THE WALNUT FORMATION OF

CENTRAL TEXAS

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THE WALNUT FORMATION OF CENTRAL TEXAS

THESIS

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By

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Preface

The writer wishes to express his gratitude to Professor F.L. Whitney, under whose supervision this work was done, for his constructive criticism and advice, and for his assistance in the photographing of the fossils.

The reports of Messrs. R.T. Hill, J.A. Taff, W.S. Adkins, and W.M. Winton have been of invaluable assistance.

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THE WALNUT FORMATION OF CENTRAL TEXAS

Introduction

The Walnut formation is a comparatively thin formation lying at the base of the Fredericksburg division, and having its greatest development in the region between the Brazos and the Colorado rivers. It is a very persistent formation in this region, but its lithology changes both laterally and vertically within short distances. The fauna is very similar to that of the Glen Rose, for which it could easily be mistaken, were it not for a few exceptions which will be considered later. As there is such a great similarity between certain clay members of the Glen Rose and the Walnut, it was suggested by Professor F.L. Whitney that a detailed study be made to determine their exact relationship.

The Walnut formation, sometimes referred to as the Exogyra texana beds or the Texana beds, was first named and described by Dr. R.T. Hill[1] in 1891, after the town of Walnut Springs in Bosque County where he found it most typically exposed.

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1 Hill, R.T.: "The Comanche Series of the Texas-Arkansas Region," Geol. Soc. America, Vol. 2, 1891, pp.503-512.

In the area treated within this paper, the Walnut formation occurs as a bench below the scarp of the Comanche Peak limestone. It forms a very gentle and easily recognized slope, because of its characteristic capping of limestone and its almost total lack of vegetation. In practically all of the regions visited, there has been a noticeable absence of any really characteristic vegetation. The Bosque River in Bosque County, and the Nolans River in Bell County flow in valleys which have a predominant Walnut base, and support a more or less profitable agriculture. In these valleys one finds the characteristic Walnut at the bottom, with the Comanche Peak and Edwards along the outer margin.

Beginning in the Red River region of Grayson and Cooke Counties and following the line of strike in a general south to southwestward direction to Bosque and Coryell Counties, the outcrop widens, attaining its greatest width in these central counties, then narrowing southward until there are only a few scattered outcrops, which appear merely as benches below the harder cap of limestone.

In the north central part of the state, in the Grand Prairie region, we find the Walnut well expos-

ed in a comparatively wide belt, having its greatest width across Coryell, Bosque, Hamilton, and Comanche Counties, and becoming narrower in its exposure and extent as it progresses southward. In the Geology of Trans-Pecos,[2] C.L. Baker states that he finds one hundred feet of Walnut below the overthrust in the northeast flank of the southern Quitman Mountains, in the lower part of the Rio Grande Cañon across the Quitman Mountains and in the southern part of the Van Horn Mountains. In the University Bulletin by J. W. Beede and V.V. Waite,[3] on the geology of Runnels County, there appears a section of Walnut taken near County Line Gap which shows that the formation has an approximate thickness of fifty feet.

Toward the east, the Walnut is known from well cores in McLennan County, which show that it has an average thickness of about one hundred feet. Its eastermost outcrop is in Coryell and Bell counties, where it forms the floor of many of the valleys. According to Adkins,[4] the outcrop of the Walnut covers nearly half the area of Coryell County.

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[2] Baker, C.L.: "Exploratory Geology of a part of Southwestern Trans-Pecos, Texas," Univ. of Texas Bull. No. 2745, 1927, p.26.

[3] Beede, J.W. and Waite, V.V.: "Geology of Runnels County," Univ. of Texas Bull. No. 1816, Pt.4, 1918, p.52.

[4] Adkins, W.S.: "Geol. and Mineral Resources of McLennan County," Univ. of Texas Bull. No. 2340, 1923, p.31.

The formation is known as far south as Medina County,[5] where it is exposed in the main Balcones Fault zone for about a mile. This exposure is on the Tarpley road, sixteen miles north of Hondo, whence it dips steeply to the south and disappears under later formations.

In general the Walnut is apparently conformable with both the overlying and underlying rocks; one notable exception in Burnett County is pointed out by Paige.[6] Here the Trinity division is entirely lacking in certain areas due apparently to non-deposition and the Walnut rests on the Ordovician limestone. In the southern part of the Grand Prairie region, beginning in Coryell and McLennan Counties, and continuing southward, the Walnut rests upon easily recognized Glen Rose strata, making a definable contact. From McLennan and Coryell Counties northward to Wise County, the Walnut rests upon the Paluxy sand, which thins to the southward. Northward from Wise County, the Walnut passes into the Antlers sand, the upper part of

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5 Liddle,R.A.: "Geol. and Mineral Resources of Medina County," Univ. of Texas Bull., No. 1860,1918,p.28.

6 Paige,S.: "Llano-Burnett Folio," Geologic Atlas of the United States, 1912, p.9.

which at least is thought to be a phase of the Walnut.

The Walnut formation as a whole consists largely of laminated calcareous clays, marly in nature, weathering yellow on exposure, and interrelated with shell agglomerate and semi-crystalline limestone flags. In the central part of the state it grades up almost imperceptibly into the Comanche Peak above, a change being recognizable only in a vertical section of two or three feet, while further to the south the transition is more distinct.

There is relatively little or no difficulty encountered in Central Texas in determining the lower contact, either with the Glen Rose, which in many places is marked by an iron red discoloration, or the Ordovician in Burnet County, while further northward the contact with the Paluxy is not so easily determined nor well agreed upon, but considered by Winton[7] to be marked by a coarse red sandstone at the contact of the Paluxy, which is a great contrast in comparison with the overlying lighter and finer grained sands considered by him as being the Walnut.

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[7] Winton, W.M.: "Geology of Denton County," Univ. of Texas Bull., No. 2544, 1925, p. 16.

In North Texas the top of the Walnut is marked by a shell conglomerate having an average thickness of eighteen to twenty-five feet, and made up chiefly of Gryphaea marcoui. This makes a very persistent and easily recognized cap rock, and is used as both a surface and subsurface horizon marker in this area. The lower part of the formation consists of alternating sand, sandstone and clay, and contains the remains of few or no fossils. Winton,[8] in his bulletin on Denton County, gives the following section in the northwestern part of the county, which will give some idea of the Walnut and its overlying formations.

Section No. 1 (Figure 5) Clear Creek Section in Descending Series

		Feet
Duck Creek:		
13.	Massive gray limestones containing Hamites fremonti, Hamites comanchensis, fragments of Desmoceras brazoensis	4.0
Kiamitia:		
12.	Marls and clays containing many specimens of Gryphaea navia	2.0
11.	Black shales weathering to yellowish brown, containing a few Gryphaea navia	20.0
10.	Sandy ledge containing Schloenbachia belknapii	1.0
9.	Black shales weathering to yellowish brown, containing Exogyra tex-	

[8] Winton, W.M.: "Geology of Denton County," Univ. of Texas Bull., No. 2544,1925, p.20.

		Feet
	ana, Gryphaea marcoui, and Schloenbachia belknapii	5.0
8.	Sandstone ledge	1.0
7.	Black shales containing a few Gryphaea marcoui	13.0
Goodland:		
6.	White massive limestone	5.0
5.	Marl seam	.5
4.	White massive limestone containing Schloenbachia trinitensis	4.0
3.	Thin seams of limestone alternating with marl containing Schloenbachia acutocarinata	35.0
Walnut:		
2.	Shell conglomerate containing vast numbers of Gryphaea marcoui, also many Exogyra texana	16.0
1.	White sands, very fine with rounded oval grains, no fossils	?

In Parker County, Taff[9] measured the following section which Hill gives in the Twenty-first Annual Report,[10] and which presents a more detailed description of the character of the Walnut in its northern extent. The section is as follows:

Section No. 13--Hiner, Parker County, Texas, (Taff) Fredericksburg Division

Comanche Peak Formation:		Feet
16.	Comanche Peak chalky limestone	40
15.	Chalky limestone with large Exogyra texana, Enallaster texanus, Lima, and Cyprimeria texana	30
14.	Hard chalky limestone	40
Walnut formation:		
13.	Gryphaea shell limestone	10
12.	Chalky limestone	1.66

9 Taff, J.A.: "Report of the Cretaceous Area North of the Colorado River," Third Ann. Rept., Geol. Survey of Texas, 1891, p. 313.

10 Hill, R.T.: "The Geology of the Black and Grand Prairies", U.S. Geol. Survey, Twenty-first Ann. Rept. Pt. 7, 1900, p. 188.

11.	Hard limestone, with many small Gryphaea	1.5
10.	Chalky limestone, with few Gryphaea	15.0
9.	Marly limestone, containing Exogyra texana, Gryphaea pitcheri, and Ammonites, all in great abundance	30.0

Paluxy Formation:

In Johnson County the Walnut has a thickness of one hundred feet. It is sandy at the base, but has twenty-five feet of shell conglomerate toward the top. Winton and Scott,[11] in their bulletin on Johnson County, give the log of the Joshua well, which illustrates the character of the Walnut in this region.

Log of the Walnut Formation in the Joshua well (Furnished by Mr. A. H. Woodfin)

40 feet shell	490	Walnut
25 feet Pyrites and lime	515	
10 feet white sand	525	
10 feet blue shale	535	
10 feet white sand	545	
5 feet blue shale	550	
55 feet white sand	605	

Hill[12] gives a section described by Taff,[13] which is much more detailed and accurate than the

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11 Winton, W.M. and Scott: "Geol. of Johnson County," Univ. of Texas Bull., No. 2229, 1922, p. 61.

12 Hill, R.T.: "Geol. of the Black and Grand Prairies," U.S. Geol. Survey, Twenty-first Ann. Rept., Pt. 7, p. 222.

13 Taff, J.A.: "Report of the Cretaceous Area North of the Colorado River," Fourth Ann. Rept., Geol. Survey of Texas, 1892, p. 253.

above section. The section is as follows:

Section No.24--Section two miles south of Pleasant Point, Johnson County, Texas (Taff)

		Feet
	Goodland formation:	
8.	Chalky white to buff limestone, varying slightly in hardness, and bearing numerous large Exogyra texana, Enallaster texanus, Lima wacoensis, Natica (?), Turritella seriatim-granulata, and Sphenodiscus pedernalis	30
	Walnut formation:	
7.	White to yellowish limestone, very much the same in character as that of No.8, but no fossils found	40
6.	Thin-bedded, compact, yellow limestone, bearing many small Gryphaea marcoui	10
5.	Whitish limestone, similiar to Nos. 7 and 8	15
4.	Thin-bedded, hard, shaly limestone, bearing numerous small Gryphaea pitcheri	2
3.	Limestone, similar to No.5	18
2.	Basal Gryphaea limestone, the upper 10 feet composed almost entirely of fossil Gryphaea pitcheri, and containing many Schloenbachia acuto-carinata; the portion below this is a crumbling limestone, which bears many Gryphaea pitcheri and associated forms	30
1.	Arenaceous lime marl which grades downward from the top with increasing proportion of sand to its contact with the Paluxy sand	15

Southward, in Bosque and the surrounding counties, one finds that the shell conglomerate at the top becomes gradually thinner and is displaced by thin layers of compact limestone containing a few small fossils, the shell conglomerate varying in

thickness from a few inches to several feet, interstratified with clay, and presenting this alternating character from near the base through half of the formation.

In the valley of the north Bosque River Hill[14] gives the following section:

Section No. 20. Bosque River Valley

	Feet
Comanche Peak formation:	
6. Calcareous and argillaceous, chalky, white and light blue limestone, which contains in its upper portion Exogyra texana, in their greatest development in point of size, Enallaster texanus, Epiaster elegans, Holectypus planatus, Sphenodiscus pedernalis, Gryphaea marcoui and casts of gastropods.....	15
Walnut Clays:	
5. Uppermost Gryphaea marcoui zone; compact thin layers of limestone. The fossils are small and are cemented in the hard limestone	3
4. Marly white to buff limestone bearing but few fossils ..... Fragments of oyster shells and fossils casts occur. On weathering, the marly lime breaks up into soft marl and angular balls of marly lime.	25
3. Middle Gryphaea marcoui zone; composed of layers of hard and semi-crystalline lime, bearing numerous individuals of small Gryphaea marcoui fossils.....	3
2. Marly limestone beds	30

[14] Hill, R.T.: "The Geology of the Black and Grand Prairies," U.S. Geol. Survey, Twenty-first Ann. Rept., pt.7, 1900, p. 206.

The limestone layers composing this bed are of varying thicknesses. Occasional hard bands project from the surface and leave fragments of limestone on the sloping hillsides.

1. Soft marly and compact semi-crystalline limestone in alternating layers, varying in thickness from very thin bands to beds ½ to 4 feet thick.... 35

Paluxy sand.

Near the town of Clifton in Bosque county, a section was run from the top of the Glen Rose to the base of the Comanche Peak and the Walnut was found to have a thickness of one hundred and three feet. The following is a description of the section:

Section of Walnut, 4 miles east of Clifton, on Neils Creek.

		Feet
19.	Compact limestone containing great numbers of small Gryphaea	2
18.	Marly to chalky limestone containing very few fossils. Section for most part covered by vegetation	30
17.	Ledge of semi-crystalline limestone, containing an abundance of Gryphaea. Fragments break off and are found on the hillside..	2
16.	Chalky to marly limestone, the exact character of which is hard to determine because of the vegetation. Apparently the limestone is in ledges, for it varies in both density and thickness	27

15.	Semi-crystalline limestone containing few fossils.....	7
14.	Soft marly to chalky limestone, alternating with clay and containing numerous Gryphaea marcoui.....	8
13.	Clay alternating with Gryphaea shell breccia	5
12.	Shell breccia containing Gryphaea and Exogyra	.5
11.	Arenaceous, yellow to white limestone, having Gryphaea, Exogyra and Pecten	3.0
10.	Brecciated Gryphaea ledge	.5
9.	Arenaceous limestone with numerous Gryphaea	2.0
8.	Gryphaea shell breccia with univalves and bivalves	5.0
7.	Compact, dense, buff to white limestone having stylolitic structure, with great numbers of Exogyra texana and Gryphaea marcoui, as well as a few Granocardia, Pecten, Turritella, and univalves present	4.0
6.	Argillaceous limestone with Gryphaea marcoui, Exogyra texana, bivalves and univalves abundant .	2
5.	Arenaceous and argillaceous clay containing good specimens of Engonoceras pedernalis	2
4.	Shell breccia containing numerous fossils as, Gryphaea marcoui, Exogyra texana, Protocardia, Cyprimeria and many other bivalves ...	1.5
3.	Argillaceous and arenaceous clay with Gryphaea marcoui, Exogyra texana and Engonoceras pedernalis.	1.0
2.	Shell breccia containing Gryphaea marcoui and Exogyra texana.....	.5
1.	Compact arenaceous and argillaceous limestone, white to yellow in color	1.0

Glen Rose

Hill,[15] in his Trinity River section, carries

[15] Hill, R.T.: "The Geol. of the Black and Grand Prairies," U.S. Geol. Survey, Twenty-first Ann. Rept., pt. 7, 1900, p. 124.

the Walnut through Terrell, Dallas, Ft. Worth, and Weatherford, slightly diagonal to dip. This section shows the greatest thickness yet described of the Walnut. The section is as follows:

Section No.2--Ft.Worth or Trinity River Section
Fredericksburg Division

	Feet
Goodland limestone, as seen in the Western part of Tarrant County:	
Crumbling chalky limestone, with characteristic fossils	18
Alternate strata of soft, massive white limestone and shelly limestone	36
	54
Walnut formation:	
Alternations of soft and shelly limestone and argillaceous lime marl in strata of 5 to 6 inches each	14
Massive limestone	8
Alternations of compact and shaly limestone	68
Agglomerates of Gryphaea marcoui, with thin separation layers of marl	150
	130

Further southward, with only a few local variations, the formation becomes increasingly argillaceous especially near the top, the contact with the overlying formation being more easily discernable. This changing condition is well shown in Hill's[16] section on Bee Caves-Burnet road, at the western border of the Austin quadrangle. The following section was made at the summit of one of these buttes.

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16 Ibid, p. 211.

Section No. 21--Section at border of Blanco and Travis Quadrangles, 4 miles south of the Colorado River.

Edwards limestone (upward continuation eroded away):	Feet
10. Firm white limestone containing flints 1 inch thick which have been worked by the Indians. This is the lower portion of the Edwards limestone, which is here preserved as a cap rock less than 100 square feet in area	1
Comanche Peak:	
9. White chalky limestone	15
8. Firm calcareo-siliceous clays containing great quantitites of Exogyra texana	10
Walnut beds:	
7. Thin, indurated layers	0.25
6. Calcareo-arenaceous clays containing great quantities of Exogyra texana	15
5. Yellow, rotten, honeycombed limestone	1
4. Yellow clay with abundance of Exogyra texana	10
3. White chalky limestone band with Exogyra texana	2
2. Firm limestone	2
1. Yellow arenaceous limestone, forming ledge	2
Glen Rose beds:	
Top of Glen Rose beds; firm, yellow arenaceous limestone weathering into ledges.	
Total Comanche Peak beds in section	25
Total Walnut beds in section	32
Total Glen Rose beds in section	280

On the Burnett road, three and one-half miles west of Bull Creek, there was found a good exposure of Walnut, having a total thickness of fifteen and a half feet. The section is as follows:

Bull Creek Section	Feet
Non-chalky, indurated lime	.5
Yellow argillaceous clay with an abundance of Exogyra texana	6.0
Rotten honeycombed limestone, white to yellow in color, with Exogyra texana and Engonoceras pedernalis	.5
Yellow calcareous clays with large numbers of Exogyra texana	8.0
Ledge of arenaceous limestone	.5

In the Walnut's southern extent, where it is closely associated with the Glen Rose, it might easily be mistaken for one of the clay members of the Glen Rose. The clay, however, of the underlying formation, although similar in color, contains neither the shell breccia nor the same fauna as the Glen Rose. This faunal change is discussed under the heading of Paleontology. The Walnut, too, is highly laminated on its weathered surface, the laminae appearing as shaly fragments. In the clay members of the Glen Rose, there is no such weathering.

The Walnut thickens along its line of strike from Cooke southward to Bosque and McLennan counties, where it attains its maximum thickness. From this region, continuing along the strike, it thins to where it is only fifteen feet in Austin, but has a reported thick-

ness of twenty feet in Medina County, where it disappears below later formations. This decrease in thickness southward is apparently accomplished by the disappearance of the lower beds of the formation, the upper argillaceous layers being the predominant feature in this region. The sea approaching from the southwest, with alternate shallow and deep sea conditions, giving us limestone, clay and shell conglomerate attained its maximum depth in Bosque and the surrounding counties, and towards the latter part of the period sent an arm of the sea southward, giving us comparatively shallow water conditions as shown by the character of the deposits. The character of the material shows that the surrounding land was low and featureless, for there is relatively little sand in the Walnut of Central Texas.

In the depth of the sea, however, there are many local variations, showing warping of the bottom, and corresponding changes in the character of deposition as well as thickness. At Austin, there is fifteen feet of Walnut, predominately clay; three miles west of Fredericksburg there is twenty feet of the formation made up totally of clay; seventeen miles west

of Fredericksburg one finds only nine feet of Walnut, with the lower seven feet made up of limestone, followed by two feet of clay, while seven miles west of Henly, in Hays county, one finds twenty-six feet of Walnut, the lower fourteen feet being compact limestone, followed by eleven feet of clay, which grades into a foot of poor grade limestone at the top. This well illustrates the local variation in thickness and character of deposit over a comparatively small area of its outcrop.

Paleontology

Paleontologically, the Walnut shows a distinct faunal development in comparison with the Glen Rose, both in number and character of the fossils. At first sight the Walnut is noticeable by the great number of shells of Exogyra texana Roemer and Gryphaea marcoui Hill and Vaughan, which are found in abundance in the clay as well as the shell breccia and limestone. It is this phase of the formation which caused it to be the first named and referred to as Exogyra texana beds and Texana beds. There is some development of Tylostoma, as shown by Tylostoma pedernalis Roemer and other species. There are also a great number of other smaller gastropods which will be described in

the appropriate place.

In the micro-fauna, the Orbitolina walnutensis Carsey is the best and most determinative horizon marker found. It has a range which, as far as is known, is limited strictly to the Walnut formation. It is a fossil that is easily identified, and is found in comparatively great abundance in the Walnut.

A comparison of the fauna of the Walnut of Texas with that of European and Mexican formations, leads one to the conclusion that the Walnut is middle Albian. There is much more work to be done, however, in both Europe and America before an exact correlation can be made.

The following description of the fauna of the Walnut is not an exhaustive study, for many rare and poorly preserved forms have been omitted, but is here intended to be of practical value in determining the formation as a unit, as well as a basis for separating the Walnut from the underlying Glen Rose.

Cephalopods

Engonoceras pedernalis von Buch

1849: Ammonites pedernalis Roemer: Texas, p.418.

1852: Ammonites pedernalis Roemer: Die Kreidebildungen von Texas, p.43,pl.1, fig. 3.

1869: Ammonites pedernalis Gabb: Geol. Surv. Cal., Paleont., Vol.2, pp.258-259, pl.35,figs.1,1a.

1901: Engonoceras pedernale Lasswitz: Geol. Pal. Abh. (Koken) N.F., bd.6, heft 4.

1903: Engonoceras pierdenale Hyatt: U.S. Geol.Survey, Mono. 54, p.165, pl.20, fig. 6-13.

1910: Engonoceras cfr. pedernale Böse: Inst. Geol. Mex., Bol. 25, p.82, pl.11, fig. 1-3.

Test medium, smooth, involute, compressed; keel sharp, narrow; concave near the umbilicus, but becoming slightly convex outward; sutures small, numerous, becoming smaller and more numerous toward the umbilicus; lobes are bifid and some apparently irregularly trifid; saddles are entire.

Echinoids.

Diplopodia texanum Roemer

1849: Diadema texanum Roemer: Texas, p.392.

1893: Diplopodia texana Cragin: Fourth Ann. Rept., Geol. Surv. Texas, p.149.

1893: Diplopodia texanum Clark: U.S. Geol. Survey, Bull. 97, p. 48, pl.15, figs. 1 a-f; pl.16, figs. 1 a-d.

Test subcircular, large, with sides inflated; dorsal side gently elevated; ventral side concave. Ambulacra conspicuous, with two rows of tubercles; poriferous zones narrowing towards the ventral side. Interambulacra broad, with two rows of tubercles increasing to four at the ambitus. Peristome large, circular, with distinct incisions; periproct subpentagonal, large.

Enallaster texanus Roemer

1849: Toxaster texanus Roemer: Texas, p.393.

1852: Toxaster texanus Roemer: Die Kreidebildungungen von Texas, pp.85,86, pl.10, fig.3.

1893: Enallaster inflatus Cragin: Fourth Ann. Rept., Geol. Surv. Texas, p.151.

1893: Enallaster texanus Clark: U.S. Geol. Survey, Bull.97, p. 78, pl.39, figs. 2 a-g.

1910: Enallaster texanus Böse: Inst. Geol. Mex., Bol. 25, p.166, pl.40, figs. 6-10; pl.41, figs. 2-4; pl.42, fig. 1.

1915: Enallaster texanus Clark and Twitchell: U. S. Geol. Survey, Mono. 54, p. 86, pl.39, figs.

2 a-g.

1919: Enallaster texanus Adkins and Winton: Univ. of Texas Bull. No. 1945, p. 55, pl.9, figs. 12,13.

Test medium, elongate, cordiform; dorsal side elevated, convex; ventral side flat, concave at the peristome; anterior portion broad, rounded, with deep anterior groove; posterior portion truncate; side inflated, rounded. The ambulacra are unequal, and narrow; antero-lateral pair large, curving backward as they progress outward; postero-lateral pair symmetrical and short. The pores are unequal, the posterior ones are elongate, the outer nearly twice as large as the inner series; pores of anterior zone small and regular. In the anterior groove there are unpaired ambulacra, the area being twice as wide as the other areas. The apical system is compact.

Holectypus planatus Roemer

1849: Holectypus planatus Roemer: Texas, p.393.

1852: Holectypus planatus Roemer: Die Kreidebildungen von Texas, p.84,pl.10, figs. 2 a-g.

1853: Holectypus planatus Shumard: Pal. Expl. Red River of La., p. 211.

1857: Holectypus planatus Conrad: Mex. Bdry. Surv. Vol. I, p. 145, pl.1, fig. 4 a-f.

1858: Holectypus planatus Desor: Synop. Echinoides Foss., p. 174.

1892: Holectypus planatus Cragin: Fourth Ann. Rept., Geol. Surv. Texas, p. 159.

1893: Holectypus planatus Clark: U.S. Geol. Survey, Bull. 97, p. 58, pl.23, figs. 2 a-f.

1915: Holectypus planatus Clark and Twitchell: U. S. Geol. Survey, Mono. 54, p. 65, pl.25, figs. 2 a-f; pl. 26, figs. 1 a-e.

1916: Holectypus planatus Whitney: Bull. Am. Pal., No. 26, p. 12, pl. 7, figs.1-5.

1919: Holectypus planatus Adkins and Winton: Univ. of Texas Bull. No. 1945, p. 50, pl. 9, fig.2.

Subcircular to pentagonal, symmetrical; dorsal side convex; ventral side flat to concave on approaching peristome; apical system small; ovarial plates perforated, with madreporite large but difficult to distinguish; ambulacra are straight, narrow, with increase in width toward ambitus; poriferous zones narrow, with pores increasing in size toward the ambitus; interambulacra about three times the width of the ambulacra; plates narrow, each having a row

of small tubercles, five or six at the ambitus, but few above and below.

Holectypus planatus distinguished from H. limitis by the shape of periproct. In H. planatus periproct is located near the margin of the test and has both ends pointed, while the periproct of H. limitis is smaller and has only the end approaching the margin pointed.

Pseudodiadema texanum Roemer

1849: Diadema texanum Roemer: Texas, pp.392,393.

1852: Diadema texanum Roemer: Die Kreidebildungen von Texas, p. 82, pl. 10, fig. 5.

1858: Pseudodiadema texanum Desor: Synop. Echinoides Foss., p. 72.

1893: Pseudodiadema texanum Cragin: Fourth Ann. Rept. Geol. Surv. Texas, pp. 161, 162.

1893: Pseudodiadema texanum Clark: U.S. Geol. Survey Bull. 97, pp. 47,48, pl.13, figs.2 a-n; pl.14, figs. 1 a-g.

1915: Pseudodiadema texanum Clark and Twitchell: U. S. Geol. Survey, Mono. 54, p. 55, pl.18, figs. 1 a-i.

Test small, circular, with sides inflated; dorsal and ventral sides equally depressed; ambulacra

narrow, with two rows of prominent tubercles, decreasing in size from the ambitus to the poles; poriferous zones narrow, with minute granules interspersed; interambulacra zone wide, with two rows of tubercles of greater size than those of the ambulacra; peristome large, covering half of test; periproct subcircular, with deep incision in right anterior ambulacrum.

Pelecypods

Anatina whitneyi n.sp.

Pl. I, figs. 1-2.

Shell medium, elongate-ovate, inequilateral; posterior end greatly produced; umbos low, depressed, located approximately at the anterior margin; ventral margin slightly curved, with well rounded curves at anterior and posterior margins. The ornamentation consists of concentric undulations parallel with the lines of growth.

Cucullaea terminalis Conrad

1857: Cucullaea terminalis Conrad: Mex. Bdry. Surv., p. 148, pl.4, figs. 2 a,b.

1892: Cucullaea terminalis Cragin: Fourth Ann. Rept. Geol. Surv. Texas, p. 174.

1893: Cucullaea terminalis Hill: Proc. Biol. Soc.

of Washington, p. 26.

Shell cuneiform, triangular, ventricose; beaks prominent, adjacent to anterior extremity, bending forward and inward, apecis little compressed; posterior end produced, angular; ventral margin straight, extensive; both muscle impressions strong.

Cyprimeria texana Roemer

1852: Arcopagia texana Roemer: Die Kreidebildungen von Texas, pp.46, 47, pl.6, figs.8 a,b.

1857: Arcopagia texana Conrad: Mex. Bdry.Surv., p. 149, pl.4, figs. 3 a,b.

1893: Cyprimeria texana Cragin: Fourth Ann. Rept., Geol. Surv. Texas, p. 177.

1919: Cyprimeria texana Adkins and Winton: Univ. of Texas Bull. No. 1945, p. 76, pl.18, fig. 6.

Cast is subcircular, thin, inequivalve; right valve gently convex, with the left valve only slightly so; beaks somewhat raised, and centrally located. Surface markings rare, but sometimes shows hinge structure and muscle scars.

Cyrena brilli n. sp.

Pl.II, figs. 1-2.

Shell medium to small, convex, subtrigonal, equi-

lateral; anterior and posterior extremities gently rounded; beaks rather prominent, depressed anteriorly, practically central; dorsal outline declining unequally from the beaks in front and rear, the anterior slope being concave in outline and the posterior convex; ventral margin forming an elliptic curve; surface marked by very fine growth lines.

Exogyra texana Roemer

Pl. III, fig. 1.

1849: Exogyra texana Roemer: Texas, pp. 396,397.

1852: Exogyra texana Roemer: Die Kreidebildungen von Texas, p. 69, pl.10, figs. 1 a-e.

1853: Exogyra texana Shumard: Expl. Red River, La., p. 205, pl. 5, figs. 1 a,b and fig. 5.

1855: Exogyra texana Blake: Rep. Expl. and Sur. P.R.R. Mississippi River to Pacific Ocean, Vol. 2, p. 39.

1884: Exogyra texana White: Fourth Ann. Rept. U. S. Geol. Survey, p. 306, pl. 51, figs. 1-5.

1899: Exogyra texana Hill: U.S. Geol. Survey, Twenty-first Ann. Rept., pt. 7, pl.27, figs. 1 a, b.

1910: Exogyra texana Böse: Inst. Geol. Mex., Bol. 25, p.112, pl.20, figs. 14-16; pl.21, figs. 1-11; pl.22, figs. 1-9.

1919: Exogyra texana Adkins and Winton: Univ. of Texas Bull. No. 1945, p. 64, pl.13, figs. 15-16.

Shell sub-oval, curved; dorsal valve convex, provided with blunt keel; outer surface covered with irregular, radiating ribs, slightly laminated by growth marks; ventral valve covered with small radiating ribs, at times indistinct; valve convex with slightly sloping surfaces, corresponding to dorsal valve; attachment area of beaks distinct and large on interior of shell; interior of both valves smooth, with border finely striated.

Gryphaea marcoui Hill and Vaughan

1898: Gryphaea marcoui Hill and Vaughan; U.S. Geol. Survey, Bull. 151, p.50, pls. 2-5.

1919: Gryphaea marcoui Adkins and Winton: Univ. of Texas Bull. No. 1945, p. 61, pl.15, figs. 15-18.

Sub-oval to oval; beak narrow, slightly truncated, overlapping the hinge line; surface rough, with dorsal sinus running entire length of shell, and flaring at its ventral margin; flaring of wing not extensive as compared with other forms of Gryphaea, and giving shell a narrow appearance.

Granocardium alleni n. sp.

Pl. IV, figs. 1-2.

Shell medium, cordate, slightly inequilateral; globose dorsally, sloping gently ventrally; umbose conspicuous, incurved, produced, located approximately central in relation to hinge line; hinge line gently curved. Surface ornamentation consists of radiating grooves and ribs, from which arise coarse spines and granules.

Homomya Cuyleri n. sp.

Pl. V, figs. 1-2.

Shell medium, globose, elongate, equivalved, inequilateral; posterior end distinctly produced; umbos low, curving downward, and situated approximately at anterior margin; dorsal margin straight; ventral margin not whole in specimen; ornamentation consists of concentric growth lines of varying intensity.

Modiola concentrico-costellata Roemer

1849: Modiola concentrico-costellata Roemer: Texas, p. 403.

1852: Modiola concentrico-costellata Roemer: Die Kreidebildungen von Texas, p.54, pl.7, fig. 10 a, b, c.

Test moderate, trapezoid, gently arched; posterior portion narrow, with middle and anterior por-

tion inflated, broadest near the middle; beaks small and only slightly elevated above the hinge line, and in approximate contact; proceeding from beaks are narrow longitudinal ridges, broadly rounded, to the posterior part of the basal margin, below which, in the middle, the flanks are concave; surface marked by concentric growth lines.

Neithea irregularis Böse

1910: Vola irregularis Böse: Inst. Geol. de Mexico, Bol. 25, pp.97,98, pl.15, figs. 10-18.

1918: Neithea irregularis Kniker: Univ. of Texas Bull., 1817, pp. 18,19, pl.2, figs. 1-6.

1919: Pecten irregularis Adkins and Winton: Univ. of Texas Bull. No. 1945, p.67, pl. 11, figs. 11-15.

Shell slender, elongate, subtrigonal, equilateral; hinge line straight, with umbos incurved; right valve sub-oval, rounded, convex; surface ornamented with high, narrow, radiating ribs, averaging sixteen in number; every third rib raised slightly above the other, and much wider than those in the depressions. The furrows between the ribs are narrow, concave, but much wider adjoining the raised ribs. Fine tertiary ribs can be seen on the side of the prominent, raised ribs, in specimens not too badly weathered.

The radiating ribs of the left valve correspond with the furrows of the right valve.

Protocardia texana Conrad

1857: Cardium (Protocardium) texana Conrad: Mex. Bdry. Surv., p. 150, pl.4, fig. 6, a-c.

1919: Protocardia texana Adkins and Winton: Univ. of Texas Bull. No. 1945, p. 75, pl.18, fig. 7.

Test medium, subcircular, inflated, cordate; posterior end rounded; umbos prominent, submedial; ribs fine and numerous at the beaks, becoming larger and more pronounced posteriorly; ribs concentric over greater portion of cast, but radial on one side.

Protocardia walnutensis n. sp.

Pl. VI, figs. 1-2.

Shell small, sub-triangular, convex to ovate, nearly as high as long; beak produced and directed obliquely forward, subtruncate; anterior side short and ornamented with radiating costae, averaging about twenty in number; posterior side produced, angulated, with small concentric ribs covering the greater portion.

Trigonia emoryi Conrad

1857: Trigonia emoryi Conrad: Mex. Bdry. Surv., p. 148, pl.3, fig. 2,a-c.

1903: Trigonia emoryi Shattuck: U.S. Geol. Survey Bull. 205, p. 23, pl.8, figs.6-8.

Shell medium, with anterior margin much larger than posterior; anterior margin short; posterior end produced; umbos slightly produced, recurved; ornamentation consists of tubercled, curved ribs, becoming indeterminate posteriorly.

Gastropods

Rostellaria sp. undet.

Shell, as indicated by cast, large, with an elevated spire, and consisting of four to five volutions. The volutions are moderately convex on their outer surface, with strongly marked and abrupt sutures; body volution medium with aperture elongate-eliptical in outline; surface of the cast is entirely smooth, not showing the least indication of any surface features.

Rostellaria sp. undet.

Shell medium, elongate, ovate, with elevated spire; volutions four to five in number, with body volution forming over one-third of the length of the cast; moderately convex on the upper part, but becoming concave below; sutures well defined, depressed; aperture narrowly elliptical, acute above

and pointed below; slight plication on upper part of aperture, with lip extending slightly above the next volution.

Turritella sp.

Cast spireform, elevated, medium; volutions five in number, convexly rounded; sutures conspicuous; aperture not preserved. Cast poorly preserved, but body volution apparently has four large crenulated ribs, with several intermediate, crenulated lines.

Tylostoma sp.

Shell moderate, ovate, with spire gently produced; volutions generally five in number; whorls flat to slightly rounded, with sutures well defined and making an angle with adjoining whorl; aperture elongate.

This shell resembles very closely the one erroneously pictured by Hill as **Buccinopsis(?) parryi** Conrad.[18] A comparison of this with Conrad's[19] original will clearly show the difference in genera.

Tylostoma pedernalis Roemer

1849: Natica pedernalis Roemer: Texas, p. 410.

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[18] Proc. of the Geol. Soc. of Wash., 1893, pl.6,fig.1.

[19] Mex. Bdry. Surv., 1857, pl.13, fig.5, a,b.

1852: Natica pedernalis Roemer: Die Kreide-
bildungen von Texas, p.43, pl.4, figs.
1, a, b.

1893: Tylostoma pedernalis Hill: Proc. of the
Biol. Soc. of Wash., p.33, pl.6, fig.2.

Test ovate, large; whorls are gently rounded to flat, angular above; basal whorl largest and most prominent; spire short, sub-truncate, consisting of three whorls; aperture elliptical, ovate.

Corals

Parasmilia sp.

Test small, conical, and approximately straight. The septa are plainly visible, with a series of secondaries and tertiaries, giving the appearance of compactness.

Family Lituolidae

Orbitolina walnutensis Carsey

1926: Orbitolina walnutensis Carsey: Univ. of Texas Bull. No. 2612, p.23,pl.7,figs. 11 a,b.

Test is medium, conical, and generally smooth; base of shell gently concave; slightly higher than broad; chambers porous and numerous.

Undetermined Phylum

Porocystis globularis Giebel

1853: Siphonula globularis Giebel: Beitr. derPal.,

Bohn.

1893: Porocystis, Gen. nov. Cragin: Fourth Ann. Rept., Geol. Surv. Texas, p. 165.

1893: Porocystis pruniformis Cragin: Fourth Ann. Rept., Geol. Surv. Texas, p.165, pl.24, figs. 2-6.

1893: Araucarite wardi Hill: Wash. Biol. Soc. Proc. Vol. 8, p.39, pl.1, figs. 1 a,b,c, d.

1895: Porocystis pruniformis Rauff: Neues Jahrbuch Min., Band I, Seite I, Tofel I, ~~#~~ 1, holzschmitt.

1895: Araucarites wardi Hill: Neues Jahrbuch Min., Band I, Seite I, Tofel 1-15, holzschmitt.

1905: Porocystis pruniformis Jarvis: Biol. Bull., Vol.9, p.388, figs.1-6.

Cyst globular, spheroidal; aperture marginal to slightly inverted; surface rough, pitted, granulated; interior structureless. All specimens poorly preserved.

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PLATES

PLATE I

PLATE I

Figures 1-2. *Anatina whitneyi* n. sp.

PLATE I

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PLATE II

PLATE II

Figures 1-2. *Cyrena brilli*, n. sp.

PLATE II

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PLATE III

PLATE III

Figure 1. *Exogyra texana* Roemer

PLATE III

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PLATE IV

PLATE IV

Figures 1-2. *Granocardium alleni* n. sp.

PLATE IV

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PLATE V

PLATE V

Figures 1-2. *Homomya cuyleri* n.sp.

PLATE V

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PLATE VI

PLATE VI

Figures 1-2. *Protocardia walnutensis* n.sp.

PLATE VI

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