimens, to draw any definite conclusions regarding the other species of *Stegomastodon*. However, by reference to the descriptions and figures certain facts become obvious.

Osborn depended greatly on the number of ridge-crests to arrange the species of *Stegomastodon* in an orderly ascending sequence. He considered the Aftonian species *S. primitivus* to be the most primitive of the series. On the basis of M/3 it appears to be as advanced, if not more so, than some of the more simplified individuals from the Blanco. It matters little, however, whether it is more primitive than the Blanco species or not; but if it is, there certainly remains no justification for believing that the geologic age of *S. primitivus* demands further investigation. It seems fairly well established that its age is Aftonian. It is far more logical to reconsider the age of the Blanco.

S. mirificus seems clearly to fall within the range of variation displayed by the Blanco specimens.

In the type jaw of *S. texanus* there is a heptalophid of three cones and an octalophid consisting of two cones. The ridge-crest formula is given as 6½ +. The heptalophid and octalophid are fully as well developed as in M/3 of *S. arizonae* in which the ridge-crest formula is given as 7½. The writer suspects that further study will reveal no specific difference between the Curtis and the Blanco stegomastodons.

The most progressive species, *S. aftoniae*, with a ridge-crest formula of 7½ can be matched with specimen No. 31171–25 from the Blanco, in which the last ridge is composed of 3 conelets and may be considered a rudiamentary octaloph.

It is to be expected that *Stegomastodon* should have a great amount of individual variation. There is a basic pattern of ridge-crests in the molars of the genus. These ridge-crests are buttressed by numerous cones and conelets of varying numbers and complexities. Buttressing cones developing at the posterior margin of the tooth apparently varied greatly, in some individuals growing into larger cones and forming a ridge-crest, in others remaining as numerous small conelets on the talon or talonid. This tooth variation is well demonstrated in the Blanco specimens which show gradations from the simplest to the most progressive of the named species. This indicates that all the species of *Stegomastodon* may be variants of a single species. Certainly there is no indication of more than one species of *Stegomastodon* in the Blanco. This is *S. successor*, inasmuch as it was named prior to *S. texanus*.

Order EDENTATA

Family MEGATHERIIDAE

MEGALONYX LEPTOSTOMUS Cope

Pl. 55, figs. 5, 6

Referred specimens.—Univ. Texas No. 31175–19, anterior portion of right ramus with three teeth; No. 31196–5, eight isolated teeth; West Texas Museum No. 438, anterior portion of a mandible lacking the teeth.

Discussion.—The type of *Megalonyx leptostomus* consists of some skull fragments and a superior tooth. Matthew (1924b) reported the discovery of some jaw fragments and teeth from the Blanco. The present material, while also fragmentary, is unquestionably referable to the same species.

The jaw is deep and, in the region of the cheek-teeth, quite thick. A keel is developed on the upper part of the anterior end of the symphyseal region. It flares widely at the upper extremity and is three-lobed. A large mental foramen is located on each side between the keel and the anterior tooth. A deep sulcus lies on the outer face of the jaw between the caniniform tooth and the first cheek tooth. This sulcus, however, is not nearly so deep as in *Megalonyx jeffersoni californicus.* It extends lingually only slightly beyond the outer margin of the first cheek tooth. Accordingly, the width of the jaw between the caniniform tooth and the first cheek tooth is considerably wider than in *M. jeffersoni californicus.*

The caniniform tooth is essentially like that of *M. jeffersoni.* The outer face is convex, the inner face convex in the posterior portion with a concavity in the anterior third of the tooth. The first cheek tooth is separated from the caniniform tooth by a diastema. The anterior face is slightly concave. the posterior face slightly convex, and wider transversely than the anterior face. The first and second cheek teeth are widest antero-posteriorly on the outer side. The second cheek tooth narrows toward the inner side as in *M. jeffersoni californicus.*

Measurements of *Megalonyx leptostomus*

	No. 31175–19	No. 438*
Greatest length of symphysis	80.0	
Diastema between anterior tooth and first cheek-tooth	24.4	
Anterior tooth, greatest antero-posterior diameter	30.0	29.5
greatest transverse diameter	14.5	13.2
First cheek-tooth. greatest antero-posterior diameter	16.5	16.0
greatest transverse diameter	23.0	20.0
Second cheek-tooth, greatest antero-posterior diameter	16.0	15.0
greatest transverse diameter	23.0	22.6

*Tooth measurements made on alveoli.

Family GLYPTODONTIDAE

GLYPTOTHERIUM TEXANUM Osborn

Pl. 48, fig. 3

Referred specimens.—Univ. Texas No. 31194–3, ten osseous plates; No. 31193–7. an osseous plate; West Texas Museum No. 439. five osseous plates.

Discussion.—The plates possess a relatively large central area surrounded by nine to ten peripheral plates of much smaller size which are irregularly pentagonal or hexagonal in shape. There is a wide range of variation within the plates of an individual glyptodon, but these possess no characters which distinguish them from the plates of the type specimen of this species.

Order PERISSODACTYLA

Family EQUIDAE

HIPPOTIGRIS SIMPLICIDENS (Cope)

Referred specimens.—Univ. Texas No. 31176–58, right maxillary; No. 31216–1, left maxillary; No. 31179–29, partial left jaw; a number of isolated superior and inferior cheek teeth and numerous limb bones.

Discussion.—The superior cheek teeth are large, high crowned, and with a moderate curvature. The parastyle and mesostyle are well developed. The protocone is elongate, grooved ventrally, and with a large heel on the anterior portion. The medial sides of the enamel lakes have a few folds, variable in number and in size; the lateral sides usually have one distinct fold, which becomes inconspicuous or absent in well-worn teeth.

In the lower teeth the metaconid and metastylid are separated by a distinct groove to the base of the tooth. In unworn teeth the groove is rather narrow and V-shaped, but in teeth showing extreme wear the groove becomes widely U-shaped. This tendency is also noticeable on unworn teeth as shown by the broadening of the metaconid-metastylid groove as it approaches the base of the tooth. With teeth in the same stage of wear the metaconid-metastylid groove is more angular than in the specimens of *Equus* that were examined. The metaconid and metastylid are quite round in unworn teeth, but become progressively more angular with wear, particularly the metastylid.

These characters definitely place the large Blanco equids in the *Hippotigris* group and serve to confirm McGrew's (1944) observations on the distinctions between this group and the true *Equus* of the later Pleistocene of North America.

Hibbard (1938) suggested that *Plesippus cumminsii* represents heavily worn teeth of smaller individuals of *P. simplicidens.* The present material from the Blanco contains a few well-worn teeth which approach the appearance of Cope's *P. cumminsii.* The writer can see no justifiable reason for specifically separating them from the larger teeth. It seems best to relegate this questionable species to a synonym of *Hippotigris simplicidens.*

NANNIPPUS PHLEGON (Hay)

Referred specimens.—Univ. Texas No. 31216–7, a right superior cheek tooth; No. 31216–15, a left inferior cheek tooth; West Texas Museum No. 440, a partial right ramus with P/2–4—M/1.

Discussion.—The remains of *Nannippus* are not nearly as abundant as are those of *Hippotigris.* Blancan time represents the latest reported occurrence of this small genus. McGrew (1944) has indicated that the geographic range of *Nannippus* was already restricted by Blancan time as shown by its absence in equivalent deposits of the west and in Sand Draw. Inasmuch as *Nannippus* and *Hippotigris* are contemporary genera, living under the same environmental conditions, one should expect to find their remains about equally well represented in the Blanco if they had been of comparable numbers during Blancan time. The paucity of *Nannippus* material in the Blanco is undoubtedly attributable to the diminishing number of individuals prefacing their final extinction.

The Blanco material does not add to the knowledge of this species.

Order ARTIODACTYLA

Family TAGASSUIDAE

PLATYGONUS BICALCARATUS Cope

Pl. 51, figs. 4–6; Pl. 52, figs. 1, 2

Referred specimens.—Univ. Texas No. 31175–12, anterior portion of a skull with right canine, and complete premolar-molar series, except for damaged portions of the right M 1–2/; No. 31179–55, left M/1; No. 31193–8, left P 2/; No. 31178–30, right P 2/; No. 31176–10, right DM/4–M/1; No. 31176–22, fragmentary left mandibular ramus with DM/4M/1. The last two specimens are from the same site, agree in size, and in the stage of wear of the teeth, and perhaps belong to the same individual.

Discussion.—No. 31175–12, a partial skull, is too incomplete for descriptive purposes, except for the teeth. The canine is large, elliptical in cross section, and with the anterior face well worn by the lower canine.

There is a considerable variation in the structure of the premolars. There is also a great difference in the amount of wear, the left premolars being fairly well worn, while the right show but slight signs of wear. The specimen agrees in essential details and in size with the palate of *P. bicalcaratus* described by Gidley (1903a).[5]

Gidley (1903a) lists the chief distinguishing characters of *Platygonus bicalcaratus* as follows: "(1) The posterior and anterior crests of the molars are high and completely divided by the cross valley. (2) The cones forming the crests are comparatively wide apart at their summits; thus when they become a little worn the upper molars of this species present very much the appearance of the lower molars of the tapir. (3) The posterior heel in M3/ is entirely wanting."

The present material may be too inadequate to permit definite confirmation of all these differences. However, on the basis of the additional specimens from the Blanco the writer is able to make the following observations:

Valid characters.—Size slightly smaller than *P. texanus;* absence of a posterior heel on M3/; posterior cingulum on superior molars not distinctly separated from the posterior oblique ridge; anterior and posterior lophs of inferior molars relatively lower than in *P. texanus;* and posterior cingulum of M/1–2 forming a more conspicuous cusp than in *P. texanus.*

Doubtfully valid characters.—The anterior and posterior crests of the superior molars are not completely divided by the cross valley as in the specimen described by Gidley. No. 31176–61,

[5]A cast of *Platygonus bicalcaratus* (Amer. Mus. No. 10701) was made available by Dr. E. H. Colbert for comparisons.

referred to *P. texanus* because of its larger size, and the shelf-like appearance of the posterior cingula on M 1–2/, have the lophs completely divided by the cross valley. It appears that this feature may be present in either species. The material does not permit definite determination of the reliability of this character. Also it cannot be demonstrated that the crests of the lophs are any wider apart at their summit in *P. bicalcaratus* than in *P. texanus.*

Two of the features listed as valid deserve a more complete description. These are observed in the character of the posterior cingula. In the superior molars there is a conspicuous ridge on the posterior portion of the tooth which extends obliquely from the apex of the postero-internal cusp to the middle of the posterior cingulum. The ridge merges so completely with the cingulum that there is no line of demarcation between the two. The ridge and cingulum are more prominent on M 3/ and become progressively less prominent on M 2/ and M 1/. These same characters are present in *P. texanus,* but the oblique ridge is distinctly separated from the posterior cingulum; the latter extends around the base of the tooth as a prominent shelf.

In the inferior molars there is a similar ridge which extends obliquely from the apex of the postero-external cusp to merge with the posterior cingulum in its mid-portion. In *P. bicalcaratus* this forms a conspicuous cusp. In *P. texanus* the cusp is somewhat less well developed.

Gazin (1938) pointed out the inconsistency in size between the type of *P. bicalcaratus* Cope, which consists of a fragmentary tooth, and the palate referred to that species by Gidley. Gazin suggested that the type of *P. bicalcaratus,* considered by Cope to be part of M/3, represents an incomplete P/3 or P/4. The tooth is too small to represent M/3 of any known species of *Platygonus,* and in all probability the type specimen does represent a premolar.

PIATYGONUS TEXANUS Gidley

Pl. 51, figs. 1–3; Pl. 52, figs. 3, 4

Referred specimens.—Univ. Texas No. 31178–13, a right mandibular ramus with P/4–M/3; No. 31176–59, right mandibular ramus with P/3–M/3; No. 31178–3, right mandibular ramus with canine DM/3–4, part of M/1, and unerupted M/2–3; No. 31175–3, fragmentary left mandibular ramus with P/2–4; No. 31197–2, fragmentary left mandibular ramus with M/2–3; No. 31178–5, left M/1; No. 31193–9, right P 3/; No. 31176–60, fragmentary right ramus with M/1 and erupting M/2; No. 31176–61, right, M 1/ and erupting M 2/. These last two specimens are thought to pertain to the same individual.

Discussion.—The type of *Platygonus texanus* is a palate (No. 10702, Amer. Mus. Coll.) from the Blanco, described by Gidley (1903a). The lower dentition of this species has hitherto remained unknown or unreported.

Lower dentition.—In unworn teeth the transverse lophs are high and separated into two distinct cones at their apex by a longitudinal groove as in other species of *Platygonus.* It may be distinguished from *P. bicalcaratus* by its somewhat greater size, the relatively higher lophs on the molars, and by the presence of a less conspicuous cusp near the base of the posterior portion of the molars. M/3 of *P. bicalcaratus* is not known, but it may be supposed that the posterior heel of this tooth is less well developed than in *P. texanus,* inasmuch as the heel of M 3/ is lacking in the former species. DM/4 of No. 31178–3 is also slightly larger and with relatively higher lophs than the corresponding tooth of *P. bicalcaratus.*

Upper dentition.—The upper molars of *P. texanus* may be distinguished from *P. bicalcaratus* by the somewhat greater size of the former and by the relatively greater height of the anterior and posterior lophs of *P. texanus.* On M 1/ and M 2/, the oblique ridge on the posterior part of the tooth extends from the apex of the postero-internal cusp to the middle of the posterior cingulum. The ridge is distinctly separated from the cingulum, not merging with it as in *P. bicalcaratus.* In addition the cingulum is more prominent, and extends beyond the posterior extension of the ridge as a distinct shelf around the posterior portion of the tooth. M 3/ possesses a distinct and well-developed heel which does not occur in *P. bicalcaratus.*

Measurements, in mm., of *Platygonus*

Upper Dentition	*P. bicalcaratus*			*P. texanus*	
	No. 31175-12		Amer. Mus. No. 10701	No. 31176-61	Amer. Mus. No. 10702
Canine, greatest antero-posterior diameter	25.0				
greatest transverse diameter	15.0				
	Right	Left			
P 2/, greatest antero-posterior diameter	11.5	10.6	11.		11.5
greatest transverse diameter	12.3	10.5	12.		10.5
P 3/, greatest antero-posterior diameter	13.4	12.0	12.		13.5
greatest transverse diameter	14.6	15.0	13.		12.0
P 4/, greatest antero-posterior diameter	11.0	11.4	12.		14.0
greatest transverse diameter	15.0	15.5	14.		14.0
M 1/, greatest antero-posterior diameter	15.0	16.0	16.5	18.4	17.5
greatest transverse diameter	16.4	17.0	15.	16.0	15.5
M 2/, greatest antero-posterior diameter	19.4	21.7	19.5	22.2	20.0
greatest transverse diameter	20.0	20.0	17.5	20.2	20.0
M 3/, greatest antero-posterior diameter		24.3	20.		25.5
greatest transverse diameter		20.4	16.		21.5
Length, premolar series	34.0	34.0			
Length, molar series		60.			
Length, premolar-molar series		93.0	93.0*		101.

*Measured on cast.

Measurements, in mm., of *Platygonus*

Lower Dentition	*P. bicalcaratus*			*P. texanus*			
	No. 31176-10	No. 31176-22	No. 31179-55	No. 31178-13	No. 31176-59	No. 31175-3	No. 31179-2
P/2, greatest antero-posterior diameter						11.0	
greatest transverse diameter						9.0	
P/3, greatest antero-posterior diameter					13.7	13.8	
greatest transverse diameter					11.3	13.5	
P/4, greatest antero-posterior diameter				14.0	15.0	13.6	
greatest transverse diameter				13.0	13.2	13.0	
M/1, greatest antero-posterior diameter	15.5	15.7	15.0	17.8	16.5		
greatest transverse diameter	11.5	11.8	11.7	14.8	13.5		
M/2, greatest antero-posterior diameter				21.4	20.4		22.0
greatest transverse diameter				17.7	16.6		15.0
M/3, greatest antero-posterior diameter				31.0	30.5		30.5
greatest transverse diameter				18.6	17.0		16.0
Length, M/1–M/3, inclusive				70.0	66.5		
Length, P/2–M/3, inclusive				109.0 e	107.0 e		

e, Estimated.

Family CAMELIDAE

GIGANTOCAMELUS SPATULA (Cope)

Pls. 53, 54

Pliauchenia spatula Cope, Geol. Survey Texas, 4th Ann. Rept. (1892), pp. 1–137, 1893.
Gigantocamelus fricki Barbour and Schultz, Univ. Neb. State Mus. Bull., vol. 2, pp. 17–27, 1939.

Referred specimens.—Univ. Texas No. 31181–235, 31181–189, and 31181–237, nearly complete skulls; Nos. 31181–240, 31181–181, 31181–163, and 31181–18, nearly complete rami or mandibles. Also a number of partial skulls and jaws and numerous skeletal parts.

Discussion.—In 1893, Cope described an unusually large camel, *Pliauchenia spatula,* from the Blanco beds. Matthew (1924b) referred additional material secured by the American Museum to the genus *Megatylopus.* Barbour and Schultz (1939) suggested that: "*Pliauchenia spatula* Cope, a species often referred to the genus *Megatylopus,* seems to be much more closely allied to *Gigantocamelus fricki* than to *M. gigas,* the genotypic species of *Megatylopus.*" The exact relationships of this large Blanco camel have not been clearly understood. A study of these large Blanco camels shows that they are specifically identical with the large Broadwater camels, and with Cope's original *Pliauchenia spatula.*

Skull.—All of the skulls are somewhat broken and distorted. Therefore, it is necessary to estimate some measurements, but inasmuch as there is considerable individual variation in size among them, a few millimeters of possible error on specimens of this size is not important. No. 31181–189 is one of the best-preserved skulls in the collection. Fortunately the skull is but slightly, if at all, crushed in the dorso-ventral plane. All the other skulls have suffered from being compressed in either the horizontal or the vertical plane, or in both.

Viewed in profile, one of the most striking features is the great height of the muzzle above P 1/. The nasals appear to extend in a plane more nearly parallel to the plane of the palate than in other camels. This appearance, however, may be exaggerated by slight lateral compression suffered in the anterior maxillary region. In this respect it is more like the typical *Procamelus* skulls which tend to have a noticeably higher muzzle than *Alticamelus* or *Pliauchenia.* The skull is high and long and proportionately of average width between the orbits. The sagittal and occipital crests are broken and damaged in all specimens, but the indications are that both were well developed. The occipital crest is particularly well developed and greatly overhangs the occipital condyles.

The orbit is approximately circular, though the condition of the skulls does not afford definite conclusions. There is no evidence of a supraorbital notch, but its absence may be due to the condition of preservation. There is a large vacuity located just above and anterior to the orbit. The infraorbital foramen is located above P 4/. The condition of preservation has made it impossible to note more than an occasional suture upon the skulls.

The external opening of the nares is widest over the mid-point between the canines and P 1/. The rostrum is greatly constricted between P 1/ and P 3/ and flares anteriorly to its maximum width at the canines. The internal opening of the nares is well shown on No. 31181–235. They are of a compressed U-shape; the anterior end, or lower part of the U, flares slightly. The anterior end of the internal nares opens just posterior to a line drawn transversely through the centers of M 2/.

Upper teeth.—The dental formula of the Blanco specimens is identical with that of the Broadwater specimens described as *Gigantocamelus fricki.* The presence of an occasional third incisor cannot be verified in these specimens because in that area of most specimens the pre-maxillae are either damaged or missing. The canine is a heavy, enlarged tooth, somewhat recurved and with a thin, sharp posterior edge as in the Nebraska specimens. On many of the specimens, the superior canines show a variable amount of wear on the surface caused by the abrasion of the inferior canines.

P 1/ is caniniform, well developed, and recurved, but lacking the sharp posterior edge characteristic of the canines.

P 2/ is absent. P 3/ is well developed and is the most variable of the cheek teeth in structure. The internal crescent is incomplete in all specimens. In No. 31189–189, it consists of a faint anterior and posterior vertical fold. In No. 31189–235, the posterior fold is but slightly developed, while the anterior fold is heavy and extends obliquely from the crown almost to the middle of the base of the tooth. In no specimens do the folds meet at the base of the tooth, so that in no stage of wear would the internal crescent become complete.

P 4/ is typically camelid, with a complete well-developed internal crescent and fairly well-developed parastyle, mesostyle, and metastyle.

The molars have a heavy parastyle and mesostyle. The metastyle is but slightly developed on M 1–2/ but is prominent on M 3/. The vertical ridge between parastyle and mesostyle is well developed on M 2–3/; the ridge between mesostyle and metastyle much less prominent.

Lower jaw.—The jaw is long, moderately deep, and fairly massive. There is a considerable variation in the symphyseal region of the jaw. In some it is somewhat procumbent, with widely flaring canines. In other jaws the incisors and the canines are almost vertical in position. The symphysis extends back about 25 mm. from the posterior border of P/1. There is a slight flare of the anterior portion of the symphysis. As noted by Cope in his original description of *Pliauchenia spatula*, there is a groove on the inferior face of the symphysis between the median incisors, which extends from the tip of the symphysis posteriorly to the roots of the incisors. On No. 31181–240, this groove is about 35 mm. long and about 5 mm. deep.

The angular process is well developed with a marked inward inflection. The mental foramen lies directly beneath P/1.

Lower dentition.—Of the incisors, Cope (1893, p. 71) states: "The median four incisors stand on a nearly transverse line, while the external ones are sublateral. In their present state of wear the masticating surfaces of the middle pair form very wide ovals, with the longer diameters converging posteriorly. The surfaces of the second incisors are narrower and are acuminate exteriorly, while those of the third are still narrower and more acuminate externally and posteriorly." In specimen No. 31181–240, this is the condition of the median incisors. The third incisors are missing, but the alveoli are placed in a sublateral position. This same condition prevails in other specimens with but little variation.

The canines are also well described by Cope (1893, p. 71), who states that: "The canines are very robust, and point forward, upward and outward. There is an enamel ridge on the outside of the oblique anterior face, and there is a less prominent ridge on the apical part of the middle line posteriorly. Between these crests the external face is much more convex than the internal one, and the latter exhibits a shallow groove just behind the antero-internal keel." On specimen No. 31181–240 the canines are more heavily worn than in Cope's specimen. The antero-internal face of the canine is beveled from wear from the crown nearly to the base of the tooth. The enamel surface is worn through, exposing the dentine, but at the base of the tooth there is a small remnant of the enamel ridge referred to by Cope. The enamel ridge on the posterior face of the canine has also been worn from crown to base so that here too the dentine is exposed in a narrow strip about 2 mm. wide, extending the full length of the enameled surface. Thus in no place on the posterior face of the canine is the enamel continuous from the inside to the outside portion of the tooth. Toward the base of the tooth there is a shallow groove just behind the antero-internal keel which would undoubtedly be more prominent in less worn teeth. The canines appear to be much larger than in the Broadwater camels referred to this genus.

Most of the inferior canines show a considerable amount of wear on the postero-internal side of the tooth, caused by attrition against the superior canine. However, some specimens show great wear on the antero-interal side of the lower canine. Many also exhibit incisors worn to short stubs.

In connection with the wear upon the posterior portion of the canine there is a unique feature that is not mentioned by either Cope or Barbour and Schultz. This is a depression on each side of the jaw immediately behind the canine. It is elliptical in outline, measuring about 35 mm. along the axis of the jaw and about 30 mm. transversely. It is from 10 to 12 mm. deep. The depression between the canines and P/1 are shown even better in a Hartley County specimen because of the better preservation of the bone. In this specimen the posterior face of the right canine is well worn, and its worn surface is continuous with the anterior portion of the depression. Apparently the superior canines are responsible for the wear on the posterior face of the lower canines, but there seems to be no logical explanation for the broadly open depression immediately posterior to P/1.

P/1 is described by Cope as the fourth premolar. This tooth is compressed transversely, well developed, and is recurved. There is a slight ridge on both the anterior and posterior edges.

P/2 is absent. P/3 is a simple transversely compressed tooth; widest in the middle and narrowing both anteriorly and posteriorly.

P/4 is typically camelid in shape, wide at the posterior end and narrower at the anterior end, which is inflected inward. In unworn teeth there is an open groove on the posterior border, which with wear becomes an isolated lake on the posterior portion of the crown of the tooth.

The molars appear to present no distinguishing characters. Internal ridges are prominent in unworn teeth but become less conspicuous in moderately worn molars. There is a well-developed vertical valley on the internal side of the molars between the anterior and posterior lobes, and just behind the median vertical style. On specimen No. 31181–181, M/2 and M/3 possess well-developed antero-external vertical styles as in *Tanupolama*. These are present, but less conspicuous, in other specimens. The figures of *Gigantocamelus* from the Broadwater show these same styles to be present.

The third lobe of M/3 is distinctly set off from the posterior lobe by a well-developed vertical groove. It is set in the same plane as the rest of the tooth and is not obliquely set to the long axis of the anterior and posterior lobes of M/3.

Measurements, in mm., of *Gigantocamelus spatula*

Skull	No. 31181–235	No. 31181–189	No. 31181–237
Maximum length of skull			825
Length, tip premaxillary to condyle	750 e	730 e	750
Length, tip premaxillary to front of P 3/	260 e	285 e	260
Breadth, maximum at orbits	310 e	237 e	320
Length of dental series (C–M 3/, inclusive)	360	370	402
Diastema between C–P 1/	46	56	49
Diastema between P 1/–P 3/	68	81.6	95
Length, P /3–M 3/, inclusive (at crown)	197	194	194
(at alveolar border)	191	186	192
Length, P 3/–P 4/, inclusive (at crown)	59	60	60
(at alveolar border)	54	52.5	54
Length, M 1/–M 3/, inclusive (at crown)	143	139	137
(at alveolar border)	139	138	140
Height of canine	88	77	84
Antero-posterior diameter of canine at alveolar border	45	42.8	38.5
Width of canine at alveolar border	28	25.4	34
P 1/, greatest antero-posterior diameter	21	19	21
greatest transverse diameter	14	14.4	15
P 3/, greatest antero-posterior diameter	28.6	28	29.3
greatest transverse diameter	17.5	15.5	18.
P 4/, greatest antero-posterior diameter	32.5	31.7	31.
greatest transverse diameter	28.	24.	27.
M 1/, greatest antero-posterior diameter	40.	41.3	37.
greatest transverse diameter	36.5	35.	34.
M 2/, greatest antero-posterior diameter	53.7	54.	49.5
greatest transverse diameter	35.	35.	37.6
M 3/, greatest antero-posterior diameter	59.6	57.	58
greatest transverse diameter	33.	34.	39.

e, Estimated.

Measurements, in mm., of *Gigantocamelus spatula*

Jaw	No. 31181–240	No. 31181–181	No. 31181–163	No. 31180–18
Length, tip incisors to angular process	665		585	640
Height vertical ramus	340 a		360	
Depth of ramus below anterior end of M/3	98		90	92
Depth of ramus below anterior end of M/1	87		83	81
Length, canine–M/3, inclusive	417		370	400
Length, P/1–M/3, inclusive	320		305	326
Diastema between C–P/1	49		35	47
Diastema between P/1–P/3	92		90	103
Length, P/3–M/3, inclusive (at crown)	206	202	200	200
(at alveolar border)	205	205	205	204
Length, P/3–P/4, inclusive (at crown)	56	44	48	43.5
(at alveolar border)	51.7	47	45	
Length, M/1–M/3, inclusive (at crown)	153	161	155	152
(at alveolar border)	154	157	156	
Height of canine	62		55	48
Antero-posterior diameter of canine at alveolar border	35		29	30.3
Width of canine at alveolar border	27.5		23	23
P/1, greatest antero-posterior diameter	22.6		19	20
greatest transverse diameter	14		12	13.4
P/3, greatest antero-posterior diameter	25	22	22	19.5
greatest transverse diameter	12.5	9	12	10
P/4, greatest antero-posterior diameter	30.7	26	26.7	22
greatest transverse diameter	15.4	11.2	15	16
M/1, greatest antero-posterior diameter	33.6	33.8	38.5	37
greatest transverse diameter	23	21.2	20.4	24
M/2, greatest antero-posterior diameter	48.3	53	50	44.5
greatest transverse diameter	26.2	22.4	26	26.3
M/3, greatest antero-posterior diameter	71	69	69.2	74
greatest transverse diameter	27.5	21.7	26	26.5

a, Approximation.

Measurements, in mm., of *Gigantocamelus spatula*

Humeri	No. 31178–14	No. 31195–9	No. 31181–195
Length, distal end to proximal end of head	427	540	550
Greatest width at proximal end	160	195	200
Width, distal end at articular surface	93	112	108

Radio-Ulnae	No. 31178–15	No. 31181–58	No. 31181–218
Maximum length	660	685	760
Width, distal end sigmoid notch	109	107.5	107
Greatest width, distal end	108	102	130

Metacarpals	No. 31181–22	No. 31181–111	No. 31181–122	No. 31193–6
Length	450	475	497	395
Width proximal end	97	98	103	85
Width distal end	118	121	148	104.5

Proximal Phalanges	No. 31181–17	No. 31177–17	No. 31181–79	No. 31181–15	No. 31177–19
Length	138	120	133	112	123
Width proximal end	62.5	57	62	55	57
Width distal end	50	48.5	52	45	48.5

Measurements, in mm., of *Gigantocamelus spatula*

Median Phalanges	No. 31181–251				
Length	86	80	87	79.5	82.5
Width proximal end	45	43.5	48	42	47
Width distal end	42	41	42	39	42

Femur	No. 31179–25
Maximum length	628
Greatest width distal end	165

Patellae	No. 31177—3	No. 31181–252	No. 31181–252
Length	125	115	121
Width at center	68	62	68

Tibia	No. 31195–7
Maximum length	585
Greatest width proximal end	166
Greatest width distal end	120

Astragali	No. 31179–44	No. 31179–49	No. 31176–36	No. 31181–191	No. 31181–43
Length	91.5	93.5	86.0	94.0	96.0
Greatest width	66.5	63.0	63.0	71.0	75.0

Calcanei	No. 31175–12	No. 31176–52	No. 31181–73	No. 31181–44	No. 31176–13
Length	158	176	198	202	210

Metatarsals	No. 31181–157	No. 31181–232	No. 31181–120	No. 31176–20	No. 31181–90
Length (front)	438	405	425	432	402
Width proximal end	85	88	89	91	88.5
Width distal end	105	127	120	118	106

Vertebrae	
No. 31181–129, Atlas. Maximum length	170
No. 31181–68, Axis. Length, odontoid process to posterior edge of centrum	275
No. 31180–15, Cervical. Length of centrum	168
No. 31176–21, Lumbar. Length of centrum	102
Length transverse process	180

TANUPOLAMA BLANCOENSIS, n.sp.

Pl. 55, figs. 1–4

Holotype.—Univ. Texas No. 31181–126, partial right jaw with P/4–M/3 incl.

Paratypes—Univ. Texas No. 31176–25, partial mandible with M/1–3; No. 31182–42, partial left jaw with P/4–M/3; No. 31176–5, partial right maxillary with DM 3–4/ and M 1–2/.

Horizon and locality.—Lower Pleistocene, Blanco beds, Crosby County, Texas.

Diagnosis.—Internal side of P/4 more deeply infolded than in *Tanupolama stevensi*. Median, internal vertical folds on M/1–2 more strongly developed than in either *T. stevensi* or *T. mirifica*, and similar in development to those of *Lama*. Parastyle and mesostyle on M 1–2/ similar to those of *T. mirifica;* more strongly developed than in *T. stevensi*. Anterior lobes of M 1–2/ but slightly wider basally than posterior lobes, in contrast to *T. mirifica*.

Discussion.—The crown of P/3 is not preserved in either of the jaws, but the double roots indicate a greatly reduced and transversely compressed tooth. This tooth is only occasionally present in the McKittrick specimens and is supported by only a single root when present. Additional specimens from the Blanco might show the absence of this tooth in some individuals, but its double-rooted character in the known jaws from these beds indicates a tooth not quite as reduced as in the California species. The double-rooted character of P/3, however, is not considered a diagnostic character of the Blanco fossils because of the great amount of variability to be found in this tooth in the later Pliocene and Pleistocene camels. P/3 is absent in the type of *Tanupolama americanus* and is represented by a single alveolus in *T. mirifica.*

P/4 is rather deeply infolded on the internal side, similar to that of *Lama.* It is more deeply infolded than in *T. stevensi* and *T. mirifica.* On the crown there is a groove, open posteriorly and extending anteriorly to a point above the middle of the external groove. This open groove would become an isolated lake with additional wear on the tooth.

On M/1 the antero-external stylar fold is but faintly developed, while on M/2 and M/3 the stylar folds are quite prominent, being comparable to the development shown in *T. stevensi* and *T. mirifica.* The inner face of M/1–2 is more deeply folded than in *T. stevensi.* The median longitudinal groove is deeper and the vertical style just anterior to it is more strongly developed. The antero-internal style is not as well developed as the antero-external style. The median, internal, vertical style is inconspicuous on M/1. In *T. stevensi,* this style appears to be only fairly well developed and present only on M/2. The internal folds are more prominent than in *T. mirifica* and appear to be nearly equal in development to those of *Lama.*

The posterior lobe of M/3 is distinctly set off from the second lobe on the external side by a deep groove, but on the internal side there is only an inconspicuous groove and ridge to mark the separation. In *Lama* the posterior lobe is distinctly set off from the second lobe also.

No. 31176–5 is a partial maxillary with DM 3–4/ and M 1–2/ present. DM 2/ is represented by a single small root measuring about 2 by 2 mm. Apparently it was ready to be shed, and there is no indication of replacement by a permanent tooth. On the reverse side of the maxillary the roots of the permanent P 3–4/ can

Measurements, in mm., of *Tanupolama blancoensis*

Lower Jaw	No. 31181–126	No. 31181–42
P/4, greatest antero-posterior diameter	18.0	19.4
greatest transverse diameter	8.9	8.7
M/1, greatest antero-posterior diameter	26.6	26.2
greatest transverse diameter	15.4	15.6
M/2, greatest antero-posterior diameter	32.5	30.6
greatest transverse diameter	16.8	16.5
M/3, greatest antero-posterior diameter	40.0	36.0
greatest transverse diameter	15.0	16.0
Length, P/4–M/3, inclusive	115.0	113.7
Upper Dentition	**No. 31176–5**	
DM 3/, greatest antero-posterior diameter	20.3	
greatest transverse diameter	14.7	
DM 4/, greatest antero-posterior diameter	21.6	
greatest transverse diameter	17.5	
M 1/, greatest antero-posterior diameter	29.4	
greatest transverse diameter	21.0	
M 2/, greatest antero-posterior diameter	32.2	
greatest transverse diameter	20.0	

be seen. They are well formed and nearly ready to erupt.

DM 3/ is an elongated tooth antero-posteriorly with a small anterior lobe. Its dimensions agree closely with the corresponding tooth of the McKittrick specimen. DM 4/ also agrees closely in size with the McKittrick specimen. It is a molariform tooth, proportionately wider transversely than the molars.

The parastyle and mesostyle of M 1–2/ are more strongly developed than in *T. stevensi* and of about equal development with those of *T. mirifica.* If the molars were reduced by wear to the same stage as exhibited by one of the paratypes of *T. mirifica* (Amer. Mus. No. 23489) they would become shorter and wider and have about the same size and proportions as the latter specimen.

CAMELOPS cf. KANSANUS Leidy

Pl. 55, figs. 7, 8

Referred specimens.—Univ. Texas No. 31181–134 and 31181–14, right rami; Nos. 31199–8, 31181–142, 31181–175, left rami; No. 31181–212, partial mandible. Also a number of skeletal parts.

Discussion. — The *Camelops* material from the Blanco is provisionally referred to *C. kansanus.* The writer does not find it possible to refer these specimens definitely to any of the known species of *Camelops,* and it is possible that they represent a new species. Their true determination must await the discovery of more material, particularly upper dentition, and the more adequate diagnosis of the various species of this genus.

Since *Camelops* has not been previously reported from the Blanco it seems best to give a brief description of the material. No. 31181–212 is an incomplete mandible with complete cheek-tooth dentition. No. 31181–134 is a complete right ramus, lacking the incisors. Nos. 31181–142 and 31181–14 are separate jaws, but both are in the same stage of wear and they agree so closely in size and tooth characters that it is possible they belong to the same individual.

Nos. 31181–42 and 31181–14 represent a young adult with all molars erupted and in use at the time of the death of the individual. **There is a small** caniniform

Measurements, in mm., of *Camelops* cf. *kansanus*

Lower Jaw	No. 31181–175	No. 31181–142	No. 31181–14	No. 31181–212	No. 31181–134	No. 31199–8
Diastema between I/3–C	13.5					
Diastema between C–P/4	97.3	102.0		91.0		
Diastema between P/1–P/4		67.0	74.0		48.0	
Diastema between C–P/1		26.5			25.0	
P/4, greatest antero-posterior diameter	26.3	23.6	24.0	27.3	23.7	29.
greatest transverse diameter	15.2	14.5	15.0	14.3	14.2	17.7
M/1, greatest antero-posterior diameter	33.0	33.0	33.0	36.0	31.5	37.0
greatest transverse diameter	24.0	21.0	20.7	24.0	21.7	26.0
M/2, greatest antero-posterior diameter	43.8	43.3	43.2	44.0	41.6	53.0
greatest transverse diameter	25.0	21.8	22.5	23.8	23.0	27.0
M/3, greatest antero-posterior diameter	56.0	55.3	65.4	58.7	53.0	65.2
greatest transverse diameter	24.4	20.5	20.0	22.0	21.6	24.6
Length, P/4–M/3, inclusive	157.0	155.0	157.0	157.0	150.0	181.0
Length, M/1–M/3, inclusive	132.0	132.0	133.0	135.0	127.0	152.0

P/1 present that does not occur in any of the other specimens. The canine is also less robust than in the other jaws. It is slightly smaller in size, but this is undoubtedly individual variation.

P/4 in all specimens is a triangular tooth, with a marked vertical sulcus on the internal side and a fainter sulcus on the external side. There is a considerable amount of individual variation in the structure of this tooth. In No. 31181–212, the internal groove is deeply infolded, but faintly visible in No. 31178–175, and is intermediate in this respect in the other specimens.

The inner face of the molars is but slightly convex from the base to the crown of the tooth. The face posterior to the internal median style is longer than the anterior face. In No. 31178–175 the inner face of the third lobe of M/3 extends posteriorly in the same plane as the rest of the tooth, so that on the internal side it is scarcely set off from the posterior lobe. In all the other specimens the third lobe of M/3 is distinctly set off from the posterior lobe by being placed obliquely to the long axis of the tooth.

LEPTOTYLOPUS PERCELSUS Matthew[6]

Referred specimens.—Univ. Texas No. 31179–28, a radius-ulna; No. 31179–20, a metacarpal; No. 31176–24, a tibia; and several phalanges.

Discussion.—This interesting camel was discovered by the American Museum expedition of 1924. Unfortunately Dr. Matthew did not publish a formal description of this new genus. In his manuscript (1924b) Matthew states: "*Leptotylopus* similarly carries the *Alticamelus* phylum into the '*Pliauchenia* stage' and is decidedly more specialized than *A. procerus* of the lower Pliocene."

The limb bones are too long and slender to be referred to any other genus and judging from Matthew's brief description seem clearly referable to his new genus. If *Leptotylopus* is a descendant of the *Alticamelus* line, as suggested by Matthew, then this genus presents a most interesting parallel to the evolution of *Nannippus*. The skeletal parts of *Leptotylopus* are similar to *Alticamelus* in their great length but differ from the lower Pliocene representatives of that genus in being relatively shorter and more slender.

[6]Rachel H. Nichols has kindly supplied the following information concerning *Leptotylopus* in a letter dated October 15, 1943. "Our catalogue card for A. M. 20085 has the name *Leptotylopus percelsus* Type written on it in pencil, in Dr. Matthew's lettering. The data on the catalogue card is given as 'Skeleton, from the Blanco, north side of Crawfish draw, Blanco Canyon, Crosby Co., Texas, collected by Charles Falkenbach in 1924.' "

Measurements, in mm., of *Leptotylopus percelsus*

Radius-Ulna	No. 31179–28
Maximum length	775.0
Width, distal end sigmoid notch	88.0
Width distal end	96.0

Metacarpal	No. 31179–20
Length	610.0
Width proximal end	75.0
Width distal end	104.0

Tibia	No. 31193–2
Length	650.4
Width distal end	71.0

Proximal Phalanges	No. 31176–39		No. 31176–35	
Length	142.0	141.0	141.0	121.0
Width proximal end	36.5	36.0	35.0	31.0
Width distal end	30.7	30.0	31.5	25.0

Median Phalanges	No. 31193–2	
Length	70.0	68.0
Width proximal end	37.3	37.0
Width distal end	31.0	30.6

a, Approximation.

Family ANTILOCARPIDAE

CAPROMERYX sp.

Referred specimens.—Univ. Texas No. 31176–2, partial right M/3; West Texas Museum No. 441, right P 3–4/.

Discussion.—On specimen No. 31176–2, a portion of the third lobe is missing. The anterior and posterior lobes measure 11.5 mm., and the estimated length of the tooth at the crown is from 15 to 16 mm. The transverse diameter is 5.4 mm. The height of the tooth is 21 mm. Specific identification is not possible on the basis of such incomplete material. It records, however, the first occurrence of antilocaprids in the Blanco; a group which undoubtedly was present in large numbers but which has not been found either because of the accidents of preservation or of collecting.

No. 441, a right P 3–4/, shows no characteristics which might distinguish it from other species, or make reference to one of the described species possible.

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PLATE 48


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PLATE 49


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PLATE 50

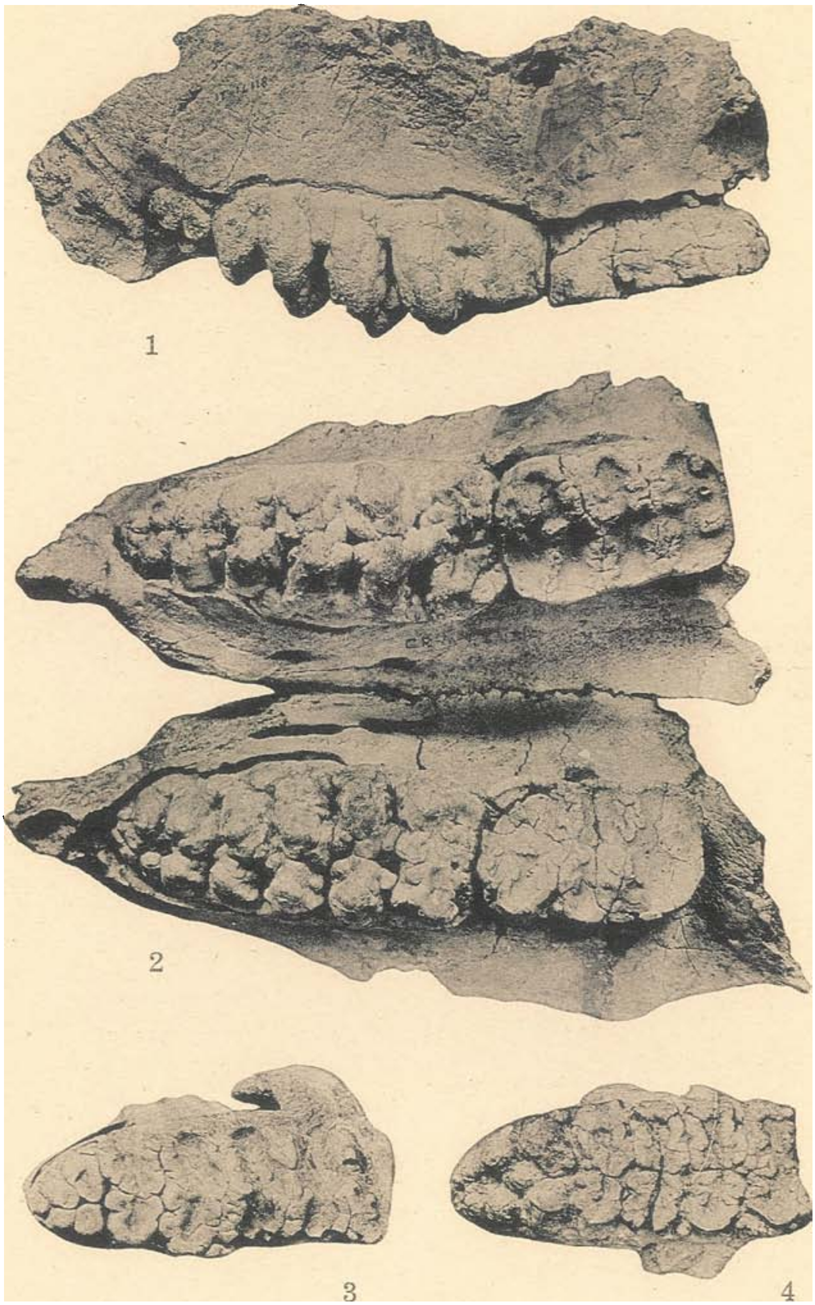

PLATE 51

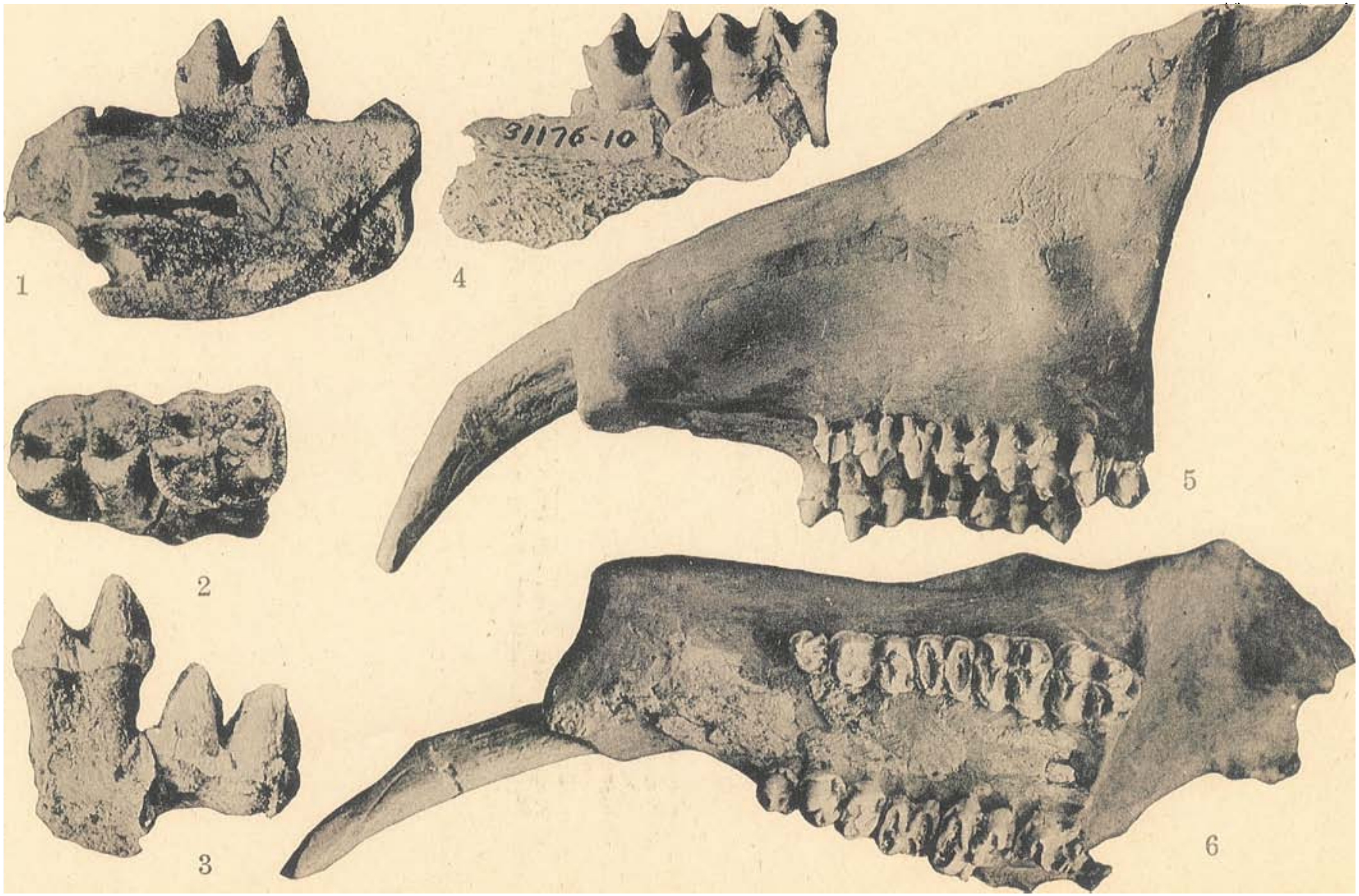
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PLATE 52


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PLATE 53

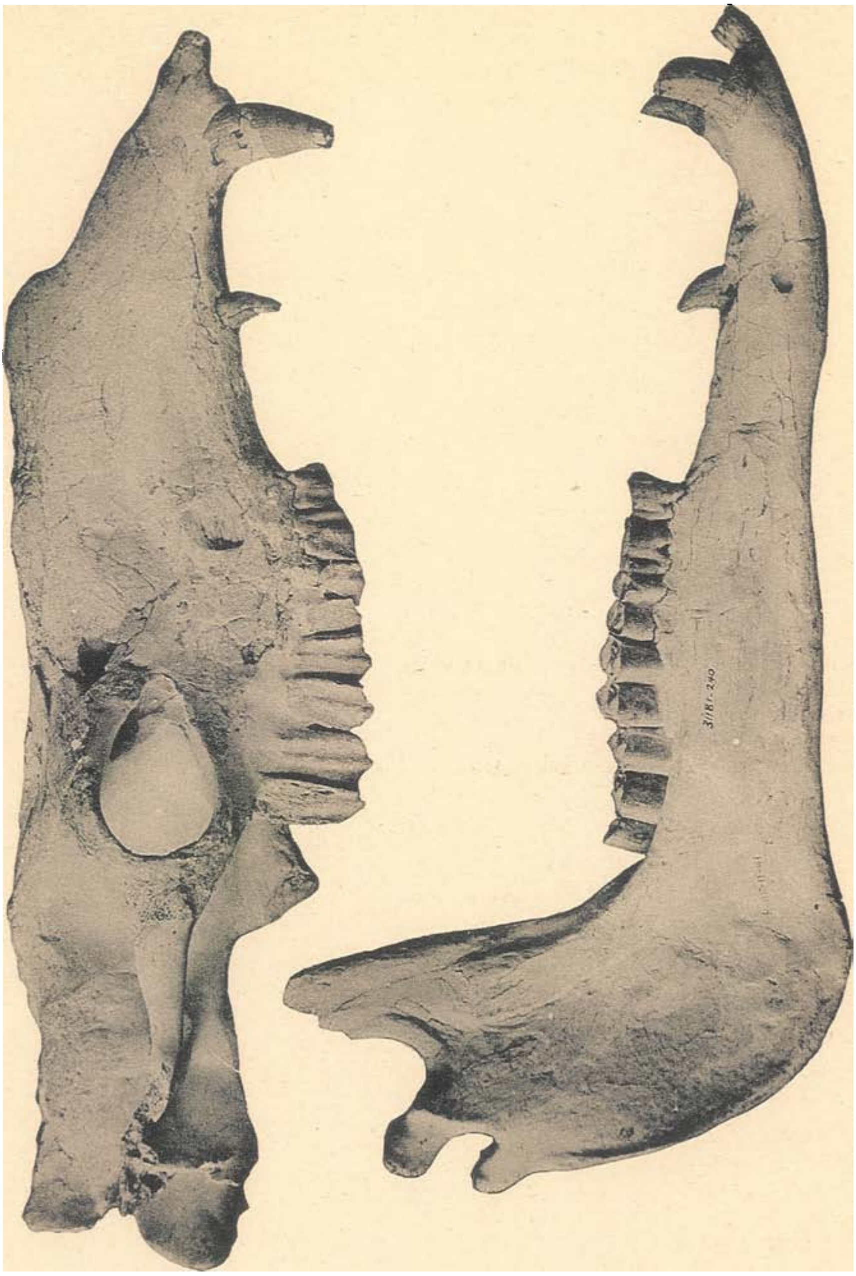
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PLATE 54

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Tanupolama blancoensis, n.sp., x½ 535

1, 2. Right mandibular fragment with P/4–M/3, lateral and occlusal views, specimen No. 31181–126.

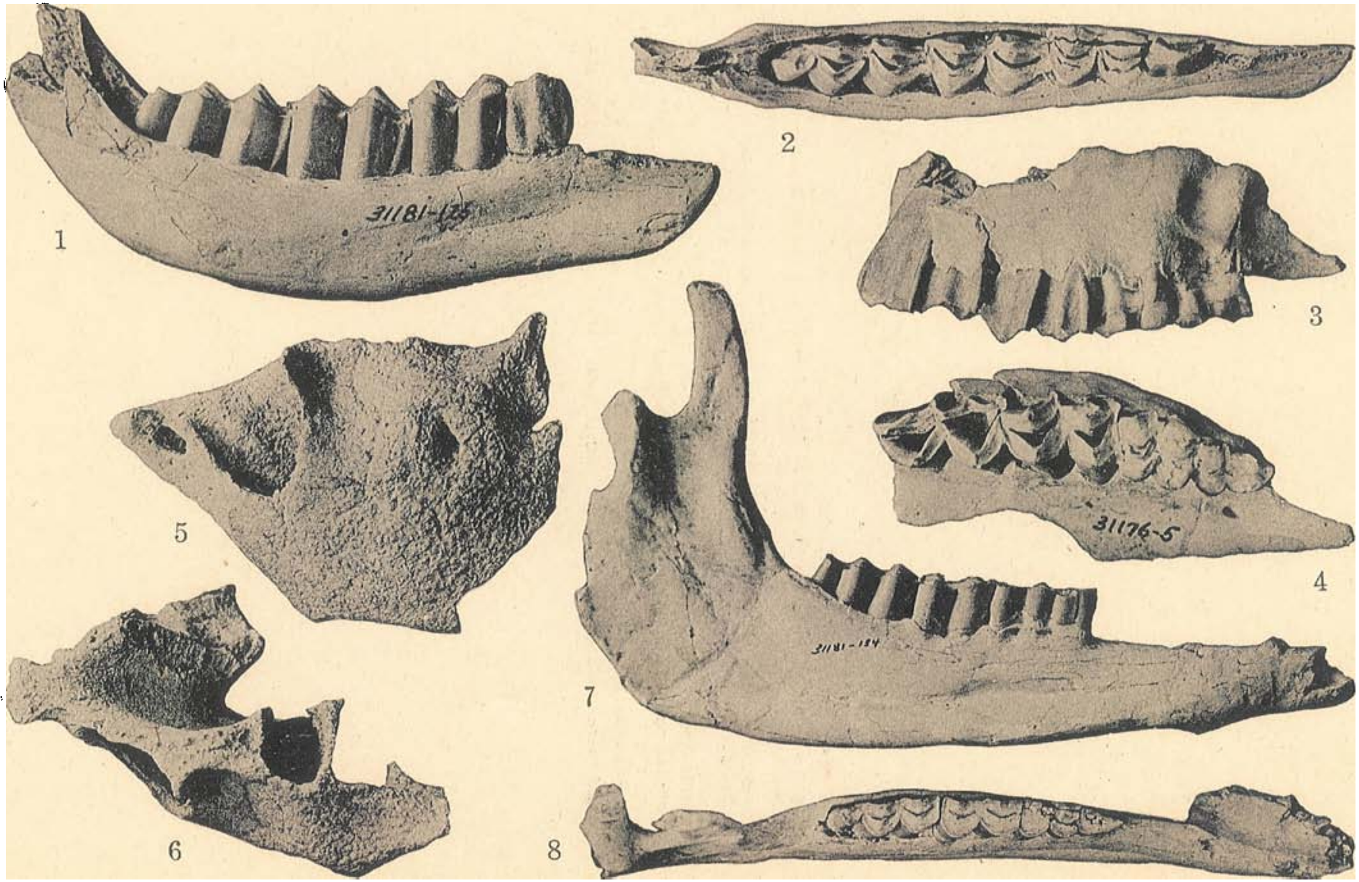
3, 4. Fragment of right maxilla with DM 3/–M 2/, lateral and occlusal views, specimen No. 31176–5.

Megalonyx leptostomus Cope, x½ 525

5, 6. Anterior portion of mandible, lateral and occlusal views, specimen No. 438.

Camelops cf. *kansanus* Leidy, x¼ 537

7, 8. Right ramus with P/4–M/3, lateral and occlusal views, specimen No. 31181–134.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