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THE GEOLOGY OF THE GLASS MOUNTAINS, TEXAS

PART I
DESCRIPTIVE GEOLOGY

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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 virture, 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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FOREWORD

This publication on the Geology of the Glass Mountains is the result of coöperative work between Yale University, the Bureau of Economic Geology of The University of Texas, and the authors. The work was begun by Philip and Robert King in the summer of 1925 and was aided financially by Charles Schuchert during 1926 and 1927. Dr. Carl Dunbar of Yale University has given much assistance in supervising the preparation of the manuscript. The publication is in two parts as follows: Part I, Descriptive Geology by Philip Burke King, and Part II, Faunal Summary and Correlation of the Permian Formations With Description of Brachiopoda by Robert E. King.

The publication is in part printed from a fund contributed to The University of Texas by the Fort Worth Geological Society and known as the Fort Worth Geological Society Publication Fund of the Bureau of Economic Geology. The generous aid of this society in the publication of this report is gratefully acknowledged by the University and the Bureau. The fund is contributed as a revolving publication fund.

E. H. Sellards,
Associate Director.

THE GEOLOGY OF THE GLASS MOUNTAINS, TEXAS

PHILIP BURKE KING

ABSTRACT

This memoir describes the physiography, stratigraphy, and structure of the Glass Mountains and northern Marathon Basin in Trans-Pecos Texas. These two districts, which may collectively be spoken of as the Marathon region, are formed of Paleozoic rocks revealed by the erosion of a broad post-Cretaceous dome which lies slightly in front of the main Cordilleran ranges. The dome was originally sheeted over by Cretaceous rocks, which still surround it, and which rim the Paleozoic area in bounding escarpments.

The Marathon basin is excavated from relatively weak Carboniferous and early Paleozoic beds which were strongly deformed before Permian time. The early Paleozoic group, which is only briefly described, includes several Ordovician formations, of limestone and shale below, and bedded chert above, overlain by the Devonian(?) Caballos novaculite. Succeeding it is the Tesnus sandstone and shale, 3000 feet thick, the Dimple limestone, 1000 feet, the Haymond sandstone and shale, 2000 feet, and the Gaptank limestone, sandstone, shale, and conglomerate, 1800 feet thick. Only the last formation contains Pennsylvanian fossils in any abundance; these indicate a middle and upper Pennsylvanian age for this formation; the other three probably extend well back into Carboniferous time. The Carboniferous sediments were mostly derived from the old crystalline land-mass, Llanoris, to the south, and the microscope shows that they contain fragments of schistose and metamorphic rocks. In the Gaptank, however, are conglomerates of local origin, which indicate the beginnings of the Marathon disturbance.

Finally, the Marathon disturbance resulted in strong deformation in the Marathon region, with asymmetrical or overturned folds, broken in places by thrust faults. In the northwest part of the Marathon Basin, the early Paleozoic was thrust for more than 5 miles across the upper Pennsylvanian along the flat-lying Dugout Creek overthrust.

The Glass Mountains are a cuesta-like asymmetrical upland, made up of Permian rocks tilted to the northwest. This system rests unconformably on the Marathon folds and is similarly overlain by the Cretaceous. The Permian is divided into six formations, made up of limestone, dolomite, radiolaria-bearing siliceous shale, and subordinate amounts of sandstone. The most striking feature of the Permian stratigraphy is the rapid lateral variation of the thickness and lithology of the formations. Their total thickness is about 7000 feet. The lower half of the section contains great amounts of conglomerate derived from the Marathon folds. In general fossils are abundant, and are of the normal marine facies of the Permian. At the top of the Permian system is the Bissett conglomerate, derived from the erosion of the beds below.

At the close of Permian time the Permian rocks, including the Bissett formation, were tilted to the northwest, and during the early Mesozoic were worn down to a peneplain. They were then buried by Cretaceous rocks, of which the lower half, the Comanche series, remain as remnants on the top and north slopes of the Glass Mountains.

After Cretaceous time, probably in the early Cenozoic, the Marathon dome was uplifted and somewhat folded, and late in the same era the Glass Mountains area was transected by northwest-trending normal faults, with displacements as great as 750 feet. The streams of the region are consequent to the post-Cretaceous folds and are antecedent to those fault blocks which were uplifted against them. After the epoch of normal faulting the Marathon dome was deeply eroded, the consequent streams were superimposed on the Paleozoic structures, and subsequent and obsequent tributary drainage was developed. During the later stages of this erosional period there were arid conditions, though the region at all times maintained an exterior drainage.

INTRODUCTION

GENERAL STATEMENT

In eastern Trans-Pecos, Texas, where the table lands of the Edwards Plateau end against the mountains of the Cordillera, the erosion of a broad dome of Cretaceous rocks has laid bare an oval area in which, as through a window, we may observe more ancient strata with distinctive structures of their own. This is the Marathon dome, named for the village of Marathon in the north-central part of the area. Along the northwest side of the dome rise the Glass Mountains, formed of Permian limestones and dolomites. The area to the south of these mountains made up of less resistant strata, is excavated to form the hilly lowland of the Marathon basin, whose rocks were strongly deformed before Permian time.

The area covered by this report comprises the northern part of the Marathon dome, including the Glass Mountains and immediately adjacent portions of the Marathon Basin. The primary purpose of the investigation on which it is based was to make known the stratigraphy of the Permian formations, for it is here, with little doubt, that we find the best section of the system in North America. The development of the Permian in Trans-Pecos Texas, is not only longer and more complete than elsewhere, but it reveals throughout its extent, though most particularly in the lower half, the

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marine faunal facies of the system in all its richness and diversity. In the Glass Mountains, the rocks of this age are all tilted as a unit toward the northwest, so that the twelve-mile width of the range exposes a continuous section from base to top, uninterrupted by faults or other complications. The only comparable section, that in the Guadalupe Mountains, exposes only the upper Permian, and has an important unconformity in the lower part.

The Glass Mountains section will eventually serve as the standard of reference for the Permian throughout the rest of the continent. The faunas of the Permian strata of other parts of North America, as those of the mid-continent area, New Mexico, Arizona, and other places, are too limited or too monotonous for satisfactory intercontinental correlation, but they carry enough guide fossils to link them with the Glass Mountains section, which in turn bears those forms of world-wide significance, such as the ammonoids and brachiopods, which serve to link the Marathon Permian with that of the rest of the world.

The study of the Glass Mountains area was accomplished by nine months of field work by the writer and his brother, Robert E. King, during the summers of 1925, 1926, and 1927. During this time two fifteen-minute quadrangles (the Altuda and Hess Canyon) were surveyed in detail, and bordering areas were mapped in varying degrees of detailed and reconnaissance study. Over a part of the area no topographic surveys were available and the base had to be constructed by plane table methods. The first season of field work was done independently, after which it was continued with the financial assistance of the Bureau of Economic Geology of The University of Texas, and of Professor Charles Schuchert of Yale University.

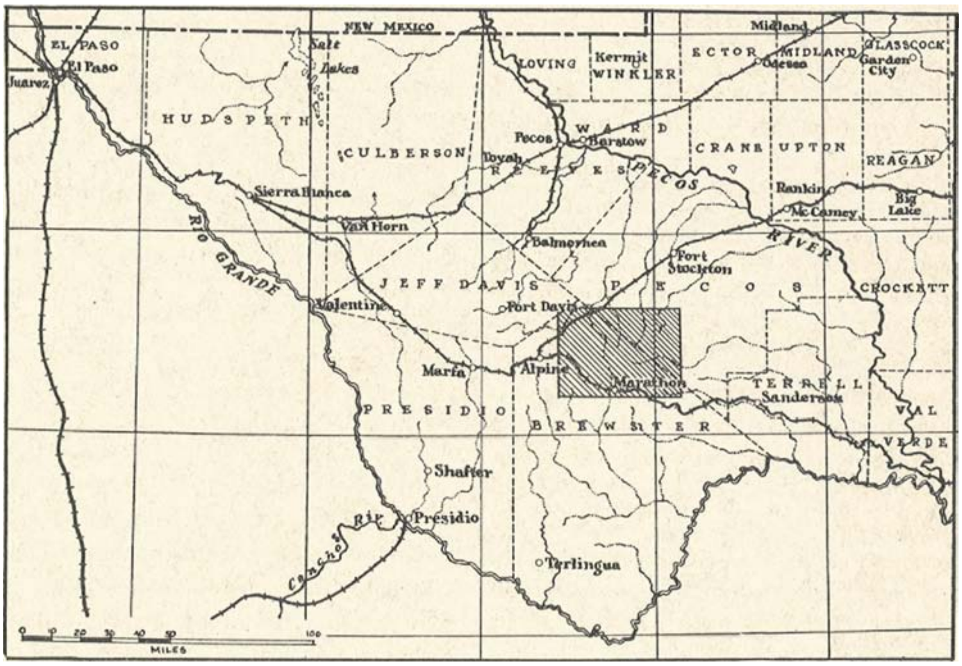


FIG. 1. Map of Trans-Pecos Texas, showing location of area covered by geologic map (in shading).

The results of the investigation have been divided into two parts. The present memoir sets forth the physiography, stratigraphy, and structure of the area. The description of the Glass Mountains brachiopod faunas, large parts of which are new, and the discussion of their inter-relations and correlation are given by R. E. King in a companion memoir.

ACKNOWLEDGMENTS

In a work of as protracted a nature as this one, the list of acknowledgments is necessarily a long one, and it is recognized that in this note of thanks some persons may inadvertently be slighted who may have aided materially in the work.

The writer wishes to acknowledge his indebtedness to his brother and co-worker, R. E. King, who

is jointly responsible with him for the field work, and who has contributed many ideas regarding the stratigraphy as it relates to the fossils. The writer, however, is alone responsible for a great many of the interpretations, for which he should receive the blame, if incorrect. The writer is also indebted to his father, who generously furnished much financial support for the work.

He also wishes to express a deep debt of gratitude to Prof. Charles Schuchert of Yale University and to Dr. E. H. Sellards of the Bureau of Economic Geology of The University of Texas, both of whom have studied the Marathon area in the field, for their encouragement to carry on the work and for much helpful advice during its progress.

The present paper was written as a doctor's dissertation at Yale University under the direction of Professors Carl O. Dunbar and Chester R. Longwell. These gentlemen have aided materially in developing the ideas set forth in the paper. The writer and his brother have also had the pleasure of spending some days in the field in the area with both of them. Prof. Dunbar has identified the Pennsylvanian fusulinids, and has compared them with his extensive collections of the same group from the mid-continent region. A discussion of the physiography was presented as a master's thesis at the University of Iowa; this has been revised and rewritten, and included within this report. Prof. W. M. Davis of Harvard University has given valuable help in starting the work on this subject, and Professors A. C. Trowbridge of the University of Iowa, and R. F. Flint of Yale University have aided in the development of ideas presented in the chapter. The microscopic petrography of the sedimentary and igneous rocks of the region received far less time and care than the subject deserved; in this work the writer is indebted to Prof. Adolf Knopf for many valuable suggestions.

Mr. W. S. Adkins of the Bureau of Economic Geology has discussed the problems of the Comanchean stratigraphy with the writer, and Dr. T. W. Stanton has generously supplied some unpublished information on these same rocks. Dr. N. H. Darton of the federal survey, who has mapped in reconnaissance a large part of the surrounding area has furnished the writer with many topographic and areal geologic data. In July, 1929, the writer had the privilege of spending some days in the Glass Mountains with Dr. G. H. Girty, during part of which time they were accompanied by Prof. I. A. Keyte. Among other problems, the age of the disputed beds at the Gaptank-Wolfcamp contact was discussed. At a somewhat earlier period, in 1927, the same problem was studied in the field with Mr. Grant Blanchard, who had previously worked with Prof. Keyte in the area.

Mr. C. L. Baker, who did much of the earlier work in the region for the Bureau of Economic Geology, has discussed its problems with the writer and published a printed criticism of the latter's conclusions. Though the writer cannot agree with all of Mr. Baker's interpretations, he has found the questions raised by him stimulating and pertinent. Mr. Leo Horton aided greatly in the survey of the area east of Marathon not covered by a topographic base. Several other geologists who have worked in this part of the state for oil companies have assisted in various ways.

After the greater part of this report had been written, in the summer of 1929, the writer had the privilege of making a reconnaissance geologic survey of the southern half of the Marathon Basin for the U. S. Geological Survey. With the kind permission of the Director some of this material has been used in the present report, though the greater part of it has been reserved for later publications. A small part of the geologic mapping along the southern edge of the accompanying map is derived from this work, and some further notes have been added to the chapters on Carboniferous stratigraphy and Geologic Structure. The greatest value of this later work for the present report, however, lies in the broader viewpoint which the writer has obtained of the Marathon region.

The majority of the land owners in the area proved hospitable and gave free access to their land, and many other privileges whereby the work of investigation could be carried on.

HISTORY OF GEOLOGIC WORK

Permian rocks were first reported in North America when certain fossils collected by Major Hawn near the junction of the Smoky Hill and Kansas rivers were identified in 1858, first by Meek, and later by Swallow, as belonging to the Permian period. In the same year, B. F. Shumard described collections of fossils made by his brother some years previously in the Guadalupe Mountains of Texas, and identified the fauna as Permian. The latter work lay forgotten for nearly half a century, when in 1901, G. H. Girty revisited Shumard's old locality and in 1908 published his Guadalupian Fauna, demonstrating beyond question the existence of true Permian in North America. Strangely enough, the best section remained the last to be discovered, for not until 1917 was the Glass Mountains section described by J. A. Udden.

References to the Glass Mountains area prior to that time are scanty, and are only worth noting in the light of later developments. A few Carboniferous fossils were collected near Leon Springs by Major Emory's Boundary Commission in 1849, and identified by James Hall. These may have come from the Glass Mountains. The first description of the mountains was made by R. T. Hill in 1903;* he speaks of the Comanche (or Glass) Mountains and the Sierra Caballos. Of the former he writes:

> These are an elongate sierra, extending northeast, directly at right angles to the continental trend . . . and are composed of barren Paleozoic limestone and sandstone hills, probably capped on their highest points by Cretaceous limestones. They occur in a series of sub-parallel ridges dipping to the north . . . .
> They are intersected on the west, at Altuda, by the Santiago Sierra, trending northwest-southeast.

Hill's description was sufficient, however, to arouse the interest of Eduard Suess,[1] who, in his *Antlitz der Erde*, characterizes the folds of the Marathon region as:

> . . . the type of the Appalachians, which here, close to the foot of the Cordillera of New Mexico is yet once more visible. These are the free ends of the longest branch of the western Altaides.

Hill also made fossil collections in these mountains which were studied and described by Girty in his Guadalupian fauna. They were probably from the Leonard and Word formations, though the exact localities are uncertain.

In 1907, J. A. Udden described the Altuda Mountain section of Permian at the western end of the Marathon Plain. He gave a correlation of the Altuda section with that of Shafter.

It was not until 1915 that he could return to the area, although from the first he realized its importance. In that year, in company with Emil Böse and C. L. Baker, he began the first systematic study of the region. Udden studied the Glass Mountains area and Baker undertook an exploration of the entire surrounding region. Böse also took part in the field work and worked upon the stratigraphy and correlation of the formations. The results of this investigation are embodied in two reports published in 1917; one, by Udden, Baker, and Bowman, dealing with the general geology of the region, the other, by Böse, describing the ammonoid fauna and discussing the correlation of the Permian.

Though much work has been done since that time, both in the Glass Mountains, and upon the Permian in general, this work remains as a foundation upon which the details of later investigations are built. The formations established by them have, in general, proved to be practicable and natural, notwithstanding the complexity of the stratigraphy. Where local revisions have been necessary, the writers have attempted to adhere as closely as possible to the intent of these original investigators.

Since the beginning of oil activity in West Texas, about 1923, great interest has been manifested in the Glass Mountains because equivalents of the producing horizons undoubtedly outcrop here.

At the close of this memoir will be found a nearly complete bibliography of the Glass Mountains area.

PHYSIOGRAPHY

The foundations for the study of the physiography of the Texas region were laid many years ago by R. T. Hill who summarized his observations in 1900 **(2)**. His wide observations in Trans-Pecos Texas, in what was then a frontier region, remain valuable to this day though later investigations have served to amplify the details. Udden **(3,** pp. 10-15), in his description of the geology of the Chisos country south of Marathon in 1907, added to our knowledge of the physical features of the province with his description of the "graded plains," which anticipated the better known works on desert pediments by many years. C. L. Baker **(6)** in 1917 described the main physical features of the Marathon region as a result of his reconnaissance studies, and Adkins[2] in 1927 presented a concise account of the physiography of the plateau region northeast of the Glass Mountains. Nevertheless, there still remains much to be learned re-

*Hill, R. T., Physical Geography of the Texas Region, Folio 3, Topographic Atlas of the United States, p. 4, 1900.

[1]Suess, E., Antlitz der Erde (Face of the Earth), Oxford Edition, Vol. IV, pp. 85-86.

[2]Adkins, W. S., Geology and Mineral Resources of the Fort Stockton Quadrangle, Univ. Texas Bull. 2738, pp. 14-17, 1927.

garding the physiography and physiographic history of this most interesting province. The greater part of the area still remains to be examined critically from a geographic viewpoint, and such major problems as the origin and history of the Rio Grande are still obscured by conflicting evidence and interpretations.

PHYSIOGRAPHIC FACTORS

CLIMATE

The climate of Trans-Pecos Texas ranges from arid to semi-arid, for the mean annual rainfall increases from 9 inches at El Paso to 17 at Marathon and neighboring stations. East of the mountains, stations in the Pecos Valley are again near 10 inches. The Glass Mountains are thus in the slightly more humid portion of the province.

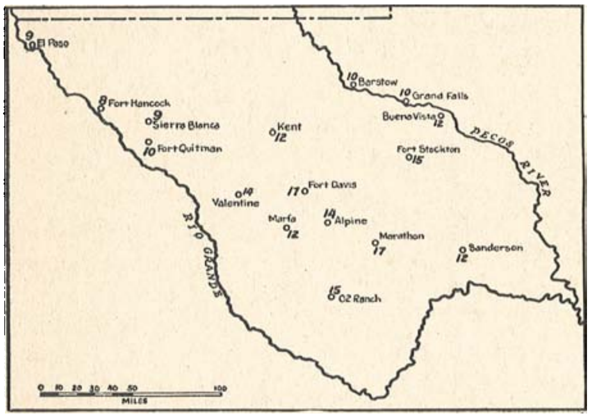


Fig. 2. Map of Trans-Pecos Texas, showing mean annual rainfall in inches at the different stations.

It should be understood that this mean figure, in common with those of other desert regions, can hardly express the actual conditions for a single year, since it is but an average of the greatly varying figures of many years. Except where local configuration is such as to determine atmospheric movements, the distribution of precipitation is erratic; some spots may receive a half dozen rains within a year, while others may remain nearly rainless for several years; and the wet spots of one year may be the dry spot of the next. The yearly rainfall at Fort Stockton has been as slight as 4 inches and as great as 34, though its mean is 15 inches. Even when these local variations are taken into account, there appears to be a cyclic alternation of wet and dry periods shared by all stations, in which the time of one maximum to the next ranges from four to six years, but without any regular periodicity in the changes.

One-half or more of the annual rainfall comes during the months of July, August, and September, most of which is of a torrential character, though there may be, during this time, one or more weeks of continuously rainy weather when the mountains are cloaked in clouds. The precipitation during the torrential rains may reach several inches; a maximum of 6 inches in twenty-four hours is recorded at El Paso. That during the longer and more steady rains is probably much more. A large part of the year's rainfall is thus confined to a few storms.

Most of the precipitation is in the form of rain, but there is some snow in the colder months, particularly on the mountain summits. Since the colder months are also the driest, this form of precipitation is not great.

The mean annual temperature at Marathon is 59.8 degrees. The hottest month is July, with a mean temperature of 76 degrees, and the coldest January, with a mean temperature of 45 degrees. Maximum temperatures of over 110 are sometimes attained in the summer, and minimum ones of zero or less in the winter. There are no available data regarding the diurnal temperature range, though in the summer it must be large. Cyclonic to anticyclonic changes may occur weekly, or more frequently; in the early autumn they sometimes result in temperature variations of nearly 40 degrees in a few days.

Winds are strongest in the spring, usually being accompanied by cloudy skies, without precipitation. During such storms there is a continuous gale of wind, augmented now and then by more violent gusts; they may last for several days at a time. The thunder gusts driven before summer thunder showers cause violent wind storms, but these are only of a few minutes or a few hours duration.[3]

EROSIONAL PROCESSES

Weathering.—In the Marathon region, made up largely of limestones, the rocks weather chiefly by solution, in spite of the low humidity. Rock breakage resulting from diurnal temperature changes is

[3]For detailed statistical data on the climate of the region see Summary of the Climatological Data of the United States, by Sections; Section 2, Western Texas and Southern New Mexico, U.S. Weather Bureau, 1921.

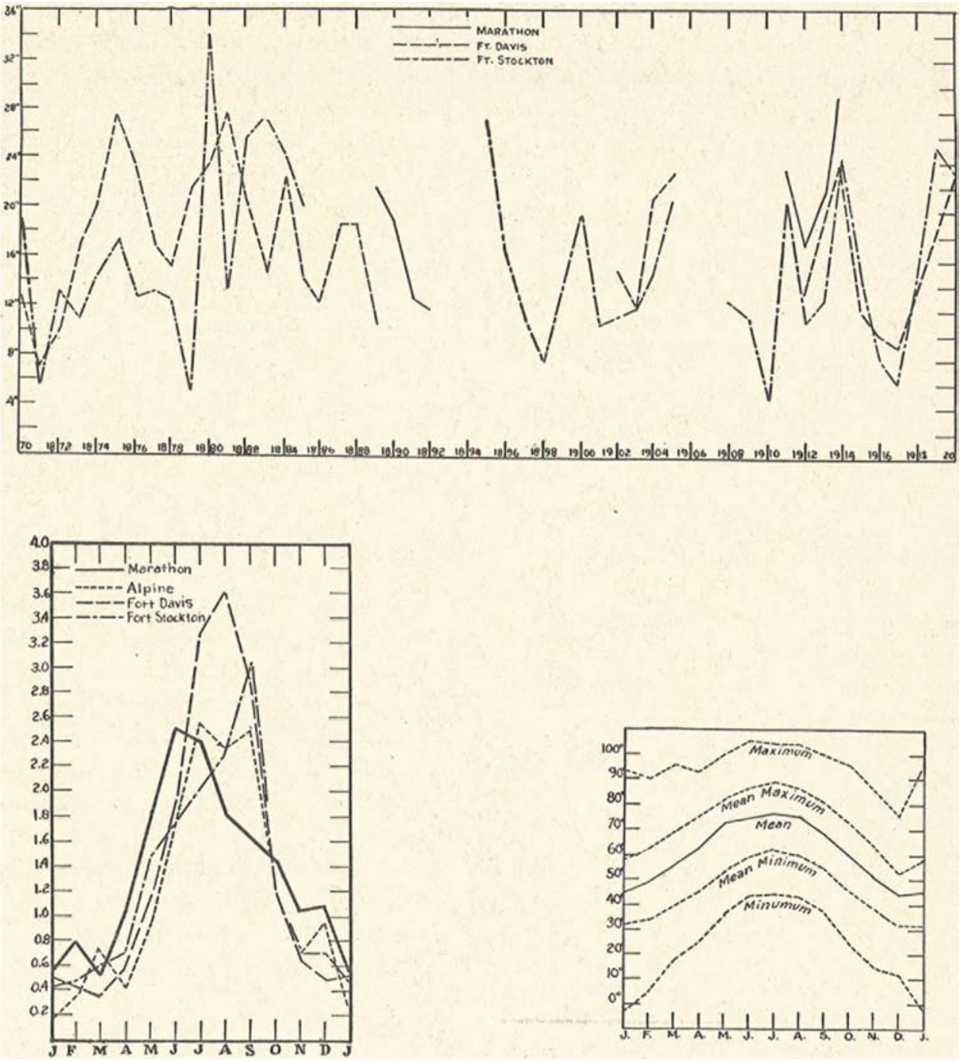


FIG. 3. *Upper.* Graph showing total annual rainfall, in inches, between the years 1870 and 1920, at Marathon and adjacent stations.
Lower right. Graph showing temperature records at Marathon, in degrees Fahrenheit.
Lower left. Graph showing mean monthly rainfall, in inches, of Marathon and adjacent stations.

of negligible importance, because of the monomineral composition of the limestones and dolomites, and their low coefficient of expansion. The limestone is prepared for weathering by the previous jointing and fracturing of the rock; frost action aids in loosening the fractured blocks, and gravity helps to carry them down the steep slopes below the outcrops. The importance of previous jointing is well illustrated by the fact that where the limestones are least fractured and have the least bedding planes they stand as bold cliffs.

Solution assumes its most striking forms in channeled *lapies* surfaces, in cavernous areas, and in the small *tinajitas* (etched potholes) described by Udden.[4] These are but a small part of the whole workings of the process, which serves to widen joints and fractures, undermine ledges, detach the corroded fragments and supply them to the slopes below. It also serves to wear down loose fragments in the process of transportation, though abrasion is also important here. The products of corrosion of the limestone outcrops are seen in the widespread deposits of caliche in the plains, forming a cement to the deposits of wash; much limestone is also carried out of the region in

[4] Udden, J. A., Etched Potholes, Univ. Texas Bull. 2509, pp. 5–9, 1925.
King, P. B., Corrosion and Corrasion on Barton Creek, Austin, Texas, Jour. Geol., Vol. 35, pp. 633-637, 1927.

solution, as indicated by the high content of calcium carbonate in the surface waters.

The igneous rocks, which are of negligible importance in the area, break down largely by exfoliation resulting from the swelling of mineral grains by chemical change.[5]

These processes are not unlike those in humid regions, and decrease in importance with increasing aridity. The arid climate inhibits the solution of the limestones sufficiently to make them the resistant rocks of the region, whereas in humid regions they form lowland belts.

Running Water.—The dominant erosional force of the region is running water, even though, under the semi-arid conditions of the area, its work is ephemeral.

After rains the water is shed rapidly down the mountain slopes, discharging into rocky gorges of the mountains or directly upon the pediments, filling the trenched drainage channels which are dry most of the year. The water may even overflow the trenches and spread in broad sheet-floods over the level pediment surface. Unless the ground is very smooth the sheet-floods are not continuous expanses but interlacing strips of shallow, moving water, flowing in low swales and filling to overflowing those gullies which may indent the surface. The flood waters gradually disappear by soaking into the pediment cover but that collected in the drainage channels may flow for considerable distances. Stories are common of the advance of floods in such channels as a wall of water; one of moderate extent was observed by the writer in Maravillas Creek in 1927. The front of the flood water advanced slowly in the channel because of insoaking into its dry bed, but in a few minutes the entire bed was filled to a depth of several feet.

The water in most of the channels disappears in a few hours after rains. A small channel in the western part of the Glass Mountains draining two or three square miles of area became dry a few hours after a heavy rain though it had performed considerable cutting of its alluvial banks and had completely altered the configuration of gravel bars in its channel. The channel of Antelope draw west of Altuda, draining about 25 square miles of area took eight or ten hours to run out after a day's rainfall.

[5]See discussion by Blackwelder, Eliot, Exfoliation as a Phase of Rock Weathering, Jour. Geol., Vol. 33, pp. 793-806, 1925.

After the water of the channels passes out of the rainy area, evaporation and insoaking deplete the supply of water, so that little ever reaches the master streams of the Pecos or Rio Grande by surface flow. Most of the trenched channels merge into faint swales eight or ten miles from the mountains though water rarely flows even this far. Much water flows down the drainage ways beneath the surface as is shown by the short stretches of running water brought to the surface where the streams cross bedrock sills.

Wind Work.—Wind erosion is an unimportant erosional factor in the Marathon region. Wind storms occupy but a short part of the year and the suspended matter in the atmosphere is not great at such times, though it serves to lower the visibility of the distant mountains. The most striking wind storms are the great gusts which go ahead of summer thunder showers, carrying large amounts of loose dust into the air. One of these was seen, in the summer of 1927, to carry dust in great streams up and over the crests of the Santiago Range. Spectacular though such winds may be, their importance is not great, for they are local in extent, of short duration, and do not have the power to carry material out of the region. No sand blasted rocks are to be observed in the mountains, nor any undrained depressions hollowed by the winds in the plains, so that no features are found which can be wholly ascribed to wind work.

DESCRIPTIVE PHYSIOGRAPHY[6]

GENERAL RELATIONS

The Marathon region is an area of low mountains and hilly lowlands carved from the stripped central portion of a broad dome lying on the western edge of the Edwards Plateau, where it ends against the Front Ranges of the Cordillera. The region contrasts with the Basin and Range Province, which lies not far to the west, for that province is characterized by recently upraised fault blocks, by structural lowlands deeply filled with mountain waste, and by the subordinate effect of differential erosion in shaping the land forms. In

[6]Though the text of this section was so designed that it could be read understandably with the assistance of the accompanying block diagram, yet the reader would probably find it valuable to refer to the topographic sheets covering the region. The four central sheets embracing most of the Marathon region are: The Altuda, Hess Canyon, Monument Spring, and Marathon. Bordering areas are shown on the Sierra Madera, Dove Mountain, Hood Spring, and Santiago Peak sheets.

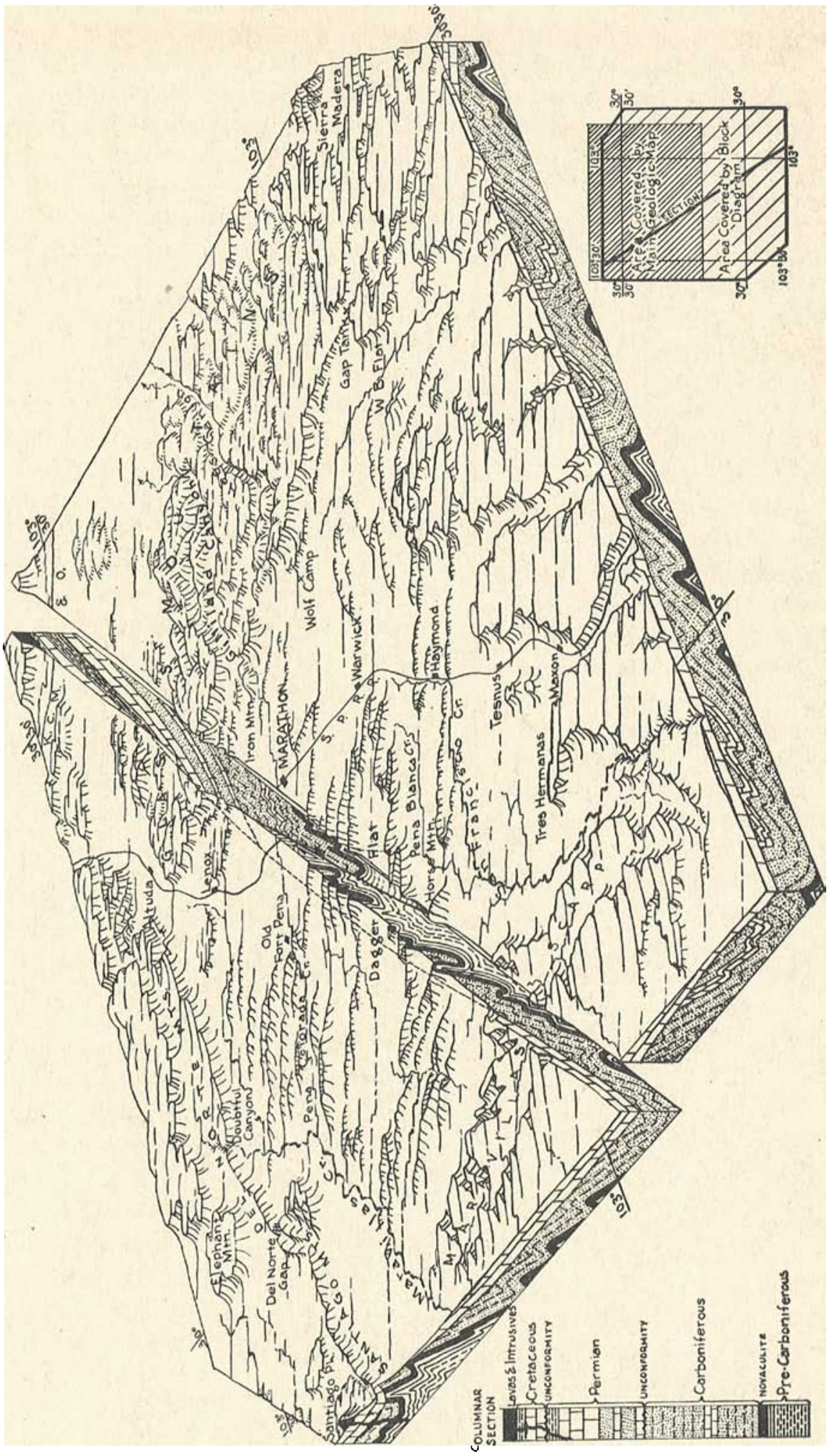


Fig. 4. Block diagram of the Marathon region, showing the Marathon Basin, the Glass Mountains, and the encircling scarps of Cretaceous limestone. The area is viewed from the southeast.

the Marathon region the major land forms are determined by the differential erosion, in a semi-arid climate, of an anciently deformed bedrock. The climate brings about the resistant quality of the limestones, which form the chief mountains of the area, and causes the conspicuous and abrupt contrast between tracts of rugged mountains and level plains.

To the east and south the Marathon region is rimmed by the slightly uptilted, frayed limestone table-lands, which merge outward into the Edwards Plateau. On the north rises the low broad range of the Glass Mountains, presenting bold, southward-facing scarps capped by limestones and dolomites, and a rugged, gently declining back slope. On the west rises an abrupt and narrow chain of mountains, the Del Norte and Santiago ranges, in which the same limestones which lie in gentle attitudes in the Edwards Plateau are sharply upturned. Encircled by these bordering uplands is the low area of the Marathon Basin, excavated from weak rocks in the center of the dome. Some six or eight sharp, narrow, monoclinal and anticlinal ridges of gleaming white novaculite and darker hued cherts traverse the basin in a northeasterly direction (the Caballos ridges of Hill) and rise above lowland areas of flat, gravel-sheeted plain, or minutely dissected rocky tracts of low relief (see Fig. 4).

The accompanying table presents in stratigraphic order the bedrock units and gives their physiographic expression.

Though the climate approaches aridity, there is yet sufficient rainfall to provide exterior drainage. The master drainage courses are prevailingly consequent and flow out north, east, and south from the area, some to the Pecos River, and some to the Rio Grande. Consequents draining southward to the nearby, relatively low lying Rio Grande, possess a distinct advantage over those flowing in a roundabout course to the distant Pecos, and have thus acquired obsequent extensions which head in the southern foothills of the Glass Mountains on the north flank of the dome. These streams are superimposed across the ridges of the Marathon Basin and notch them in narrow water gaps.

In the following pages a more detailed discussion is presented of the northern Marathon Region, which was the portion studied most thoroughly in the present investigation.

THE MARATHON BASIN

The Ridges of the Marathon Basin.— Two principal ridge formers give rise to low ranges traversing the Marathon Basin. The lower of these stratigraphically is the Caballos novaculite at the top of the pre-Carboniferous, the upper is the Dimple limestone lying midway in the Carboniferous.

Structurally, the highest portion of the pre-Permian rocks is a north-south belt in the western portion of the basin. Two large anticlinorial areas of pre-Carboniferous rock lie athwart this arch and plunge down both to the northeast and southwest. To the east is a complementary depressed area in which the higher members of the Carboniferous are exposed. (See Fig. 34.)

The Caballos novaculite rises in the uplifted area in white ridges of bare rock, for the most part monoclinal, supported on their inner sides by the less

Table showing the bedrock units in stratigraphic order and their physiographic expression.

AGE	KIND OF ROCK	PHYSIOGRAPHIC UNIT			
Tertiary	Lava flows and tuff	DAVIS MOUNTAINS High, dissected plateaus			
Upper Cretaceous	Chalk, Marl, and Shale	Intermontane lowlands west of Marathon Region			
Lower Cretaceous (Comanche Ser.)	Limestone	Del Norte and Santiago Ranges where sharply upturned to west.			Edwards Plateau (Including Maravillas Scarp) where flat lying to the east.
—Unconformity—					
Permian	Dolomite, Limestone and Shale	Marathon Region	GLASS MOUNTAINS Complex cuesta on north side of Marathon Basin		
—Unconformity—					
Carboniferous	Sandstone and Shale	Marathon Region	Marathon Basin	Upper Carboniferous Lowland	
	Limestone	Marathon Region	Marathon Basin	Mid-Carboniferous Ls. and Hogback	
	Sandstone and Shale	Marathon Region	Marathon Basin	Lower Carboniferous Lowland	
Pre-Carboniferous	Novaculite	Marathon Region	Marathon Basin	Novaculite Hogback	
	Chert and Limestone	Marathon Region	Marathon Basin	Pre-Carboniferous Lowland	

resistant underlying cherts and limestones. (Fig. 5.) They encircle the excavated cores of the anticlinoria, running in straight, nearly unbroken hogbacks on the flanks, and in convoluted zig-zags on their downward plunging termini. This is well shown at the northeastward plunge of the southern anticlinorium eight miles east of Marathon and south of Warwick siding. The northern anticlinorium is less prominently expressed, and its downward plunge east of Marathon is shown by low zig-zag novaculite hills rising but faintly above the gravel sheeted plain. The southeast flank of this anticlinorium is made up of a group of thrust slices expressed in two closely set cuesta-form ridges backed on their southeast sides by novaculite. Through them, superimposed Peña Colorada Creek has cut a water gap, along which a short stretch of permanently flowing water is collected from the gravel sheet upstream, and brought to the surface by a rise in the bedrock. This was a locus of pioneer settlement in the region and the site of old Fort Peña Colorada.

Anticlines of less height between the two anticlinoria and southeast of them rise as steep narrow, doubly plunging anticlinal mountains, sheeted over by novaculite, and in part breached along the crest by axial subsequent valleys.

The mid-Carboniferous limestone ridge-maker does not rise as high as the novaculite ridges and is breached more widely by superimposed streams which cross it. Its most conspicuous development is in the pair of hook-shaped hogbacks encircling synclinal lowlands, which lie on either side of Haymond station east of Marathon. San Francisco Creek has a superimposed course across both ridges. Other limestone hogbacks are scattered discontinuously over the plains toward the north. (Fig. 6.)

The Lowlands of the Marathon Basin.—Under the influence of the semi-arid climate, the greater part of the area of the Marathon Basin has been reduced to nearly level pediments. These differ from the typical pediments described by Bryan[7] and McGee[8] which are formed by the gradual reduction of generally massive rocks. Here the rocks

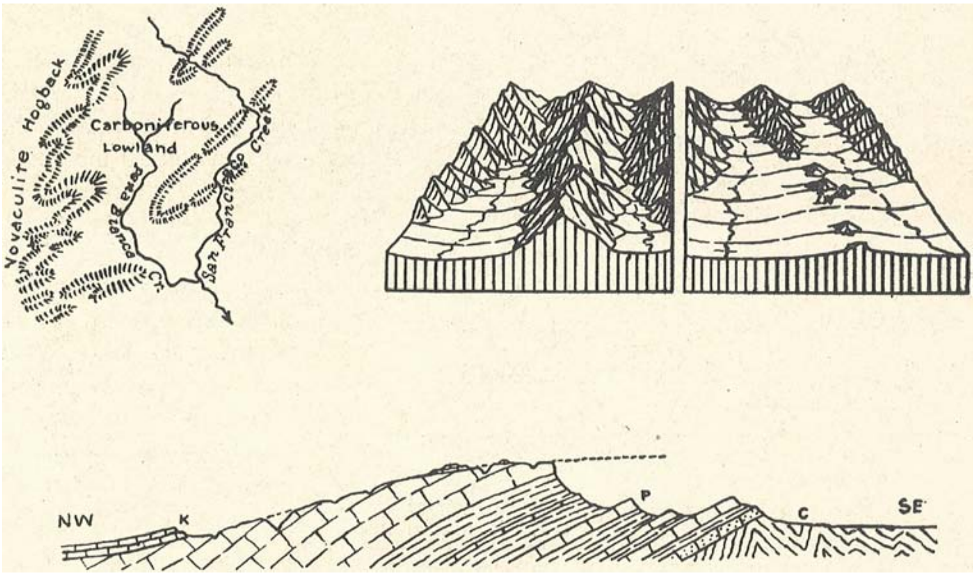


FIG. 5. Diagrams illustrating details of the physiography of the Marathon region.
Upper left. Sketch map, showing the cross-axial subsequent character of Peña Blanca Creek, in the eastern part of the Marathon Basin. Note that it flows across the axes of plunging folds along a weak-rock belt. The master stream, San Francisco Creek, is superimposed on the structure.
Upper right. Block diagrams showing two stages in the development of *inselberge* (In), such as are seen along the northern flanks of the Glass Mountains. Recession of the mountain front appears to be the chief factor.
Lower. Sketch section, showing the form of the Glass Mountains, a cuesta-like asymmetrical upland, with its front face carved from tilted strata and its back slope determined by an exhumed peneplain. Dips are exaggerated, and the section generalized.

[7]Bryan, Kirk, Erosion and Sedimentation in the Papago Country, Arizona, U.S.G.S. Bull. 730-B, 1922.

[8]McGee, W J, Sheetflood Erosion, Bull. Geol. Soc. Amer., Vol. 8, pp. 87-112, 1897.

are greatly folded, and there is sufficient contrast between weak-rock and hard-rock groups to admit of a great development of subsequent drainage. Nearly the whole of the weak-rock belts have been leveled off and connected through the ridge-making belts by strips of plain adjacent to the master superimposed drainage lines. Above the pediments the residual hogbacks of the two ridge-makers rise abruptly as a mere skeleton of the ancient mountain structure.

of the two major anticlinoria, which are nearly encircled by outward dipping novaculite hogbacks. The Carboniferous sandstones and shales, both below and above the mid-Carboniferous limestone ridge-maker form broad areas of plain surrounding the central anticlinoria.

These weak-rock belts are crossed by superimposed consequents, and are drained by subsequents, mostly axial anticlinal or axial synclinal. Peña Blanca Creek, southwest of Haymond, is a cross-

FIG. 6. Views of the ridges of the Marathon basin.
Upper. Hogbacks of Caballos novaculite; view southwest across the southern Marathon basin from the summit of Horse Mountain, a high anticlinal novaculite ridge. (Drawn from a photograph by C. L. Baker.)
Lower. Monoclinal ridge of Dimple limestone, nine miles southeast of Wolfcamp, and immediately west of Frog Creek. Tesnus sandstones and shales outcrop on plain to the left, and Haymond beds to the right. The ridge bends abruptly to the left in the middle distance, around the axis of an anticline.

Three weak-rock groups may be recognized. The lowest, stratigraphically, is that of the pre-Carboniferous limestones and cherts which lie beneath the novaculite. It gives rise to Dagger Flat and the plains about Marathon, on the excavated cores

axial subsequent,[9] flowing on the lower Carboniferous weak-rock belt, between novaculite and mid-

[9]A cross axial subsequent, as used by Davis, is a subsequent stream developed upon a zig-zag weak-rock belt which crosses the axes of plunging folds (Fig. 5).

Carboniferous limestone hogbacks along the northeastward plunge of the southern anticlinorium.

The encircling Comanche and Permian limestone scarps, with gradients of 1500 to 2000 feet per mile, flatten abruptly at their bases giving place to pediments sloping into the basin at the rate of 200 to 300 feet per mile. The pediments in turn flatten gradually, with characteristic concave upward profile, to a gradient of 75 feet per mile or less. Pediment slopes out from the hogbacks of the basin are nowhere as steep as those flanking the bounding scarps, and rarely exceed 100 feet per mile. The whole pediment surface is inclined gently to the master drainage ways, and has a general slope southward toward the Rio Grande; it is highest at the south foot of the Glass Mountains, where it exceeds 4000 feet and is but little more than 3000 feet at the south edge of the basin.

Pediments are sub-level expanses of degraded bare rock, thinly sheeted by materials in transport across them from unreduced mountains to the master drainage lines. Their form is the result of a delicate balance between run-off, the size of the transported fragments, and the base level of the master streams. This delicate balance may be upset by rejuvenation or retardation of the master streams, or by climatic changes, whereby the pediments may become dissected or mantled by waste. Few areas in the Marathon Basin show normal pediments. In part they have been more or less thickly mantled by waste from the mountains, and in part intricately dissected.

The pediment mantle is thickest adjacent to the scarps which bound the basin, particularly along the east front of the Del Norte and Santiago ranges, and the south front of the Glass Mountains. The mantle thins gradually outward from the mountain bases. Near Wolf Camp at the southern foot of the Glass Mountains, wells show a cover detritus 100 feet or more in thickness, while the pediment is generally bare three or four miles to the south. In other places, as near Lenox, the cover is thinner and bedrock is penetrated by more recent dissection at a depth of 30 to 40 feet; here again the cover nearly disappears two or three miles away from the mountains. (Fig. 10.) This covering approximates the form of the pediments beneath, though its gradient is slightly steeper. Its surface is marked at the points of debouchure of valleys from the mountains by the faint convexity of alluvial fans. Several are well shown near Wolf Camp, and one is conspicuously developed west of Altuda at the foot of the Del Norte Mountains. (Fig. 9 C-D.)[10]

The deposits consist of sub-rounded to angular cobbles and pebbles, largely of limestone and dolomite, in part cemented by caliche. Occasional boulders, reaching four feet in diameter, occur in trains along the larger drainage channels as much as three miles away from the mountains.

There is evidence that at least a part of the detritus mantle is of some antiquity. On the south side of the Dimple Hills, which rise from W B Flat in the northeast part of the Marathon Basin, the now dissected detritus mantle contains many boulders of Comanche limestone. At the present time rocks of this age outcrop on the hills only in a tiny summit remnant drained by northward flowing streams. The detritus mantle here was certainly formed at a time when the Comanchean covered a wider area on the tops of the hills, so that boulders from the diminishing residual could be supplied to the deposits at the southern base.

The mantling of the pediments is probably the result of climatic changes, quite likely toward aridity. In a region of limestone mountains, the comminution of the rocks takes place almost wholly by solution and abrasion. Decreasing rainfall will retard these processes and the materials delivered to the pediments will increase in size at the same time that transporting powers are becoming less. Thus it will become necessary for the streams to assume a steeper gradient, and filling near the mountain bases will occur.

The pediment, and the detritus mantle which covers it, are now being dissected by various types of trenches. The most vigorous pediment dissection is in the central and southern part of the Marathon Basin adjacent to the master drainage ways, particularly of San Francisco Creek. This dissection appears to be the result of rejuvenation, probably of the Rio Grande, and operates by headward cutting of the master stream and its tributaries. Behind the heads of the trenches the rugged land gives place to level, gravel sheeted plain at the same level as the ridge tops of the dissected ground. Near Haymond, tributaries to San Francisco Creek have cut to a depth of 50 or 75 feet below the waste-veneered pediment; and farther

[10]Compare Blackwelder, Eliot, Piedmont Plains of the Great Basin (Abstract), Preliminary Abstracts of Geol. Soc. Amer., Cordilleran Section, 1928.

downstream cutting has proceeded to an even greater depth. (Fig. 9B.)

In addition, trenching is taking place at the bases of the mountain slopes, particularly along the south foot of the Glass Mountains. (Fig. 9A.) Such trenches average 20 feet in depth but may reach 50. In places they are closely spaced and run nearly parallel. Some are the outward extensions of drainage channels issuing from valleys in the mountains. Others appear at the mountain bases, and more are implanted between these farther out, heading on the pediment surface itself. All the trenches fade out near the bases of the steeper pediment slopes. Most of the channels are cut only in the waste mantle, but a few penetrate the bedrock to some depth; this is particularly true east of Lenox. A large number of the trenches expose bedrock in their bottoms for a few hundred yards out from the mountain bases. (Fig. 7.)

FIG. 7. Views showing the effects of normal faulting on the topography of the Glass Mountains.

Upper. Resequent fault-line scarp in the Glass Mountains; the east face of Old Blue Mountain. This 500-foot scarp, made up of resistant dolomites, has very nearly the same height as the original throw of the fault, which runs along the base of the steep slope.

Lower. The fault-consequent valley of Hess Canyon, looking northwest from a hogback of Word limestone. The hills in the background are a part of the Vidrio member. The canyon is a graben, by which Comanche limestones which cap the hilltops on either side are downfaulted to the valley bottom.

Those which are the extensions of mountain drainage are probably merely the sluiceways for torrential run-off, for along their rims are gravel bars, minute gullying, and other evidence of occasional overflow. The trenches heading on the waste mantled pediment or at the mountain bases are possibly the result of climatic changes, though dissection as a normal feature late in the cycle of alluvial filling, as suggested by Eckis[11] may operate here. Climatic change toward increasing rainfall is indicated, however, by the not infrequent penetration of the bedrock beneath the alluvial mantle, thus suggesting that the streams are working toward a new gradient even slighter than that of the original pediments.

THE GLASS MOUNTAINS

The Glass Mountains are a cuesta-like asymmetrical upland, trending northeast, and flanking the Marathon Basin on the north. They are carved from northwest-tilted Permian dolomites, limestones, and shales, unconformable alike with the Carboniferous below and the Comanche above. The name of the range is a translation of the Spanish, *Sierra del Vidrio,* said to have been given for the fancied glassiness of the limestone scarps as seen from a distance. The mountains are also sometimes known as the Sierra Comanche.

The range assumes its most imposing appearance when viewed from some miles to the south. Its steep southward facing scarps, set on a pedestal of upward sloping pediments, rise 1000 to 2500 feet above the plains. The western half with its high, broken crests, its bold capping crags of dolomite, and its deep canyons, attains altitudes of over 6500 feet. Toward the east the summits decline somewhat into a less imposing, even-crested scarp, and the capping cliffs give way to thinner ledges. Lower cuestas which stand some miles before the main front of the range, hide its base, and form the boundary of the Marathon Plain. About midway along the front of the range, the bald knob of Iron Mountain, an intrusive stock, stands between the plains and the escarpments of stratified rock. Viewed from the north the aspect of the mountains is more monotonous, for one sees only the hilly, gradually rising back slope; and, although summits of considerable height are in view, their scarps face away from the observer.

The southward facing front of the range is carved from northwest-tilted Permian strata, with its face and fronting cuestas made up of resistant limestone ledges separated by lowland or slope-making sandy and shaly beds. The crests are capped by cliff-forming dolomites. The back slope differs from that of a cuesta in that it is not controlled by the normal dip of the beds which form its face, but by the stripped surface of the peneplain on which the Comanche series was deposited, which also declines northward, though it cuts across the Permian dolomites at a slighter angle. The resistant beds which cap the range thus thicken as a wedge down the back slope. Over the exhumed surface of the ancient peneplain are still scattered residual mesas of Comanche limestone. (Fig. 5.)

After the formation and burial of the peneplain, it was tilted toward the north, moderately folded, and transected by northwest-trending normal faults. All these deformations are now shown by the exhumed surface.

The tilting and folding are shown by the slope of the summit levels and the profiles of the ridge crests, though in the west where dissection has been great, much of the original form of the surface has disappeared. The deformation of the ancient peneplain is also well shown in the present domical form of the group of hills making up Sierra Madera, an abrupt isolated uplift bringing up Permian dolomites in the plains northeast of the Glass Mountains.

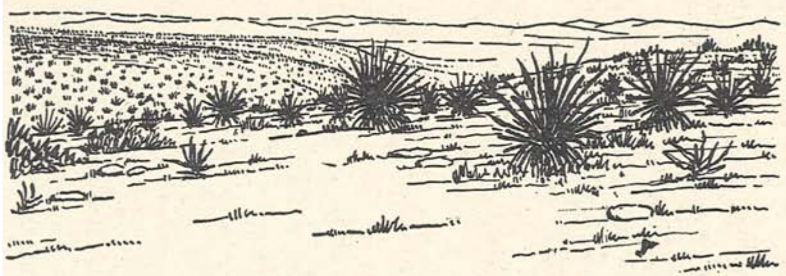
Faulting is expressed by resequent fault-line scarps[12] in which the height of the scarp is approximately the same as the original throw of the fault. (Fig. 7.) The weak Comanche rocks, which very likely buried the whole of the present scarps at the time of the faulting, have now mostly been stripped away from both upthrown and downthrown sides, so that the faulting is shown by the resistant dolomites alone. Both folding and faulting have contrived to raise the western part of the range into high irregular crests; but toward the east the throw of the faults diminishes and the summits of the range are flat and monotonous, declining gently outward down the back slope.

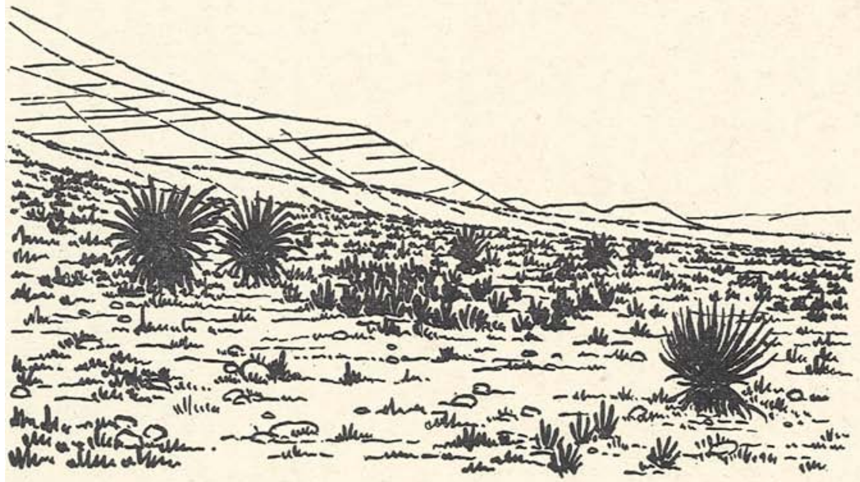
Some of the faults extend out as far as the region still sheeted over by Comanche limestones; here resequent fault-line scarps are developed at a higher level upon the stripped upper bedding plane of the resistant Edwards limestone.

Though the mountains are composed of stratified rocks, they are of such uniform resistance, and

[11]Eckis, Rollin, Alluvial Fans of the Cucamonga District, Jour. Geol., Vol. XXXVI, pp. 237-238, 1928.

[12]These scarps are believed to have been formed in a single cycle. In Davis's original definition, an intermediate epoch of base-leveling is implied, but as shown by Blackwelder single-cycle fault line scarps may form under special conditions (Blackwelder, The Recognition of Fault Scarps, Jour. Geol., Vol. 36, p. 293, 1927).





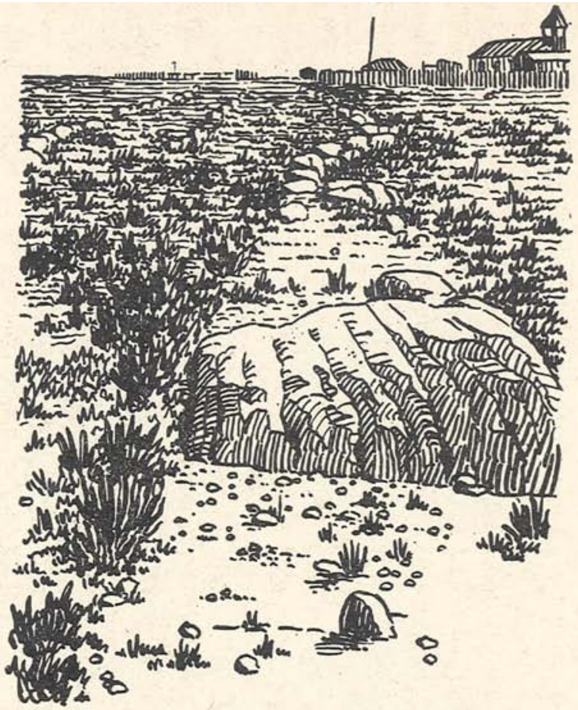


Fig. 8. Views of pediments in the Marathon region.

Upper left. Dissection of the waste-veneered pediment on the south foot of the Glass Mountains east of Lenox. View is south toward the Marathon basin away from the mountains. The bottom of this and nearby trenches is cut in bedrock.

Lower left. Base of Hess escarpment east of the Hess Ranch; looking east toward Wolf Camp Hills, which appear in the distance. Shows character of waste-veneered pediment surface, and the abrupt termination of this surface against the steeply sloping mountains. Note that the pediment itself is not level, but is inclined outward at a rather steep angle.

Right. Bare-rock pediment surface at the town of Marathon, underlain by steeply inclined Ordovician limestones.

their bedding planes in a large part so indistinct, that their erosion has proceeded much as it would in massive strata. Subsequent drainage is but a subordinate feature, in great contrast to the Marathon Basin. Drainage down the back slope is prevailingly consequent, while that down the front face is the headward obsequent extension of streams flowing off the south side of the Marathon dome.

Subsequent development is inhibited by the uniform resistance of the bedrock and the general compactness of the bedding. Only two weak-rock belts are of any great importance and these thin out along the strike. The most prominent of these is the thick wedge of clastics making up the lower half of the Permian west of Hess Canyon (Leonard and Word formations). Lowland or slope-forming shaly beds alternate with limestone scarp makers, giving rise to low cuestas between the Marathon plain and the main scarp of the mountains. These are most prominent between Iron Mountain and Lenox. In the northeastern part of the mountains a wedge of sandstones and thin-bedded dolomites (upper Gilliam) permits a discontinuous development of subsequent valleys of asymmetrical

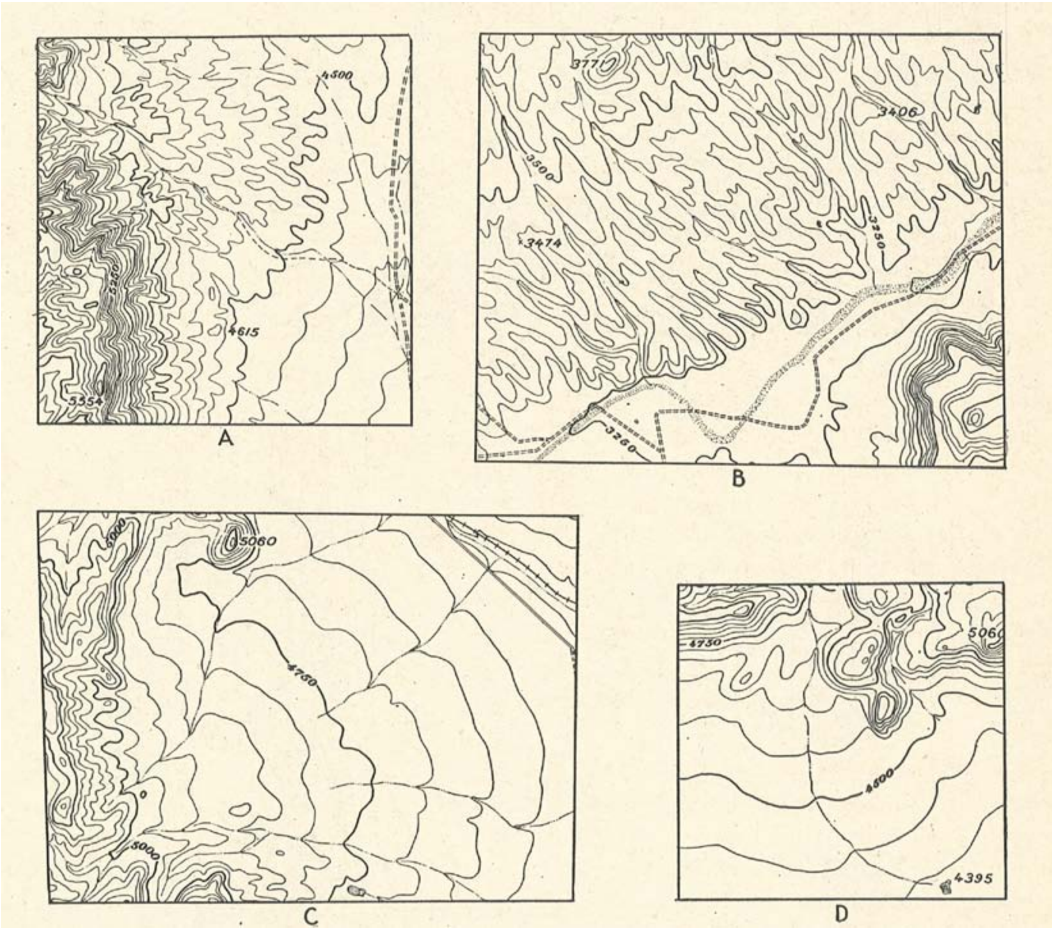


FIG. 9. Maps showing pediments of the Marathon region.

A and B. Dissected pediments. (A) is an area southwest of Lenox, at the base of the Del Norte Mountains, showing the dissection of a waste-veneered pediment at a mountain base, perhaps by climatic changes. Note the manner in which the trenches fade out down the slope. (B) is an area along San Francisco Creek near the point where it leaves the Marathon Basin, showing the dissection of a pediment cut in the Tesnus formation, probably as a result of stream rejuvenation. Scale, about 1 mile=1 inch.

C and D. Alluvial fans on the waste mantle of pediments on the south flank of the Glass Mountains. (C) is about two miles south of Altuda; (D) is at Wolf Camp. Same scale.

Erosion has proceeded in the manner characteristic of massive mountains under conditions of aridity, the slope of the unreduced mountain areas rising with oversteepened profile above pediments flanking the range. Extensions of the pediments along laterally widened consequent and obsequent valleys penetrate the range like tentacles, from all directions.

cross-section, the south side being a stripped bedding surface and the northern a low but abrupt erosion scarp.

Nearly all the streams of the back slope of the Glass Mountains are consequent to post-Cretaceous structure; they flow in a broadly radial pattern toward the north and northeast. Consequents also radiate from the small Bissett Mountain and Sierra Madera domes. These streams are superimposed upon the Permian structures of the mountains, though this is not always apparent because of the close coincidence of Comanche and Permian structures. The relation of the consequents to Comanchean structures is made clear by drawing strike lines at right angles to them; these coincide to the strike of the Comanche, even on minor folds and terraces (Fig. 11), indicating that the streams flowing today took their position in the troughs of the minor folds after the post-Cretaceous deformation.

The streams, however, seem to be wholly unrelated to the normal faults. A large number, it is true, cross the faults from the upthrow to the downthrow, but the reverse is often the case, particularly on the smaller faults. Some streams east of Hess Canyon cross areas of complex minor faulting without deflection. A few of the streams, notably Hess Canyon, are fault consequents, draining down long narrow grabens. (Fig. 7.) Hess Canyon has diverted northeast-flowing consequents all along its fault-consequent course.

Some of the streams in the northeast part of the mountains have a falsely subsequent aspect, for they approximate the Permian strikes. This relationship appears to be fortuitous, however; for they are not related to known weak-rock Permian belts, are not offset by faults, do not show asymmetrical valley cross-sections, and have winding courses, slip-off slopes, amphiteatral walls, and flood-plain scrolls resulting from consequent crooks whose amplitude has been increased by sideward cutting. Such features could not result from the headward cutting of the subsequents along weak-rock belts. Moreover, as shown by a comparison of drainage strike lines to Comanchean structure contours (Fig. 11), these pseudo-subsequents have been determined by the post-Cretaceous structure, and have been superimposed at some later date upon the Permian structures beneath.

The evidence indicates, therefore, that there are consequent streams of two ages on the back slope

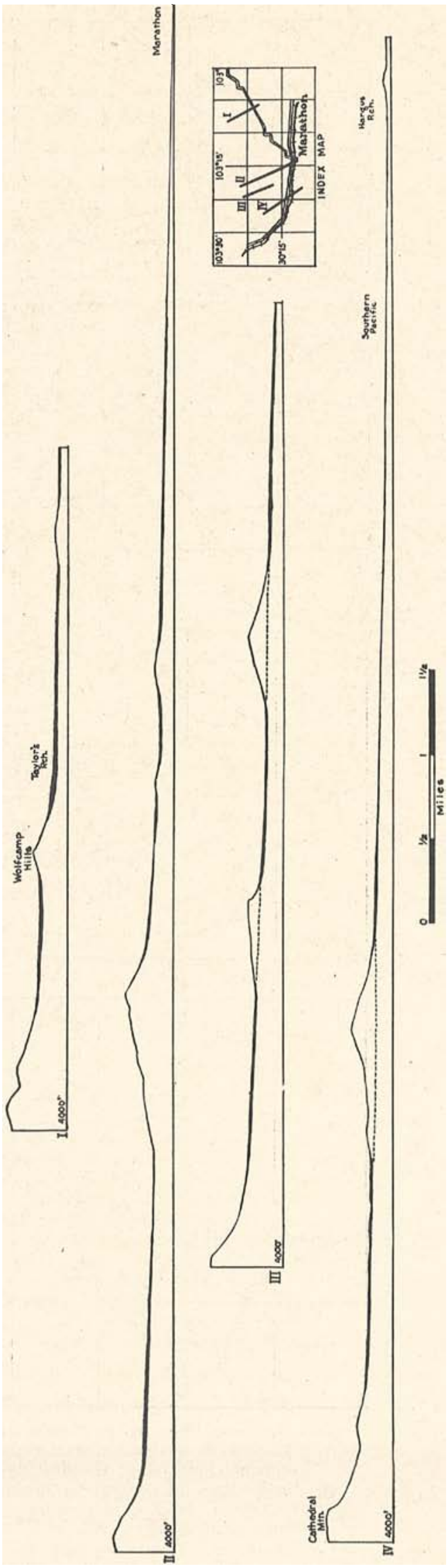


Fig. 10. Profiles showing the form of the mountain slopes and pediments along the south foot of the Glass Mountains. The waste mantle which covers the pediments in places is shown in black. Vertical scale, same as horizontal.

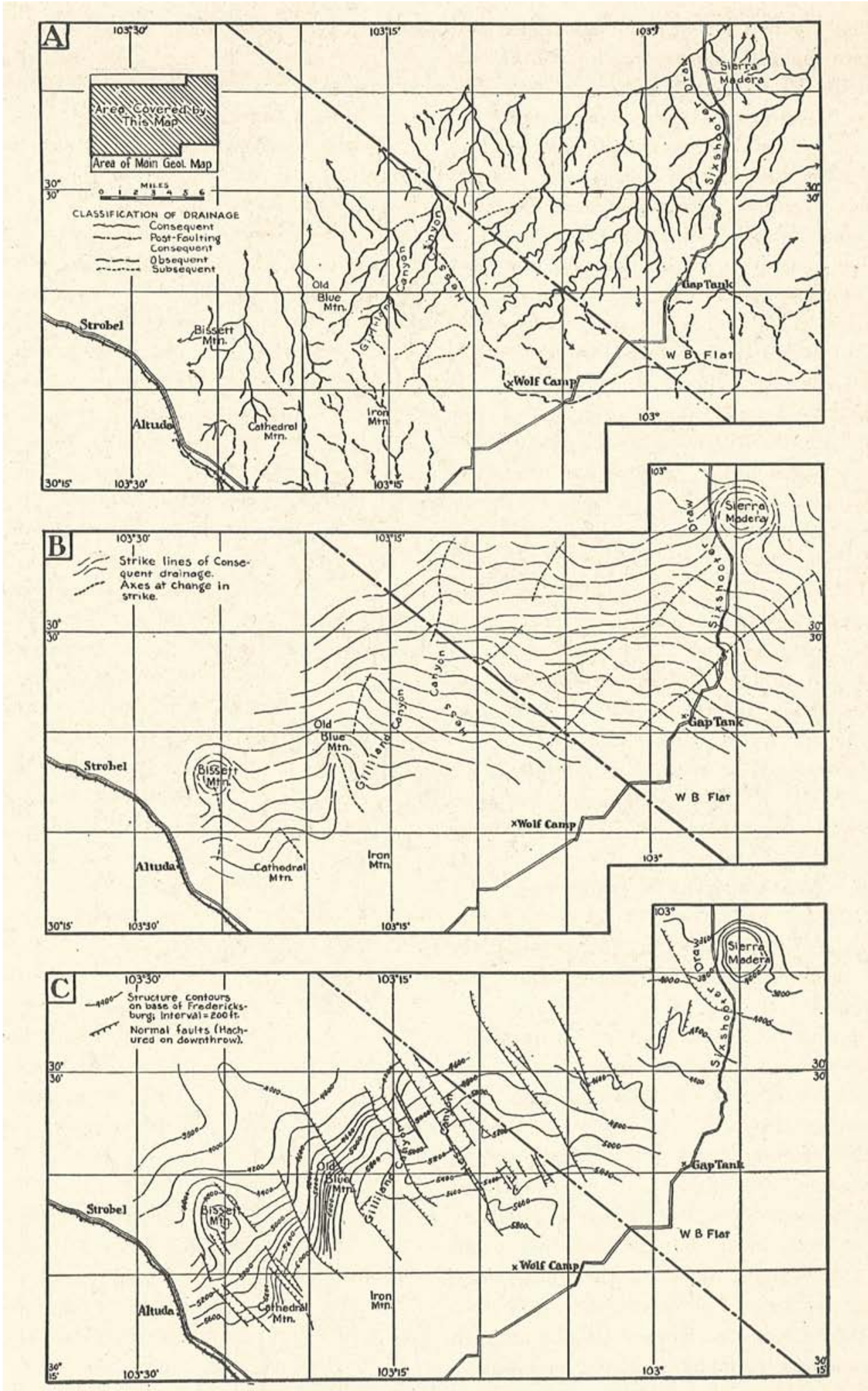


FIG. 11. Maps showing adjustment of streams to structure in the Glass Mountains.

A. An analysis of the drainage of the Glass Mountains; note the prevailingly consequent character of the drainage on their north slope.

B. Strike lines of consequent drainage, showing the deduced form of the post-Cretaceous folding obtained by drawing strike lines at right angles to the consequent streams.

C. Structure contour map, showing structure of the Comanche series, inserted for comparison. Differences between this map and the last are believed to be the result of the disruptive effects of later normal faulting.

of the Glass Mountains. By far the greater number are consequent upon post-Cretaceous folds, but are older than the normal faulting. A relatively small number flow down fault grabens and are post-faulting consequents. When the faulting took place, it was not of sufficient magnitude to prevent the streams from maintaining their original courses, except in a few cases such as Hess Canyon, down which consequents were diverted that once crossed the site of the present graben. In the consequent streams of the back slope, we thus have the living witnesses of structures now modified or obliterated.

Whereas the Marathon Basin has been largely degraded into broad bare rock pediments, with only narrow hogbacks of a few resistant members rising above it, the greater part of the Glass Mountains area still stands high above base level because it is largely made up of limestones and dolomites, which are resistant rocks under arid conditions. These unreduced mountain masses rise steeply and abruptly above the pediments in the characteristic profile of arid regions, enduring at the same angle as long as any mountain remnants remain.

The mountain slopes are of several sorts. On the escarpment faces those limestones and dolomites which are most massive and least jointed stand as sheer cliffs hundreds of feet in height broken only along widened faults or joints by infrequent steep ravines. The cliff-makers generally cap and preserve slopes of weaker sandy and shaly beds below, whose profile is characteristically concave upward. (Fig. 26.) Talus is relatively thin on these slopes, for their angles are adjusted to the size of the fragments in transport across them by gravity and infrequent rain wash from the cliffs above to the pediments below. On the back slope of the range both pediments and mountain slopes are carved from the same uniformly resistant dolomite. Slope profiles are of the same angle from base to top, except for indistinct cliffs and ledges, and are controlled by the size of the fragments which weather from them and mantle them but thinly; their angle is the angle of rest for such materials, minus a variable amount determined by the power of infrequent rain wash.

The form and nature of the pediments has been discussed in the section on the Marathon Basin. Those in the Glass Mountains likewise show an abrupt commencement at the foot of the mountain slopes, a concave upward profile, a relatively heavy detrital mantle, and the same dissection of their steeper slopes. They differ from those of the basin largely as a result of the nature of the materials from which they are carved. They flank the range all about its margins, and are reducing it, not along subsequents, but, because of the massive nature of the bedrock, along laterally widened consequent and obsequent valleys. These extensions of the encircling pediments reach like tentacles into the mountain masses, forming level valleys several miles in width into which drain youthful gorges. This penetration of pediment tentacles is most advanced in the western part of the mountains, whereas the bulk of the eastern half is untouched and is a submature upland of rugged hills and narrow gorges. As a result of sideward and headward extension of adjacent tentacles the intervening sharp rock ridges are broken through in places, changing formerly continuous mountain spurs into chains of *inselberge* (or island mountains).[13] Since each pediment tentacle has its own height and gradient, determined by its length, the nature of the rocks in its drainage area, and the level of the trunk stream into which it drains, the coalescing pediments often meet at different levels. Discordances of 50 or 100 feet are often met with between adjacent consequent pediment tentacles along the north slope of the Glass Mountains, but the greatest discrepancies are between the consequents and the south-draining obsequents, since the latter drain down to the relatively low-lying Rio Grande. The pediment of W B Flat is cutting away the heads of northeast draining consequent pediments east of Gap Tank which lie 500 feet above the flat.

It may be seen from the description of erosional forms that the Glass Mountains upland is in a mature or sub-mature state of regional reduction. The eastern half of the mountains is as yet not reached by advancing pediment tentacles and is still in early maturity. In the western part of the range, and along all its margins, the unreduced uplands are frayed out by pediments penetrating far into the mountains. With advancing erosion these coalesce, breaking the mountain spurs into chains of steep-sided *inselberge*, characteristically meeting at different levels. As the region passes into late

[13]Bornhardt, W., Zur Oberflachen Gestaltung und Geologie Deutsch-Ostafrikas, Berlin, 1900.

See, also, Passarge, S., Die Inselberglandschaften des Tropischen Afrika, Naturwissenschaftliche Wochenschrift, 1904.

maturity, the discordances between these local grade levels will be erased. Mountain remnants will continue to stand in the same steep attitudes which they now have, though with constantly dwindling area, until near the end of the cycle.

THE EDWARDS PLATEAU

The Edwards Plateau,[14] which bounds the Marathon region on three sides, is a region of plateau structure, made up of sub-horizontal limestones of varying resistance, eroded to a mature state of regional reduction under semi-arid conditions.

Along the east and south sides of the Marathon Basin the plateau breaks off in frayed-out scarps 500 feet or more in height. These are inclined outward most steeply on the south, where two prominent parallel Comanche cuestas flank the basin; these were called the Maravillas scarp by Hill.[15] They are entirely the result of differential erosion, and not of faulting as he supposed.

Along the north side of the Marathon region, the topographic boundary is less abrupt. The Comanche mesas rise gradually toward the Glass Mountains, and with the appearance of the Permian at the surface, become perched upon beveled platforms of underlying dolomite. These perched remnants become less in number up the back slope of the range, but a few are still preserved in striking topographic unconformity upon the very summits.

There are several prominent bench and mesa formers in the Comanche rocks sheeting the plateau. Of these, the lowest and strongest is the top of the Edwards formation, a resistant group of limestones from which the plateau takes its name. The overlying marls have been quite generally stripped from this surface, but isolated yellow mounds of this material sometimes rest on its summit, increasing in number out from the Marathon country. At a few places higher, mesa-forming ledges cap the marls in small residuals. The significant features of these mesa-formers and their manner of erosion have already been well discussed by Adkins[16] for the nearby Fort Stockton district.

Drainage in the plateau is prevailingly consequent, with the master streams flowing down the troughs of the gentle post-Cretaceous folds. Pediments have developed along these widened consequent drainages, extending like tentacles into the unreduced portions of the plateau. These flat-floored master consequent valleys, and their youthful V-shaped or box-canyoned tributaries have so dissected the upland that but few flat summit areas of any extent remain.

PHYSIOGRAPHIC HISTORY

The physiographic history is closely knit with the later structural history of the region. Where the two coincide, the most emphasis will here be placed upon the physiographic evidence and the effects on the physiography. The structural history is discussed in more detail in a later chapter. The known physiographic history begins with the mid-Cenozoic; events prior to that time are merely speculative.

There are three epochs of post-Cretaceous crustal disturbance indicated in the rocks of the region. The earliest was probably at the end of Cretaceous time and resulted in folding, which is unconformable beneath the Eocene lavas of the Davis Mountains. The lavas are in turn moderately folded, and evidently in a large part reflect the previous structures; we may tentatively place these movements in the mid-Cenozoic. Later on, the region was cut by normal faults which obscured and partially obliterated the previous folds, and which may provisionally be placed as Pliocene.

The first two movements cannot be distinguished east of the Davis Mountains. Together they brought about a consequent drainage down the dips of the folds, with master streams flowing in the synclines. It was probably at this time that the Marathon dome was uplifted. We cannot tell to what stage erosion progressed after the deformation, for no high level erosion surfaces remain today to record the epoch; they were probably formed on weak Cretaceous rocks, which were readily stripped away after later uplift. We do not know whether any of the Paleozoic rocks were laid bare during this epoch. Evidence indicates that the whole of the Glass Mountains were still buried, and the same conclusion may be applied to the Marathon Basin which stood no higher. It is likely that some of the headward obsequent extension of the consequents shedding off the south side of the dome took place at this time, for they must have been cut to a large degree in Cretaceous

[14]Hill has used the term Stockton Plateau (Topographic Atlas, Folio 3, 1900) for the plateaus west of the Pecos River, but they hardly have more than the rank of a sub-province of the larger region. For the sake of simplicity the broader term will be used.

[15]Hill, R. T., 2, p. 4. Hill also speaks of the San Francisco Cuesta, but his reference is so vague that it is not possible to use the term.

[16]Adkins, W. S., Geology and Mineral Resources of the Fort Stockton Quadrangle, Univ. Texas Bull. 2738, pp. 14–17, 1927.

rocks, since they are superimposed along their courses across the Paleozoic of the Marathon Basin.

This cycle was broken by the epoch of normal faulting. The consequents draining off the north slope of the Glass Mountains were able to maintain most of their courses in spite of the faulting. In most cases the faulting was not disadvantageous, since they flowed from the upthrow to the downthrow. Where minor fault blocks were raised against them, they were able to maintain their courses across them; they are to this extent antecedent. In some places, however, special conditions brought about the formation of new consequents. When the long, narrow wedge of Hess Canyon sank to form a deep graben, the consequents crossing its site could no longer maintain their flow, and were diverted into a new consequent course along its bottom. The faulting was probably accompanied by an uplift and rejuvenation of the entire region.

All the evidence points to the conclusion that, with only minor interruptions, the Marathon region has been continuously eroded since the normal faulting epoch from an erosional surface some two or three thousand feet above present grade. If pauses of any magnitude interrupted the process, they have left no record of their occurrence. During this time the Marathon dome was unroofed and the Paleozoics eroded; streams consequent on Cretaceous structures came to be superimposed upon structures of the Paleozoic; subsequents were developed along weak-rock belts. Nearly all the area of the Marathon basin was reduced.

We do not know what the nature of the climate was during the earlier stages of this epoch, but during much of the latter part, it was semi-arid or even arid, since the land forms are those characterestic of arid regions. Nearly all the weak-rock belts, and much of the hard-rock areas, were reduced to pediments.

During comparatively recent time, minor climatic fluctuations are indicated by alterations of the original form of the pediment. The burial of the pediment surface indicates a change toward aridity, whereas the latter dissection of both pediment and debris mantle on the upper slopes indicates a swing backwards toward more humid conditions, perhaps conditions even more humid than that at the time of the formation of the original pediments.

During Recent time also, and later than the detrital mantling caused by increasing aridity, the streams were rejuvenated by a change in the grade of the Rio Grande, either by its cutting through a local base level down stream or by a slight uplift. This has resulted in a headward dissection by all the tributaries draining directly to the Rio Grande.

STRATIGRAPHY

ROCKS UNDERLYING THE CARBONIFEROUS SYSTEMS

Within the area mapped, five pre-Carboniferous formations were differentiated, of which the lower four are of Ordovician age, and the uppermost probably of Devonian age. The three lowest formations have not been adequately described or defined up to this time, and were recognized during the progress of work for the United States Geological Survey in 1929. Only brief mention of the latter need be made here, for neither they nor the two which overlie them are well exposed in the area of this report, or have a more than incidental bearing on the succeeding discussion. An adequate description of them is reserved for a later report on the southern part of the Marathon Basin.

PRE-MARAVILLAS FORMATIONS

The pre-Maravillas formations were named the Marathon series by Baker and Bowman (**6**, pp. 81-87), but since these rocks do not form a natural group, and consist of a number of units of varied ages, separated by unconformities, it is considered inadvisable to continue the use of this term. There are three formations older than the Maravillas chert exposed within the area of the accompanying map.

The oldest of these consists of thin, flaggy, bluish or black, dense limestone, with partings of green shale. There are many beds of intraformational limestone conglomerate, made up of shattered limestone flags. In the lower part, near Woods Hollow Tank, south of the area mapped, *Dictyonema* sp. and *Paterula?* sp. have been identified by Edwin Kirk from the writer's collections. In the upper part, *Didymograptus* sp., *Phyllograptus* sp., and *Tetragraptus* sp. have been collected by the writer and identified by Dr. Kirk. These indicate a Beekmantown (Deep Kill) age for the unit. The formation is well exposed within the town of Marathon, which is built on the bare rock surfaces of its limestones. A thickness of about 700 feet is exposed in the plains south of Marathon, with the base not exposed.

The unit just described is succeeded by about 200 feet of cherty and sandy limestone in thick beds which outcrop in low hogbacks, one of which rises conspicuously a short distance to the north of old Fort Peña Colorada. At the base in many places is a thick basal conglomerate, and the limestones contain much intercalated reddish granular bedded chert. Fossils are not common in the formation, and its fauna has not yet received detailed study. Dr. Kirk has identified species of *Diplograptus* and *Climacograptus* from the writer's collections and states that "these lots may provisionally be given an age assignment to the Trenton, although they may prove to be somewhat older."

The cherty limestone is succeeded upward by several hundred feet of shale, with which it appears to possess a gradational relationship. The shale is of greenish color, and contains frequent intercalations of buff, fine-grained sandstone, and sandy limestone. Fossils collected from it in the eastern part of the pre-Carboniferous area by Baker and Bowman are stated by Ulrich to be Trenton types (**6**, p. 85), a conclusion which Kirk confirms from a study of the writer's collections. The formation is well exposed at several places along the slope of the Caballos escarpment northeast of Fort Pena Colorada, and southeast of the road to Terlingua. It also outcrops in a small exposure on the Marathon-Fort Stockton road one-fourth mile east of Skinner's south gate and two and one-half miles northeast of Marathon.

MARAVILLAS CHERT

The Maravillas chert was named by Baker and Bowman (**6**, pp. 87–93), who have also made observations on its character and faunas. It outcrops widely throughout the northwest part of the Marathon Basin, on the inner slopes of the Caballos novaculite hogbacks. It consists of gray or black limestone in thin and thick beds, and bedded black chert, the latter predominating toward the top. At the base there is nearly everywhere a conglomerate which reaches 20 feet in thickness, which in places contains large boulders of sandstone and limestone. The Maravillas is from 100 to 300 feet in thickness; some of its variability is undoubtedly due to pre-Caballos erosion. Graptolites, of which the genera *Climacograptus* and *Diplograptus* are most abundant, are common in the black limestones. Ulrich states that the fossils collected by Baker and Bowman are of Richmond and upper Trenton ages.

CABALLOS NOVACULITE

The Caballos novaculite was named by Baker and Bowman (**6**, pp. 93–101); it outcrops in conspicuous white hogbacks and is the most prominent ridge-maker of the Marathon Basin. It consists of two facies, which possess an interbedded and interfingering relationship. The most conspicuous of these is a thick-bedded, white or cream-colored, waxy or vitreous novaculite; this is interbedded and interfingers with thin-bedded, brown, gray, green, or reddish, vitreous chert. The greater bulk of the formation in the north part of the Marathon Basin is made up of the bedded chert facies, whereas novaculite predominates in the south. Near Fort Peña Colorada there is a lower member of white novaculite, 100 feet in thickness, succeeded by several hundred feet of bedded chert. The upper member was originally called the Santiago chert by Baker and Bowman, but this division has no more than a local stratigraphic significance, for near its middle is a thin bed of white chert, which in the anticlines to the south is seen to increase in thickness to several hundred feet, and to become the most important novaculite member in that part of the basin. Only the lower member of the Caballos is exposed east and northeast of Marathon, but the higher beds are probably present beneath the valley fill. The formation varies in thickness from 700 feet in the southern part of the Marathon Basin, to less than 200 feet in the hills south of Dugout Mountain, in the northwest part of the basin. A part of these variations is no doubt the result of overlap on the Maravillas, and erosion before the deposition of the Tesnus, but a considerable part is due to a gradual thinning out of the formation toward the northwest, presumably away from the source of the sediments.

The Caballos and Maravillas formations are separated by an unconformity. There is everywhere a sharp lithologic change at the contact; in a few places there is a basal conglomerate; and in some places the upper members of the Maravillas have evidently been removed by erosion. The upper contact is likewise unconformable, with a more or less abrupt change from the cherts of the Caballos to the sandstones and shales of the Tesnus.

At all places where the contact is exposed there are a few feet of conglomerate at the base of the Tesnus, composed of angular fragments of chert in a siliceous matrix.

No fossils have been found in the Caballos formation, but Baker and Bowman tentatively correlate it with the Arkansas novaculite of the Ouachita Mountains, which is regarded as Devonian by the U.S. Geological Survey. This conclusion is partially confirmed by the studies of R. E. King and the writer in the Hueco and Franklin Mountains where a white chert, underlain by some black shale, lies between the Silurian Fusselman limestone and the beds of Chester age in the Helms group. In the black shale, in the Franklin Mountains, orbiculoids were collected which were identified as Devonian by Edwin Kirk.[17] It is possible that the white chert of probable Devonian age in the Hueco and Franklin Mountains is the same as the Caballos novaculite.

THE CARBONIFEROUS SYSTEMS

GENERAL CHARACTER OF THE CARBONIFEROUS ROCKS

The Carboniferous rocks of the Marathon Basin make a great group, largely of clastic sediments, about 8000 feet in thickness, divided into four formations named, from below upwards, the Tesnus, Dimple, Haymond, and Gaptank formations. Diagnostic fossils have been found only in the uppermost of these, which is of upper Pennsylvanian age; the lowest beds may be as old as the Chester (upper Mississippian). These sediments were laid down in a geosyncline, and seemingly were derived from the old land of Llanoris to the south, which evidently stood high throughout much of Paleozoic time. During the latter part of the period tectonic movements began to affect the geosyncline itself, giving rise to great amounts of conglomerate, and to a variability in the deposits not seen in the older formations. These crustal movements culminated at the end of the Pennsylvanian in the Marathon disturbance by which the Carboniferous and older strata were strongly compressed and folded.

In studying the Carboniferous formations, a number of thin sections were made of the rocks. A petrographic study of these has shown many interesting features, but a more detailed study is desirable, particularly of heavy mineral separates, which will have to be left to later workers. It is hoped that the brief notes on the petrography of the formations will point out lines of investigation to be carried on in more detail by others.

TESNUS FORMATION

GENERAL FEATURES

The Tesnus formation was named by Baker and Bowman (**6**, pp. 101–105), its type locality being at Tesnus station, on the Southern Pacific railway, in the eastern part of the Marathon Basin. It is the basal Carboniferous formation of the Marathon region. The Tesnus is extensively developed around the southeast, east, and northeast edges of the Marathon Basin, where it flanks the central area of pre-Carboniferous rocks. It also outcrops in narrow synclines between the anticlinoria of older strata. Because of the generally non-resistant character of its sandstones and shales, it occupies low places on the plains, and is widely mantled by wash in the northern part of the basin. Toward the south, recent dissection has broken the old degraded surface into an intricate topography of cocks-comb sandstone ridges and shale valleys, portions of which have received such descriptive titles as Hell's Half Acre and Rough Creek.

Within the area of this report, the best exposures are in the vicinity of the Dimple Hills, and to the north and south of the Marathon-Sanderson highway from 15 to 18 miles east of Marathon. Baker[18] considers that his "Dugout beds," which outcrop west of Marathon, may be a fossiliferous northwestern facies of the Tesnus, but, as shown in later pages, evidence obtained by the writer and R. E. King would indicate that they are of Gaptank age.

The Tesnus formation is a great mass of interbedded sandstone and shale, in thin and thick beds, which commonly attains a thickness of several thousand feet. A total of 3370 feet is reported by Baker in a section south of Marathon, but recent work has shown that the thickness of the formation is variable in different portions of the basin, being greatest in the southeast. Along the lower course of San Francisco Creek, in the southeastern angle of the Marathon Basin the Tesnus is probably more than 4000 feet thick, whereas west of the town

[17]Darton, N. H., Devonian Strata in Western Texas (Abstract), Bull. Geol. Soc. America, Vol. 40, pp. 116-117, 1929.

[18]Baker, C. L., Date of Major Diastrophism and Other Problems of the Marathon Basin, Trans-Pecos Texas, Bull. Amer. Assoc. Petrol. Geol., Vol. 12, pp. 1113-1114, 1928.

of Marathon, on the overriding block of the Dugout Creek overthrust, it thins out to less than 500 feet. Most of the Tesnus sandstones are greenish and very fine-grained, weathering to a rusty-brown, which imparts a characteristic color to the exposures of the formation. In the southeastern part of the basin, however, there are many thick massive beds of white quartz sandstone, and numerous layers of arkose and graywacke. In this part of the basin the formation is nearly all sandstone, whereas to the north, in the region of the Dimple Hills, it is more than half blue and black shale. At the base of the Tesnus along lower San Francisco Creek Baker and Bowman have distinguished the Rough Creek shale member, 900 feet in thickness, which grades up into the sandstones that form the main body of the formation. This member appears to be of only local significance, and probably thins out by overlap to the northwest. Within the area of this report, only the upper portion of the formation is well exposed.

LOCAL FEATURES

The best exposures of the Tesnus formation are to the north and south of the Marathon-Sanderson highway from 12 to 18 miles east of Marathon. Here the Tesnus, Dimple, and Haymond formations are repeated several times by thrust faults (including the Frog Creek, Haymond, and Arden Draw faults), and the Tesnus occupies wide areas along the crests of faulted anticlines. The sandstone beds give rise to sharp cocks-comb ridges, separated by depressions occupied by shaly members. Fourteen miles east of Marathon and three miles north of the highway, on the east side of Frog Creek there is an exposure of several hundred feet of steeply dipping, black, splintery, much-indurated shale, with thin sandstone beds at rare intervals. Other exposures of shale are seen along the highway farther east which were found by Harlton to contain the tests of Foraminifera. It is estimated that about 40 per cent of the formation in this district is shale.

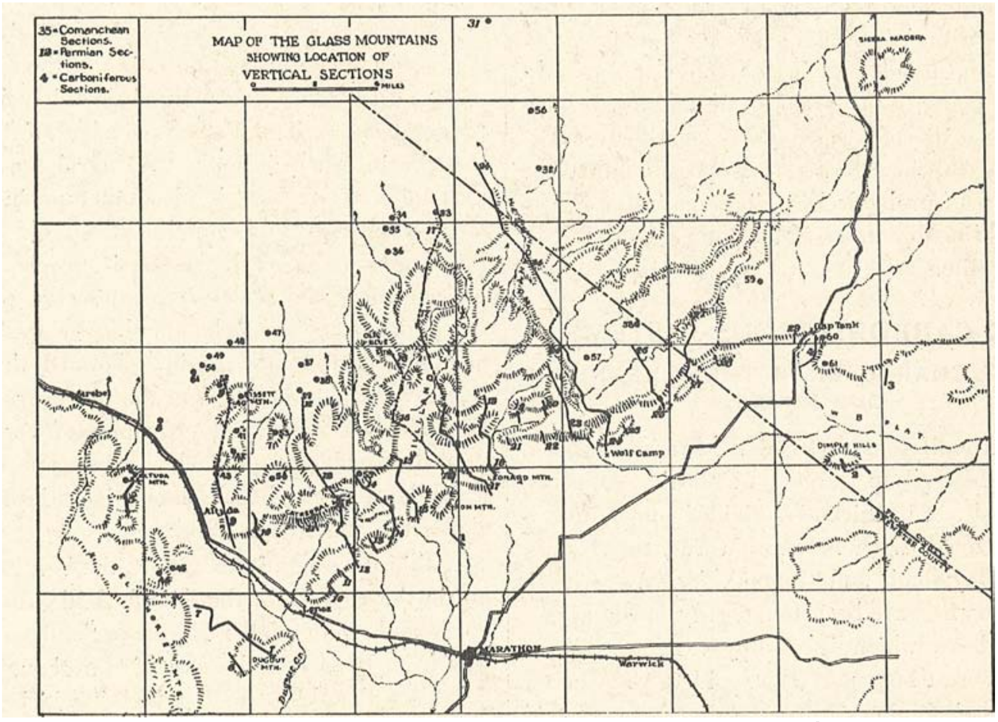


FIG. 12. Map of the Glass Mountains, showing the location of stratigraphic sections measured in Carboniferous, Permian, and Cretaceous rocks.

The top of the formation in the northeastern part of the Marathon Basin is marked by a shale member about 100 feet in thickness, of greenish-gray to black color. In this part of the area the Tesnus is succeeded by a transition zone 60 feet thick, included by the writer in the Dimple formation, made up of interbedded shales, limestones, sandy limestones, and some conglomerate beds. This grades up into thicker limestone layers forming the main mass of the Dimple formation.

The following partial section was measured on the southeast side of the Dimple Hills, from the axis of an anticline northwestward to the foot of the hills.

SECTION 2

		Feet
	Dimple formation above.	
(5)	Dark green, indurated shale and thin layers of green quartzitic sandstone	290
(4)	Covered	440
(3)	Quartzitic sandstone	55
(2)	Covered	130
(1)	Soft to quartzitic, greenish, fine-grained sandstone, with three-foot beds of greenish soft shale and sandy shale between. The sandstone contains maroon or purplish iron nodules	95
	Base not exposed; axis of anticline.	
	Total	1010

West of Haymond along San Francisco Creek, on the south side of the Southern Pacific railway, Sidney Powers[19] measured a section of the Tesnus formation between the nearest exposures of Dimple on the east and of Caballos on the west. This section totaled 7590 feet, "subject to duplication, but only two, apparently minor faults, were observed." The writer has not had an opportunity to check this section in detail, but he found the pre-Carboniferous rocks to the west to have been broken by a complex system of folded overthrusts, a fact which leads to the suspicion that there are likewise duplications within the Tesnus formation.

The Tesnus is exposed over a considerable area in the folds on the Skinner Ranch. It is found south of Iron Mountain at several localities, and northeast, along the strike, on the south slopes of Leonard Mountain. The following partial section, showing the character of the upper 280 feet of the formation, was measured one mile south of Iron Mountain, along a creek draining south through a low hogback of Dimple limestone. (Fig. 14.)

SECTION 1

		Feet
	Top of section; abrupt passage into Dimple limestone above.	
(11)	Blue-gray to black, slaty shale, with some thin conglomerate beds near the top made up of chert fragments	16
(10)	Green or buff, fine-grained sandstone	6
(9)	Dark blue-gray slaty shale, with a hackly fracture. Contains some black nodules, possibly manganiferous	38
(8)	Partly covered, a few thin beds of ferruginous sandstone are exposed, and some greenish sandy shale	24
(7)	Blue or green shale and micaceous sandy shale, much indurated. Some plant impressions noted	28
(6)	Hard greenish-gray micaceous sandstone	4
(5)	Soft green shale, in part sandy, with some sandstone lenses. Plant impressions noted	40
(4)	Covered, except for a thin layer of ferruginous sandstone	75
(3)	Hard greenish finely laminated micaceous sandstone	3
(2)	Mostly covered; soft greenish shale near middle	28
(1)	Soft greenish shale, with some indurated shale, and fine-grained shaly sandstone. Plant imprints noted	17
	Base of section.	
	Total	279

[19]Powers, Sidney, The Solitario Uplift, Bull. Geol. Soc. Amer., Vol. 32, p. 423, 1921.

During the summer of 1929 the writer found the Tesnus to be extensively exposed south and southwest of Marathon on the overriding block of the Dugout Creek overthrust. These exposures are outside the limits of the present report, but deserve brief mention because they show a remarkable northwestward thinning of the Tesnus formation. In 1917 Baker and Bowman measured 3370 feet of Tesnus formation across the valley of Peña Colorada Creek near the Bourland Ranch nine miles south-southwest of Marathon. Two miles to the northwest, and two miles southwest of Sunshine Springs the writer measured 1030 feet. In another section two miles north of the latter, 770 feet were measured across a strike valley, bounded on the north by a ridge of Caballos and on the south by a ridge of Dimple. To the southwest, along this strike valley, the Tesnus is found to thin progressively, and has a thickness of about 400 feet at Rock House, two miles south of the Roberts Ranch. At a locality two miles north-northwest of the Roberts Ranch, on the north or opposite flank of the Marathon anticlinorium, the Tesnus has a thickness of 225 feet, and similar thicknesses are found in adjacent hills to the north. This great thinning is probably a result of overlap on the Caballos formation, and the contact between the Caballos and the Tesnus is nearly everywhere marked by conglomerate in this region.

MICROSCOPIC CHARACTER

Thin sections of the Tesnus sandstones show the rock to be made up largely of fine, sub-angular to sub-rounded quartz fragments, in a chloritic matrix. The matrix imparts the characteristic greenish color to fresh exposures of the rock, and its decomposition gives rise to the characteristic rusty-brown weathered surfaces of the formation.

A thin section of sandstone 1000 feet below the top of the formation southeast of the Dimple Hills, at the base of Section 2, was of a rock approaching the character of a graywacke. (Fig. 13.) Quartz

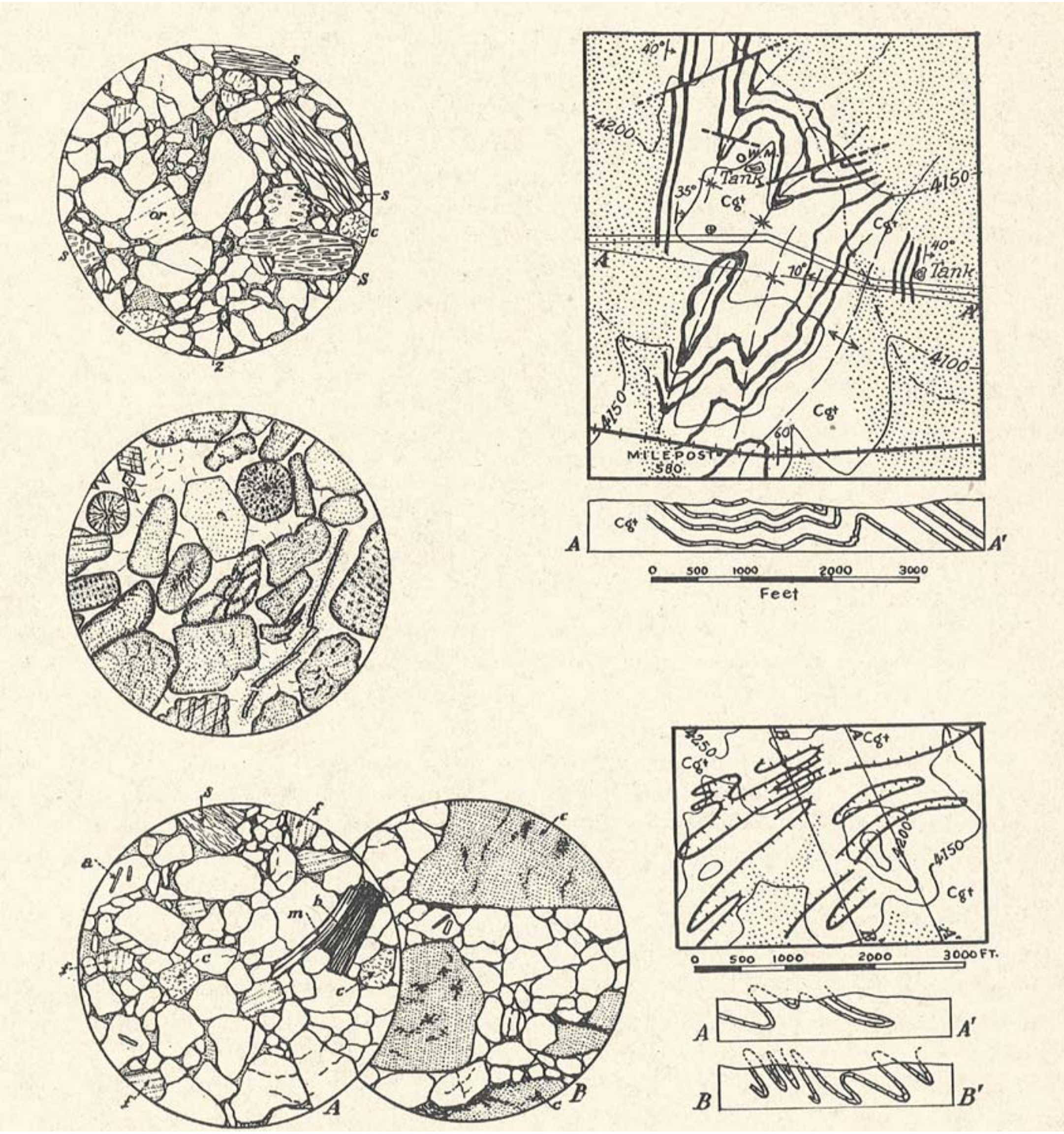


Fig. 13. *Upper left.* Thin-section of Tesnus sandstone, from a locality southeast of the Dimple Hills. The clear grains are quartz; c—chert; s—various slaty and schistose rocks; z—small grains of high refractive index, possibly zircon; or—potash feldspar.

Middle left. Thin-section of Dimple siliceous limestone from the base of the formation in section 1. Shows various calcareous grains interbedded in a clear chalcedony matrix. c—chert grains.

Lower left. Thin-sections of Haymond sandstone from section 3. A—from lower part of formation; B—Coarse-grained phase below chert conglomerate member. f—feldspar; c—chert; a—apatite; m—muscovite; b—biotite; s—slate fragment.

Upper right. Maps of typical areas of Gaptank exposure west of Marathon, in the region which has been overridden by the Dugout Creek overthrust; four miles west of Marathon, in the vicinity of Milepost 580, where the beds are of upper Gaptank age.

Lower right. Four miles S 15° W of Lenox, in the lower Gaptank. A limestone is shown by a black line, hachured on the upper bedding surface. Note the difference in structure, resulting from a greater competency of the beds in the preceding.

grains, somewhat shattered, and nearly all showing strain shadows, make up 75 per cent of the rock. Most of the other grains are fragments of sericitic slate and quartz-chlorite phyllite. There are also a few grains of potash feldspar, sodic plagioclase, chert, biotite in bleached, twisted plates, and muscovite. A few small grains of various minerals of high refractive index are seen, probably including zircon and tourmaline. An analysis of a heavy mineral separation was not made, but would doubtless prove instructive. Megascopically, this rock has a greenish color, a dull earthy appearance, and is spotted by small light and dark grains. Such rocks are common, though not predominant in the Tesnus, and have their greatest development in the south part of the Marathon Basin.

Most of the Tesnus rocks, as seen megascopically, have more quartz, and less of the materials described in the above rock, and are more nearly quartz sandstones and quartzites. Thin sections of these rocks, however, all reveal a few fragments of metamorphic rocks, and also the characteristic chlorite cement.

All sections of the sandstones show abundant effects of deformation, though true metamorphism is absent. The quartz grains all show strain shadows, and many are crushed, granulated, and sheared.

The matrix in all specimens is an iron-rich chlorite, possibly chamosite. Honess[20] suggests that the chlorite matrix in the very similar sandstones of the Stanley shale is derived from the alteration of an original ferruginous cement. Prof. Knopf states that the ferruginous chlorites of sedimentary rocks are usually the result of diagenetic changes. It was noted in the sections studied that the chlorite plates penetrate the fractures in the quartz grains, as though they had developed later than the deformation of the rock, but this relationship may have resulted from the plastic nature of the mineral.

STRATIGRAPHIC RELATIONS

The Tesnus and Caballos are separated by an unconformity representing an epoch of emergence occupying a considerable span of mid-Paleozoic time (Middle Devonian to at least late Mississippian). The conditions under which the two formations were laid down seem to have been markedly different, and locally there is evidence that a part of the Caballos was eroded before the deposition of the Tesnus. There is also evidence of a marked overlap of the Tesnus formation upon the earlier strata in a northwesterly direction. On the other hand the upper contact appears to be a conformable one, as the formation grades upward through a 60-foot transition zone into the Dimple formation.

FOSSILS AND AGE

The only known fossils in the Tesnus formation are very fragmentary land plants and several species of Foraminifera. Poorly preserved plant specimens were collected by Sidney Powers in 1920, and again in 1929, from an horizon 225 feet below the top of the Tesnus on the west side of Peña Colorada Creek, nine miles south-southwest of Marathon. Both collections were examined by David White, and of the later one he writes:[21]

> The specimens collected from the Tesnus formation . . . consist of very badly wave-worn debris which looks as if it were washed up on a beach.
>
> The following species are identified with more or less certainty:
>
> (1) *Lepidodendron clypeatum:* a few detached and deformed bolsters.
> (2) *Lepidostrobus* sp.: fragment of axis from which the bracts and sporangia have been stripped.
> (3) *Artisia:* pith of a small stem of *Cordaites.*
> (4) *Cardiocarpon:* comparable to *C. Pitcairnii.*
> (5) *Cardiocarpon* (?) sp.: uncertain as to whether it represents any kind of a seed.
> (6) *Rhabdocarpus:* narrow type, probably a new species.
> (7) *Calamites* cf. *ramifer.*
> (8) *Annularia*(?): probably a fragment of the stem of this genus.
> (9) *Stigmaria verrucosa:* displaced scars.
> (10) Fernlike stem bearing markings characteristic of the genus *Heterangium.*
>
> No fragment of fern leaf appears to be present.
>
> If the *Lepidodendron* is identified correctly, as I think it is; if the cordate fragment which I think may be the nucleus of a *Cardiocarpon* really belongs to any such type of seed, and if I am not mistaken in the identity of the *Rhabdocarpus,* the collection is undoubtedly Pottsville, and is probably Morrow in age. Numbers 4 and 10 tend to support this conclusion.
>
> On the other hand, there is a bare possibility that the material is latest Chester in age. If the above determinations, which are based upon insufficient and badly preserved material, are correct, the collection is not Chester.

[20]Honess, C. W., Geology of the Southern Ouachita Mountains of Oklahoma, Part I, Oklahoma Geological Survey, Bull. 32, p. 196, 1923.

[21]Quoted from a letter from White to Powers, 1929, and published with their permission.

Foraminifera obtained by Harlton[22] from shale samples collected near the top of the Tesnus formation 18 miles east of Marathon tend to confirm this conclusion for they are stated to be of "lowermost Pennsylvanian age" and to be identical with "microfossils in the Caney shale of Oklahoma."

On the basis of physical evidence the writer and his brother have expressed the opinion (**22**, pp. 911–912) that the Tesnus might in part be the equivalent of the Helms group of westernmost Trans-Pecos Texas, and thus be of Chester age. "A comparison of sections leads one to suspect that the Dimple may represent the Bend and the Tesnus the Chester; the occurrence of fossiliferous beds of these ages in the Hueco Mountains shows clearly that seaways extended into western Texas during Chester and Bend time. Furthermore, the fact that beds of Chester age in the Hueco Mountains thicken and become more clastic toward the southeast suggests that they are the northwestern extension of a thicker geosynclinal deposit, which may well be the Tesnus."

As has been indicated in the foregoing discussion, however, the accumulating evidence favors a very early Pennsylvanian rather than a late Mississippian age for the formation. Still, it should be pointed out that both the wood fragments and the collections of microfossils were obtained very near the top of the formation, and that thousands of feet of strata whose age has never been established, underlie the fossiliferous horizons. How far back into the Carboniferous these lower strata extend, which make up the greater bulk of the Tesnus formation, no one can say and the writer considers it entirely within the bounds of possibility that a part of the lower Tesnus is of late Mississippian age.

Probably the lowest and earliest member of the Tesnus formation is the Rough Creek shale member, which outcrops only in the southeast part of the Marathon Basin; this consists very largely of clay shale which might yield Foraminifera. A careful search of these lowermost beds should be made with this purpose in view in the hope that fossils may be obtained from which the age of the Tesnus as a whole can be determined.

[22]For this and other data regarding the micro-fossils of the Marathon region, the writer is indebted to Messrs. Sidney Powers and Bruce H. Harlton, of the Amerada Petroleum Corporation. Some of these observations are given by Powers in "Age of the Folding of the Oklahoma Mountains," Bull. Geol. Soc. Amer., Vol. 39, pp 1066–1068, 1928.

DIMPLE FORMATION

GENERAL FEATURES

The Dimple formation was named by Udden[23] for the Dimple Hills in the northeast part of the Marathon Basin, six miles south of Gap Tank. Being composed of massive and generally resistant limestones, it outcrops in long, low, monoclinal ridges, which stand above the waste-mantled plains of the northern Marathon Basin (Fig. 6).

The Dimple formation is largely composed of limestone in moderately thick beds. Most of the limestone beds are gray, granular, and somewhat sandy, with occasional seams of chert pebbles; other beds are dense and highly bituminous. In the eastern part of the Marathon Basin, much shale and bedded chert are interbedded with the limestone, forming transition zones with the Tesnus below and the Haymond above. The top and base of the formation are drawn at the highest and lowest limestone beds.

LOCAL FEATURES

At its type locality in the Dimple Hills, the formation has a thickness of 1100 feet, though the hills are a synclinal remnant and the top is not exposed. The lower transition beds here have a thickness of 60 feet, while the upper ones are somewhat thicker, reaching 200 feet. The thickness of these members appears to be nearly constant throughout the eastern part of the Marathon Basin. At several localities north of the Marathon-Sanderson road, 15 to 17 miles east of Marathon, the upper transition zone was seen to pass upward into the sandstones and shales of the Haymond formation.

The following section was measured on the south side of the Dimple Hills, up the slope of the highest summit:

SECTION 2

		Feet
	Top of section; probably near the base of the Haymond formation.	
	Upper Transition beds:	
(11)	Rather poorly exposed; consists of one-foot beds of brown sandy limestone, weathering brown or orange, interbedded with indurated shale and sandy shale of brown, green, or black color..	208

[23]Udden, J. A., Baker, C. L., and Böse, E., Review of the Geology of Texas, Univ. Texas Bull. 44, pp. 49–50, 1916.

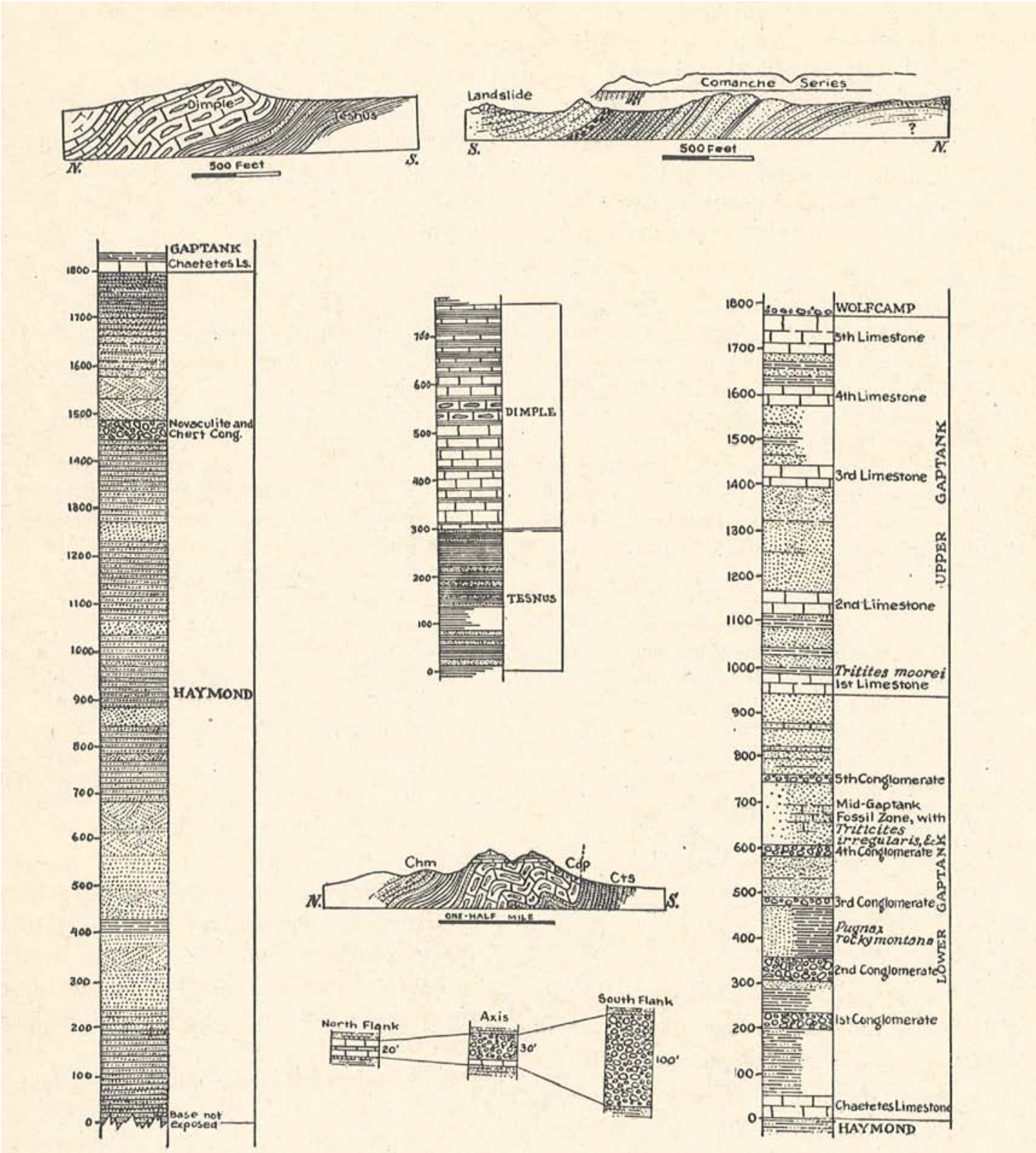


FIG. 14. *Upper left.* Profile along section of Tesnus and Dimple on the Skinner Ranch.
Upper center. Partial section of Tesnus and Dimple formations on the Skinner Ranch (Section 1).
Lower left. Section of Haymond formation on Clark Ranch, southeast of Gaptank, with the uppermost beds, above the conglomerate member, added from a measurement one and one-half miles farther west (Section 3).
Upper right. Profile across the Haymond section at the Clark Ranch; the uppermost beds, beneath the landslide on the south, were traced around the butte in the distance, and beneath the Gaptank formation.
Lower right. Section of the Gaptank formation at its type locality (Section 4).
Center. Profile through Ellis Buttes, eight miles southeast of Gaptank, to show relations of Tesnus, Dimple, and Haymond beds. The buttes are capped by Cretaceous.
Lower middle. Sections which show the northward thinning of the first conglomerate bed of the Gaptank formation, observed on its outcrop around the Gaptank anticline, a distance of somewhat more than a mile.

	Main body of Dimple Formation:	
(10)	Granular, dark gray limestone in 1′ to 4′ beds, interbedded with 2′ to 8′ beds of banded chert, and indurated shale. There are a few seams of chert pebbles in the limestone	338
(9)	Thin-bedded, ashen-gray, argillaceous limestone with a few thin layers of brown sandy limestone and some blue indurated shale	112
(8)	Limestone like bed 4	97
(7)	Greenish-gray indurated shale	4
(6)	Limestone like bed 4	86
(5)	Dense, flaggy, buff, thinly-laminated limestone, containing thin chert bands	23
(4)	Finely crystalline or granular, dark-gray limestone in 2′ to 3′ ledges, with some dense bituminous limestone, and some bedded chert	162
(3)	Dense, black, bituminous, thinly-laminated limestone, weathering pale buff	23
(2)	Finely crystalline or granular, dark gray limestone, in 2′ to 3′ beds, interbedded with thinner beds of shale, which are not well-exposed. The limestones contain chert bands, particularly near the top, and some are marked by seams of angular chert fragments	66
	Lower Transition Beds:	
(1)	Dark gray, sandy limestone, in 1′ to 3′ beds, some of which contain chert pebbles, interbedded with indurated shale, sandstone, and some bedded chert	66
	Tesnus sandstones and shales at base.	
	Total	1166

In the Dimple limestone, dome-like bodies are commonly found, set off by concentric seams of chert, which are not unlike the cryptozoons of the early Paleozoic, though they show no traces of organic origin. Along the Marathon-Sanderson highway, in a road cut 16 miles east of Marathon, at least five beds of ashen-gray clay are interbedded with the limestones, and may represent bentonite, though a detailed study was not made of them.[24]

The Dimple is also exposed in several low monoclinal ridges south of Iron Mountain on the Skinner Ranch, and at several places southwest of Iron Mountain, at the base of the Permian escarpment. The top of the formation is not exposed here, and the Haymond was probably all removed by erosion. The contact between the Tesnus and Dimple in this area is abrupt, and without an intervening transition zone. The following section was measured across a low Dimple hogback one mile south of Iron Mountain, and probably represents the maximum thickness of beds exposed in the area (Fig. 14):

SECTION 1

		Feet
	Top of section.	
(4)	Fine-grained, dark gray, sandy limestone, with some scattered chert fragments, and thin siliceous laminae. Interbedded with much siliceous shale, and bedded chert	404
(3)	Granular, dark gray limestone, containing abundant angular grains of green and gray chert. A small unidentifiable fragment of a brachiopod shell noted. Forms massive ledges 2′ to 4′ thick, with some angular siliceous material between	41
(2)	Greenish-gray shale	3
(1)	Granular sandy limestone, containing angular fragments of chert and siliceous shale, in a massive ledge	2
	Tesnus shale below.	
	Total	450

MICROSCOPIC CHARACTER

A single thin section was made of the Dimple limestone and was taken at random from specimens of the rock in bed 1, section 1 (Fig. 13).

A microscopic examination showed that the rock is a siliceous limestone, made up of limestone grains in a chalcedony matrix. The calcareous grains are of various sorts; about 50 per cent are of obvious organic origin, consisting of fragments of crinoid stems, of sponge spicules, and of the tests of Foraminifera. The other calcareous grains are mostly finely crystalline, and without distinctive structure, but a few consist of large abraded calcite crystals. There are also a few scattered angular fragments of cryptocrystalline chert. The rather wide interstices between these fragments are filled by microcrystalline chalcedony. The chalcedony rims the calcareous fragments in radiating fibers, with the central areas in places filled by large anhedral quartz crystals. In some places there are large spherules of radiating chalcedony fibers.

The large amount of calcareous organic material revealed in this rock by the microscope is interesting, in view of the paucity of megafossils.

[24]First noted by Schuchert, C., Pennsylvanian-Permian Systems of Western Texas, Amer. Jour. Sci. (5), Vol. 14, p. 384, 1927.

STRATIGRAPHIC RELATIONS

The contact between the Dimple and Haymond, as exposed north of the Marathon-Sanderson highway, from 15 to 17 miles east of Marathon, is apparently a gradational one, the Dimple limestones being separated from the Haymond shales and sandstones by about 200 feet of transition beds.

FOSSILS AND AGE

Fossils are not abundant in the Dimple formation. Many of the limestones are obviously largely of organic origin, but the fossil fragments are so finely comminuted that no identifiable material is preserved. The thin section described above is characteristic in this respect of the greater part of the formation.

Foraminifera (other than fusulinids) are reported by Harlton from interbedded shales between the limestone layers of the Dimple Hills and of the exposures 18 miles east of Marathon. They were also noted in the thin section from the locality south of Iron Mountain. According to Powers[25] this micro-fauna is also found in the Marble Falls of Texas and the Wapanucka of Oklahoma.

From an outcrop on the Sanderson road 15 miles east of Marathon Sidney Powers has collected a bryozoon fragment which Dr. G. H. Girty states is possibly a species of *Rhombopora.* From limestone of the Dimple formation two and one-half miles northeast of the Roberts Ranch the writer collected fossils which have been identified by Dr. Girty as a zaphrentoid coral, a possible species of *Streblotrypa,* and a fragment of a *Productus.*

In 1929 Dr. Girty and the writer collected a small brachiopod fauna from the lower part of the formation one and one-half miles west-northwest of Haymond, to the north of the Southern Pacific railway. From this collection Girty has identified the following species:

Orbiculoidea aff. *missouriensis*
Chonetes aff. *arkansanus*
C. aff. *levis*
Pustula aff. *globosa*
P. aff. *imbricata*
Pustula sp.
Productus aff. *cora?*
Hustedia aff. *multicostata*

Dr. Girty comments as follows on this and the two preceding collections: "Definite identifications have not been affixed to the several species recognized in this collection because the characters shown by the specimens do not warrant definite identifications especially in view of the fact that in most instances related species can be found in faunas of widely different ages. It is obvious that the fauna from the Haymond locality is quite unlike any of the Permian faunas of the Marathon Basin. On the other hand, it is clearly of Carboniferous age. It is not reminiscent of the more common Pennsylvanian faunas and is almost equally lacking in definite alliance to the more common Mississippian faunas. Very tentatively I am considering it as of Pottsville age, although one of the Producti is almost identical with a Mississippian species. *Pustula imbricata* is a manuscript name for a rather distinctive Productid that occurs in the earlier Mississippian faunas of Oklahoma and Arkansas, and the form cited as *Pustula* aff. *imbricata* resembles that species very closely. The remainder of the fauna does not very well bear out the relation suggested by that resemblance, but appears to be more closely affiliated with Pottsville faunas. The evidence for either conclusion, however, is so tenuous that both of them may prove to be wrong or the one I reject may be established as correct. The other two collections contain nothing that can be determined specifically. They have no common ground with the first lot, either in faunal or lithologic characters and they also bear very lightly on the geologic age of the Dimple formation. So far as they contribute new evidence at all, they tend rather to discredit the early Mississippian age of the Dimple but are not unfavorable to its Pottsville age."

It may be seen therefore that the age of the Dimple formation is not yet definitely established. There is, however, a certain amount of merit in the suggestion[26] that the formation correlates with some part of the Bend series, for beds of similar lithology, containing a Bend or Morrow fauna, are found at the base of the Pennsylvanian in the Hueco Mountains to the northwest. The fact that in central Texas the Bend is separated from the overlying Pennsylvanian by a well-marked unconformity, and that this unconformity is also

[25]Powers, Sidney, Age of the Folding in the Oklahoma Mountains, Bull. Geol. Soc. Amer., Vol. 39, p. 1066, 1928.

[26]Udden, J. A., and Waite, V. V., Some Microscopic Characteristics of the Bend and Ellenburger Limestone, Univ. Texas Bull. 2703, p. 7, 1927.

King, P. B., and King, R. E., Stratigraphy of Outcropping Carboniferous and Permian Formations of Trans-Pecos Texas, Bull. Amer. Assoc. Petrol. Geol., Vol. 13, pp. 911-912, 1929.

present above the fossiliferous beds in the Hueco Mountains might argue against the Dimple being as old as the Bend. However, it is to be remembered that the Marathon region was a geosynclinal area during Carboniferous time, whereas the other two sections are in the foreland area, and thus it is probable that sedimentation was less interrupted than in the thin, overlapping foreland deposits to the north.

HAYMOND FORMATION

GENERAL FEATURES

The Dimple formation is clearly overlain by the Haymond formation, but nowhere has a complete and uninterrupted sequence from the base to the top of the latter been seen. The type locality of the Haymond is in the synclines near Haymond station, on the Southern Pacific railway, east of Marathon. The formation was named by Baker,[27] who later expressed some doubt as to its existence, suggesting that it is in reality Tesnus thrust upon Dimple (**6**, p. 107; **14**, p. 1114). However, R. E. King and the writer have concluded, as announced in an earlier paper (**12**, p. 113), that the formation is a valid one. Further evidence in support of this conclusion is given below.

The Haymond outcrops in synclinal areas in the eastern part of the Marathon Basin, between Haymond station and Gap Tank, and probably occurs over still wider areas a short distance below the surface of the wash-mantled plain. Sandstones and shales on the axes of strongly folded anticlinoria west of Marathon are also tentatively placed in the Haymond formation. The Haymond is a succession of sandstones, with some interbedded shale, very much like the Tesnus in general character. This close resemblance, and the fact that the two formations can rarely be distinguished except by structural evidence, is largely responsible for the doubts regarding the validity of the formation. The total thickness is unknown, but 1800 feet of Haymond beds were measured beneath the Gaptank formation southeast of Gap Tank.

LOCAL FEATURES

Haymond-Gaptank Area.—The actual existence of the Haymond is demonstrated beyond all doubt by a study of the areal distribution of the rocks in the district between Haymond and Gap Tank. Although the Tesnus and Haymond sandstones and shales, which underlie the lowlands of the area are extensively mantled by wash, the Dimple limestones rise in prominent hogbacks, and are a reliable key for the determination of the structure. The writer's interpretation of the areal distribution and the geologic structure is shown in Figures 16 and 35. The most conclusive evidence for the existence of the Haymond is afforded by the small syncline 15 miles east of Marathon and one and one-half miles north of the Marathon-Sanderson highway, where Haymond shales and sandstones are seen above the Dimple along the axis of the fold. Gradational relations with the Dimple formation below are well-exposed on the northwest flank, where the basal Haymond beds are black shales.

The type area of the Haymond is in the two synclines to the east and west of Haymond station, where Baker and Bowman (**6**, p. 107) report a thickness of 500 feet of strata. An examination of the region near Haymond led the writer to the conclusion that the geology is essentially correct as originally mapped by them. The sandstones and shales are interpreted to be of a formation lying in normal sequence above the Dimple, with the Tesnus thrust into contact with it along the Haymond and Arden Draw faults. Baker now interprets the beds as representing Tesnus overthrust across Dimple and subsequently infolded.

During the summer of 1929 the writer discovered that folded overthrusts are an important structural feature in the south part of the Marathon Basin, and consequently reëxamined the two synclines near Haymond with considerable care for criteria by which to determine whether the faults in this area were folded overthrusts, or thrust faults. If the sandstones which lie along the axes of the synclines were Tesnus, they would be laterally continuous with undoubted Tesnus around the north termini of the Dimple exposures on the southeast flank of the synclines. Furthermore, the Dimple limestones would be terminated by a fault along their upper contact. On the contrary, the sandstones are not laterally continuous across the east flank of the syncline, but instead are broken on each syncline by a fault, traceable for some distance north of the terminus of the Dimple exposure, which separates sandstones of different lithology, and possessing dissimilar dip and strike.

[27]Udden, J. A., Baker, C. L., and Böse, E., Review of the Geology of Texas, Univ. Texas Bull. 44, p. 46.

Moreover, the two faults continue southward, not along the upper contact of the Dimple formation, but along its lower. From this structural evidence it may be concluded that the strata overlying the Dimple near Haymond lie in normal stratigraphic sequence above it, and are not brought to their present position by overthrusting.

At every place where the contact between the Dimple and Haymond formations was exposed in this region, the former grades up into the latter through a transition zone, with no evidence of thrusting. The Haymond beds are well exposed south of Haymond in the eastern of the two synclines. Here they consist of flaggy greenish sandstone of fine grain, in layers of a few inches in thickness, separated by thin partings of dark blue clay shale. There are a few thicker sandstone ledges, and, near the base, several layers from 10 to 30 feet in thickness of friable, coarse-grained, arkosic sandstone, containing abundant grains of feldspar, and of black and white mica. The flaggy beds are notably different from the Tesnus strata nearby, which are nearly all thick-bedded. They resemble very closely the strata underlying the Gaptank formation at its type locality.

To the north of the Haymond area, the Haymond formation is widely distributed, and it seems unlikely that the rather incompetent Tesnus strata could override the Dimple in a sheet of such proportions, and leave so little record of dynamic action. Baker[28] has suggested that some of the conglomerates at the horizon of the Dimple-Haymond transition zone may in reality be thrust breccias, but most of them are thin, and intercalated with incompetent shales and bedded cherts which show no unusual deformation. The upper transition beds of the Dimple are well exposed at the top of the Dimple Hills, in the trough of a gentle syncline, where duplication by structural complications is unlikely.

The Haymond formation is exposed south and southeast of Gap Tank on the north side of W B Flat. At a point seven miles S 60° E of the tank it is seen to overlie the Dimple formation, which is here nearly vertical (Fig. 14), but elsewhere the lower contact is obscured by wash which covers many square miles of the flat. East of the Old Clark Ranch, four and one-half miles S 70° E of Gap Tank, 1800 feet of beds were measured below the Gaptank, with the base not exposed. These consist of thick massive beds of buff, friable sandstone outcropping in prominent ridges, and of thin-bedded, flaggy brown sandstone. A 30-foot bed of chert conglomerate 400 feet below the top of the formation has been traced along an outcrop of over four miles. (Fig. 14.)

The following section was measured at this locality:

SECTION 3

		Feet
	Chaetetes limestone at base of Gaptank.	
(7)	Thin-bedded, slabby, fine-grained brown sandstone with massive, coarse-grained, cross-bedded sandstone in the lower part	400
(6)	Conglomerate grading up from very coarse sandstone at base, consisting of angular to sub-rounded pebbles and cobbles of Caballos novaculite, Maravillas chert, and fossiliferous Ordovician limestone	40
(5)	Thin-bedded, slabby sandstone, weathering rusty-brown, with a few thin layers of massive sandstone	780
(4)	Massive, coarse to medium-grained sandstone in layers 4′ to 12′ in thickness. The sandstone is rather friable, and its quartz grains are mixed with feldspar and occasional flakes of biotite. Some slabby fine-grained sandstone is interbedded	250
(3)	Blue soft shale, in part sandy, in 3′ to 6′ beds, with interbedded layers of slabby brown sandstone	30
(2)	Like number 4. Fossil wood imprints seen	170
(1)	Thin-bedded, slabby sandstone, weathering dark brown, with a few layers of soft blue shale.	240
	Center of anticline; base not exposed.	

Shales and flaggy sandstones underlie the Chaetetes limestone at the base of the Gaptank, in the center of the Gap Tank anticline, along the Marathon-Fort Stockton highway one to two miles SSW of Gap Tank. These evidently correspond to the upper beds of the preceding section. The Haymond beds are probably penetrated by the Whonlick *et al* Arnold No. 1 well, located three miles due south of Gap Tank. Although the bed rock is here concealed by wash, the well is believed to start in the upper part of the Haymond formation. The log shows a succession of sandstone and shale beds to a depth of 930 feet, below which limestone and

[28] Baker, C. L., personal communication, 1928.

sandy limestone is logged to near the bottom of the hole, at 1550 feet. It is possible that the beds logged as limestone are in reality some of the heavy sandstone ledges, such as seen in the lower part of the Haymond in the Clark Ranch section. On the other hand, they may represent the Dimple limestone.

Dugout Creek Area.—Beds probably belonging to the Haymond formation lie in the center of two anticlinoria near the base of the Permian escarpment west of Marathon. One area is three miles ENE of Lenox, and the other south of Dugout Mountain, three miles SW of Lenox. Here, the Haymond beds underlie a Chaetetes-bearing limestone which is considered to be the base of the Gaptank; they consist of flaggy, brown, fine-grained sandstone and soft greenish sandy shale. Channel markings are common on the sandstone bedding surfaces. The thickness of the exposed beds is indeterminable because of the complexity of the structure.

The Haymond beds have been penetrated by the Wilcox and Anderson, Gage No. 1 well, drilled at the south base of Dugout Mountain. The basal Gaptank limestone outcrops near the well. Black and gray shale and sandy shale are logged to a depth of 1700 feet, below which are limestone, with some sandstone and shale to the bottom of the hole, at 2100 feet. It is reported that Dr. J. W. Beede identified these lower beds as the Dimple formation on the basis of cuttings. Disregarding structural complexities, which may be of considerable importance, this would give the Haymond formation at this locality a thickness of approximately 1700 feet.

MICROSCOPIC CHARACTER

Two thin sections of the coarse sandstone of the Haymond were examined. One was from bed 2, and the other was from the base of bed 6, in section 3. (Fig. 13.) Both show a rather similar character and are quite different from the sections of the Tesnus sandstone that were examined. They consist of about 75 per cent of quartz, the remaining constituents being small chert fragments and granitic detritus.

The rock from the lower horizon consists of small rounded to subangular grains, mostly of quartz. The quartz grains are somewhat sheared and granulated, and many show strain shadows, but the rock does not show as abundant deformational features as does the Tesnus. Many of the quartz grains show small included blades of apatite. Biotite and muscovite plates are abundant, and are in places bent and twisted about the other grains. Feldspar grains are common, including both microcline with plaid twinning and sodic plagioclase. There are a few fragments of slaty rocks and of chert. The matrix is of small amount and is largely chloritic.

The rock from the higher horizon is of coarser grain and contains many large angular fragments of cryptocrystalline chert. Otherwise its constituents are much the same as in the other rock, consisting predominantly of quartz, with lesser amounts of biotite, muscovite, microcline, and sodic plagioclase. A few minute grains of colorless garnet and a single larger fragment of hornblende were noted.

The constituents of these sandstones suggest that they were derived from the weathering of granitic rocks. The apatite-bearing quartz and the microcline are characteristic of granites, and the occurrences of sodic plagioclase, biotite, and muscovite tend to sustain this conclusion, though they may also occur in metamorphic rocks. These characteristic constituents are quite different from those of the Tesnus, which contains a large amount of slaty fragments.

STRATIGRAPHIC RELATIONS

The contact of the Haymond with the Gaptank above is evidently a conformable one. The Chaetetes limestone everywhere forms the base of the Gaptank as defined in the present work and contains no basal conglomerate. Two and one-half miles SE of Gap Tank the two formations have the same dip and strike, about 25° NW, but the exact contact is not exposed. The top of the formation is best seen along the Marathon-Fort Stockton highway, one to two miles SSW of Gap Tank. A slight divergence in dip between the Chaetetes limestone and the Haymond is noted by Schuchert (**16**, p. 386) at Chaetetes Hill, but this appears to be the result of the bedding slip of competent limestone over incompetent sandy and shaly beds. The angular discordance reported by Baker (**14**, p. 1112) southeast of Gap Tank is not sustained by the writer's observations (Fig. 15), showing detailed mapping of the Gap Tank area. Not improbably it is also the result of bedding slip of competent conglomerate over incompetent shaly beds. So far as the writer has been able to observe, the Gaptank conglomerates never form the base of the formation, but first appear several hundred feet higher.

FOSSILS AND AGE

Fossils are not common in the Haymond formation. Four and one-half miles S 70° E of Gap Tank, in bed 2 of Section 3, David White and the writer have collected rather abundant plant remains. Collections probably also belonging to the Haymond formation were made on Dugout Creek south of Dugout Mountain, and near the trace of the Dugout Creek overthrust, at a locality discovered some years ago by J. W. Beede. These floras have not yet received detailed study, but Dr. White has stated tentatively that they belong to some part of the Pottsville. Schuchert reports gastropod trails in the uppermost Haymond sandstones southwest of Gap Tank.

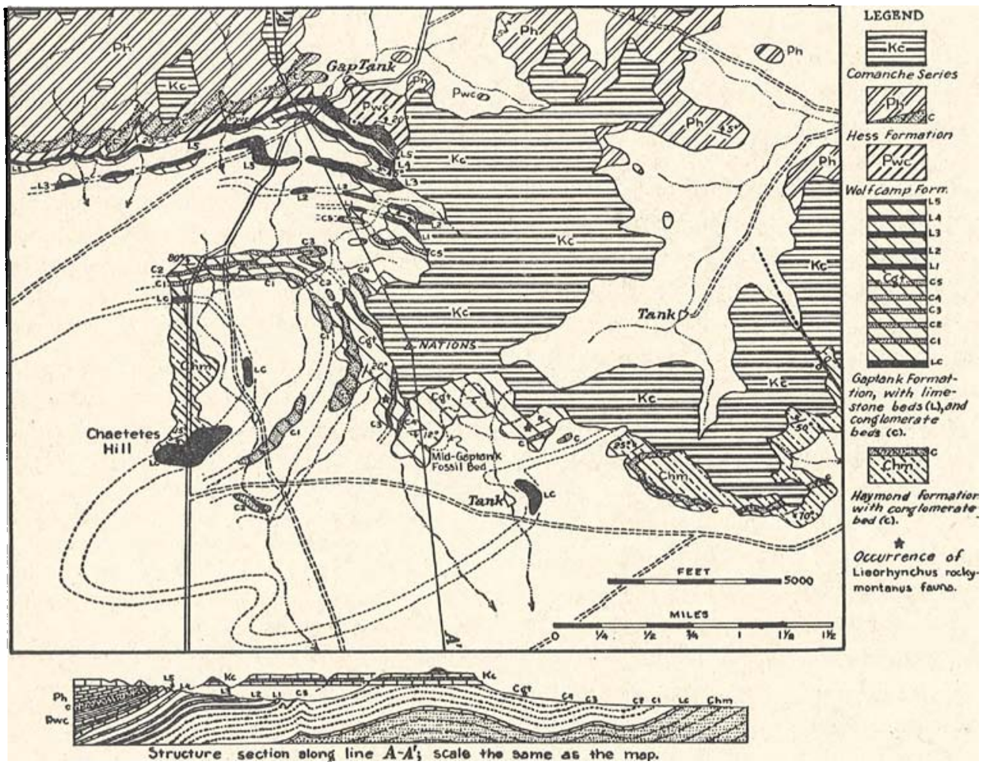
In position, character, and thickness, the Haymond has a great similarity to the Strawn group of central Texas, and the two formations are probably nearly of the same age. This conclusion is supported by the faunas of the basal Gaptank, which show that horizon to be the approximate equivalent of the upper Strawn of central Texas.*

GAPTANK FORMATION

GENERAL FEATURES

The Gaptank formation was named by Udden (**5**, p. 38) for Gap Tank, located in Stockton Gap, 23 miles northeast of Marathon. The formation outcrops only in the northern part of the Marathon Basin, while in the area to the south only the older formations remain, and the Gaptank has been removed by erosion. It is exposed in scattered areas which fringe the south foothills of the Glass Mountains, the best known locality being at Gap Tank, where a nearly complete section is exposed. From this place it extends in scattered outcrops as far as Wolf Camp. West of the town of Marathon the Gaptank formation is again exposed over an area of about 36 square miles, between the trace of the Dugout Creek overthrust on the south and the foot of the Glass Mountains on the north.

The Gaptank is the youngest Pennsylvanian formation, and the last to be involved in the Marathon



Structure section along line A-A'; scale the same as the map.

FIG. 15. Map of the Gap Tank area.

*The occurrence of boulders of large size in the Haymond formation has been described by P. B. King, C. L. Baker, and E. H. Sellards in a paper read at the Toronto meeting of the Geological Society of America, December, 1930.

disturbance. It is the only one of the Pennsylvanian system in the Marathon Basin which contains fossils in any abundance. It is somewhat more variable in character than the formations below, consisting for the most part of sandstones and shales, but with interbedded conglomerates and limestones. The conglomerate fragments are derived from the Maravillas chert, Caballos novaculite, and Dimple limestone, which are thousands of feet stratigraphically lower, and indicate the local rising folds in the Marathon geosyncline as early as mid-Gaptank time. The Gaptank environment was thus one of active diastrophism, with folds rising from the sea floor, and their erosional products distributed around them to form the conglomerates of the Gaptank formation.

LOCAL FEATURES

Gap Tank Area.—In the vicinity of Gap Tank, the formation has a measured thickness of 1800 feet. The sequence is not continuously exposed because of the extensive covering of wash, and the complete section is a composite of several partial sections within the Gap Tank area. The strata are folded into a broad east-west anticline, and beds which are covered on one flank may be found at least partially exposed on the other (Fig. 15). In this area the Gaptank formation may be conveniently divided into a lower member 1000 feet in thickness, and an upper 800 feet thick, which probably correspond respectively to the Canyon and Cisco groups of central Texas.

The lower Gaptank has at its base a limestone 50 feet in thickness, here called the Chaetetes limestone, because it is characterized by large masses of *Chaetetes milleporaceus,* which, in the center of the anticline, rests with seeming conformity on Haymond shales and thin sandstones. The main portion of the lower Gaptank consists of shales and sandstones, interbedded with five beds of coarse conglomerate from 15 to 50 feet in thickness. These conglomerates are made up of limestone, chert, and sandstone fragments reaching two feet in diameter. The limestone fragments are mostly of the lithology of the Dimple formation, but some are light gray, fossiliferous limestones, which are probably derived from beds lower down in the Gaptank. The conglomerate beds thin out northward and the lowermost of them passes into limestone on the north side of the anticline, thus implying a nearby source to the south. (Fig. 14.) At no place, as far as the writer's observations go, do these conglomerates form the base of the formation. Some of the interbedded sandstones are calcareous, and two horizons 400 and 700 feet above the base contain fossils.

The upper Gaptank is composed of five thick layers of gray limestone interbedded with sandy and shaly beds. Fossils are not abundant in the member, nor are they well preserved. A few have been collected near Gap Tank, and more in the vicinity of Wolf Camp.

The following section was measured south of Gap Tank:

SECTION 4

		Feet
	Wolfcamp formation at top of section.	
(21)	Fifth limestone; dense to coarsely crystalline light gray limestone in massive beds	75
(20)	Thin sandstone beds, interbedded with soft blue shale	60
(19)	Fourth limestone; light gray dense limestone in moderately thick beds, becoming brown and thin bedded to the west, where it contains some fossils	40
(18)	Mostly covered; some soft brown sandstone seen	124
(17)	Third limestone; light gray dense limestone in moderately thick beds, with abundant fossils in cross section	40
(16)	Mostly covered; buff, cross-bedded, medium-grained sandstone in upper part	230
(15)	Second limestone; light gray massive limestone	55
(14)	Sandstone and shale	124
(13)	First limestone; light gray, finely crystalline limestone in moderately thick beds. Contains *Triticites* cf. *moorei,* crinoid stems, and other fossils	40
(12)	Soft buff sandstone, in part calcareous, and some gray limestone near the middle	193
(11)	Fifth conglomerate; much like those below in general character	15
(10)	Covered on north side of anticline. On south it consists of brown sandstone with richly fossiliferous calcareous layers. There are some thick beds of soft blue shale at the south. This is the "lower Gaptank" fossil horizon of Udden, Böse, and Beede. The fauna includes: *Schistoceras hyatti, Triticites irregularis, Paraenteletes cooperi, Teguliferina armata,* and many other forms	140
(9)	Fourth conglomerate; like those below	15
(8)	Fine-grained buff sandstone, forming prominent ledges, cross-bedded in parts	97
(7)	Third conglomerate; like those below, but of lenticular character	25

	Feet
(6) Fine-grained buff sandstone, passing southward into a greater thickness of shale. This contains a nodular ferruginous limestone, with *Leiorhynchus rockymontanus*	80-290
(5) Second conglomerate; like first, with thin layers of sandy buff limestone	40
(4) Sandstone and shale	80
(3) First conglomerate; composed of subangular to rounded cobbles and boulders of limestone, chert, and sandstone. Most of the limestone has the lithology of the Dimple limestone, but some fossiliferous fragments may have been derived from beds lower down in the Gaptank. The matrix is a sandy limestone. Thin limestone beds appear at the base toward the north, and on the north flank the conglomerate is absent. The limestone contains *Chaetetes* and *Chonetes mesolobus*	40
(2) Shales and sandstones	150
(1) Chaetetes limestone. Dark gray, crystalline, containing large masses of *Chaetetes milleporaceus*, cup corals, brachiopods, and *Fusulinella haworthi*	50
Haymond thin-bedded sandstone below.	

Wolf Camp Area.—Southwest of Gap Tank the formation is found in scattered exposures as far as Wolf Camp, though it doubtless underlies wide areas of the wash-mantled plain near the Glass Mountains in this region. The correlation of these various exposures is problematical though they probably all belong to the upper Gaptank. In the Wolf Camp hills, 400 feet of beds are exposed (Section 25, Plate VIII), consisting mostly of blue-gray shale, with several gray limestone beds at the top, which contain *Triticites cullomensis.* The downward continuation of the shale is penetrated by several water wells in the plain south of the escarpment.

Dugout Creek Area (Dugout Beds of Baker).—West of Marathon the Gaptank formation has been overridden along the Dugout Creek overthrust by a great mass of pre-Carboniferous rocks; it is now exposed only as the result of the erosion of the overthrust sheet. The incompetent Gaptank strata beneath the thrust are intensely deformed by minor folds and thrusts (Fig. 13). This structural complexity, coupled with the scattered nature of the exposures, makes a complete section of the formation in the area impossible, though fossil collections from various localities indicate that the rocks are of the same age as those of the type section. It is estimated that about 1500 feet of beds are present.

The oldest rocks exposed below the Dugout Creek overthrust are the shales and sandstones of two anticlinoria near the base of the Permian escarpment, which are referred to the Haymond. These are overlain by a gray granular limestone attaining 20 feet in thickness, containing *Chaetetes milleporaceus* and *Fusulinella meeki.* It is considered to be the equivalent of the Chaetetes limestone forming the base of the Gaptank in the type section. The limestone is always more coarsely granular near the base, in places even conglomeratic, and it passes upward into fine-grained sandy limestone. This constant characteristic is of great value in structural work, for the beds are in many places overturned. Above the basal limestone are alternating sandstones and shales, with one, and perhaps two, thin beds of gray limestone.

The highest beds are exposed four and a half miles S. 15° E. of Lenox, where they are overlain with overthrust contact by Caballos novaculite and four miles west of Marathon at Milepost 580 on the Southern Pacific Railway. At the first locality there are several beds of limestone, one of which is crowded with ammonoids of a new fauna. At the second place, one-foot to five-foot ledges of sandy limestone crowded with angular chert pebbles are interbedded with shales and thin sandstones. The conglomeratic limestones contain *Triticites secalicus, Schistoceras hyatti,* and other fossils of Cisco age.

In the summer of 1929 the writer found an exposure of Gaptank on a hill slope one mile south-southeast of the ammonoid locality. At this place Gaptank shales, with thin sandy limestones outcrop on the lower part of the hill, and are surmounted by middle Ordovician limestone, from which they are separated by a thin thrust breccia. The thin Gaptank limestones contain *Triticites cullomensis,* a form characteristic of the Cisco of central Texas.

The beds here called Gaptank were originally described by Baker and Bowman (**6**, pp. 103–105) as Tesnus, but in a more recent publication Baker (**14**, pp. 1113–1114) suggests them to be either a marine fossiliferous facies of one of the pre-Gaptank Carboniferous formations to the southeast, or to represent the Strawn group. He therefore proposes for them the name Dugout beds. The Gaptank age of the strata was originally announced by Schuchert (**11**, pp. 386–387) and restated by

R. E. King and the writer (**12**, p. 117). Baker states: "The grouping of the strata west of the town of Marathon with the Gaptank seems to be based on the facts that both [the beds here and at Gap Tank] are marine and have in common several long-ranging Pennsylvanian fossils. Lithologically the strata of the two localities show more differences than resemblances" (p. 1113).

The strata west of Marathon, however, do contain diagnostic fossils of which the fusulinids and ammonoids are most important. These indicate a Canyon and Cisco age for the Dugout beds. The Strawn fauna of central Texas is impoverished and of slight value for correlation. A more fossiliferous facies of the Strawn is found in the Hueco Mountains, where the group is represented by a limestone 1000 feet thick. The fauna is distinctive, and wholly unlike that of the Dugout beds. Moreover, it is overlain by rocks of Canyon and Cisco age, with *Fusulinella meeki* at the base, which also occurs in the basal Gaptank of the Dugout area. While it is perfectly true that a fossiliferous facies of any one of the pre-Gaptank Carboniferous formations might be expected in the northwest part of the Marathon Basin, yet within the writer's experience, the only abundantly fossiliferous formation of this system in the region is the Gaptank, and the abundance of fossils in any exposure is nearly always suggestive of its Gaptank age.

It has also been suggested that both the Gaptank and a pre-Gaptank fossiliferous formation are present here, separated by an unconformity, but the writer has seen no evidence of this. All of the beds of the Dugout Creek area are deformed with equal intensity, including the Cisco beds at milepost 580 and the ammonoid locality, the latter being directly overlain by overthrust pre-Carboniferous strata.

The differences in lithology between the type Gaptank and the Dugout beds is to be explained by the fact that movements inaugurating the Caballos disturbance had already begun in mid-Gaptank time, but that these early phases were essentially local, so that the conglomerates at Gap Tank are of Canyon age, while those west of Marathon are somewhat younger, and of different composition.

Black Peak.—The Gaptank formation is also exposed on Black Peak, on the north side of Doubtful Canyon, in the Del Norte Mountains, southwest of the Dugout Creek area. The rocks here are evidently genetically related to those along Dugout Creek, and have been brought to their present height by a post-Cretaceous thrust fault (Fig. 41).

A much-sheared, gray crystalline limestone bed, several hundred feet in thickness forms the main mass of the peak, and dips 70° E. It is overlain and underlain by thin-bedded limestone, shale, and some sandstone. Overlying it, but separated by shales, is a 50-foot bed of dark gray limestone containing fossils.

FAUNAS AND CORRELATION OF THE GAPTANK FORMATION[29]

The Gaptank formation contains abundant fossils at several levels, both near Gap Tank, and west of Marathon. The Gaptank faunas are now fairly well known, and fossil lists have been published by a number of workers.[30]

The basal member of the formation near Gap Tank, the Chaetetes limestone (bed 1 of the section), is so called because of the sporadically abundant occurrence in it of *Chaetetes milleporaceus,* an early Pennsylvanian coral ranging as high as the Brownwood shale at the base of the Canyon in central Texas, and occurring in the northern mid-continent region in the Fort Scott and Pawnee limestones in the middle of the Des Moines group. At Chaetetes Hill, two miles SSW of Gap Tank, this limestone member contains *Fusulinella haworthi,*[31] which Dunbar and Condra[32] have found to range from the Fort Scott to Altamont limestones in the northern mid-continent. South of Dugout Mountain, the basal Gaptank limestone contains *Chaetetes* rather rarely, but associated with abundant *Fusulinella meeki,* characteristic of the Cherokee shale in the northern mid-continent area. With this species, it is somewhat surprising to find an undescribed species of *Triticites* with extremely thick walls.

The next fossiliferous layer in the section near Gap Tank is a limestone bed which appears at the base of the First Conglomerate (bed 3) on the north flank of the Gap Tank anticline, where Schuchert (**11**, p. 386) reports, among other forms,

[29]Unless otherwise stated, the fossil identifications in this section were made by Robert E. King.

[30]See Bibliography **6**, pp. 104-105; **7**, pp. 21-22; **9**, p. 175; **11**, pp. 385-388; **12**, pp. 118-119.

[31]These and other fusulinids of the Gaptank and Wolfcamp, have been identified by Dr. C. O. Dunbar.

[32]Dunbar, C. O., and Condra, G. E., The Fusulinidae of the Pennsylvanian System in Nebraska, Nebraska Geological Survey, Bull. II, Second series, table facing p. 130, 1927.

Chaetetes and *Chonetes mesolobus*. Still higher in the section, in the shales of bed 6 at two localities two miles south and SSE of Gap Tank, is a nodular ferruginous limestone which yielded the following:

Leda bellistriata
Nuculopsis ventricosus
Worthenia tabulata
Trepospira depressa
Euphemus carbonaria
Pharkidonotus percarinatus
Striatifera sp.
Lieorhynchus rockymontanus

Micro-fossils identified from this horizon by Harlton are stated by him to be typical Canyon forms.

The most prolific fossil horizon, 700 feet above the base of the formation (bed 10), is best exposed on the south side of the Gap Tank anticline two miles south and southeast of Gap Tank. Collections were made from this bed by Udden and his associates from a small knoll south of the southwest angle of the Comanchean mesa south of Gap Tank. Those of the writer and his brother were made somewhat farther east, at the base of the talus slope of the mesa. This fossil zone has been referred to as "lower Gaptank" by Udden (**5**, pp. 38-39; **7**, p. 21) and "upper Gaptank" by Schuchert (**11**, p. 388). The following forms have been identified from our collection:

Triticites irregularis (abundant)
Corals
Wewokella solida
Heterocoelia beedei
Delocrinus sp., and abundant crinoid stems
Platyceras sp. (very abundant)
Trepospira sp.
Worthenia sp.
Orthoceras sp.
Schistoceras smithi (syn. *hyatti)*
Parenteletes cooperi (not *Enteletes hemiplicatus* or *E. waageni)*
Meekella striaticostata
Rhipidomella carbonaria
Isogramma millepunctata
Derbya crassa
Marginifera wabashensis
M. splendens
Productus semireticulatus
P. magnicostatus
Linoproductus cora
Pustula semipunctata
Teguliferina armata
Rhynchopora illinoisensis
Spirifer triplicatus
Punctospirifer kentuckyensis
Squamularia perplexa
Dielasma bovidens
Composita subtilita

Most of these forms are long-ranging, and of little significance, but on the whole the fauna has its most decided resemblance to that of the Wewoka of Oklahoma.

Near Gap Tank, fossils are uncommon at higher levels in the formation, and, with the exception of the fusulinids, those which occur are of little stratigraphic value. From the First limestone (bed 13), specimens of a small *Triticites* were collected, which, though rather too greatly silicified for careful identification, strongly resemble *Triticites moorei*, which occurs in the Wayland shale of the lower Cisco. The Fourth limestone (bed 19) contains fossils in some interbedded marls one-fourth mile west of Gap Tank; here the following forms have been identified:

Heterocoelia beedei
Spirifer triplicatus
Composita subtilita
Rhipidomella carbonaria

Beds probably of upper Gaptank age underlying the Wolfcamp at Wolf Camp contain, among other fossils:

Triticites cullomensis (near top)
Cladopora sp.
Echinocrinus spines and plates
Platyceras sp.
Derbya benneti

Micro-fossils collected at this place are stated by Harlton[33] to "suggest Dimple and not Gaptank," but the evidence of the other fossils in no wise supports this conclusion.

The fauna of the basal fossiliferous limestone of the Gaptank west of Marathon has already been referred to. Fossils are also found at several higher levels, the best known locality being near Milepost 580, on the Southern Pacific Railway four miles west of Marathon. One-half mile west of the milepost, and south of the railway, Schuchert[34] collected the following:

Amblysiphonella, sp.
Marginifera splendens
Composita subtilita
Reticularia perplexa
Schistoceras smithi (syn. *hyatti)*

[33]Harlton, B. H., Pennsylvanian Ostracods from Oklahoma and Texas, Jour. Pal., Vol. 2, p. 135, 1928.

[34]Schuchert, 11, p. 387. Schuchert also gives lists of fossils collected at several other localities nearby.

From this same layer, C. O. Dunbar has identified *Triticites secalicus,* which ranges from the lower Kansas City to the upper Douglas formations in the mid-continent area.

Fossils are also found four and one-half miles S 15° E of Lenox, near the trace of the Dugout Creek overthrust, in several limestone layers. One lenticular mass is crowded with ammonoids of a new fauna which is being described by Arthur K. Miller in a forthcoming issue of the Journal of Paleontology.* The fauna includes eleven species, many of which are new, and a new genus, *Proud-denites,* intermediate between *Pronorites* and *Uddenites.* A single specimen of *Uddenites* has also been collected, but on the whole, according to Mr. Miller, the fauna "is distinctly older (though not markedly so) than the zone of *Uddenites*" in the Wolfcamp formation.

A mile to the south of this place, and directly overlain with overthrust contact by Ordovician strata, *Triticites cullomensis* is found in thin calcareous layers intercalated in the Gaptank shales. This same species is also found in the highest layers of the Gaptank formation at Wolf Camp.

Correlation of the Gaptank Formation.—From the evidence presented above it is concluded that the Gaptank formation is to be correlated in part with the Canyon group of Central Texas, but with its lower portion extending down into the Strawn, and its upper extending into the Cisco.

A Strawn age for the lower part of the lower Gaptank is indicated by the two fusulinellids, *F. meeki* and *F. haworthi,* which are characteristic of the Strawn, but which have never been found in the Canyon group; this is confirmed by their association with *Chaetetes milleporaceus* whose highest known occurrence is in the lowest Canyon, but which appears to have had its greatest development somewhat lower in the section. A little higher up, *Chonetes mesolobus* is found, and not far above it, *Leiorhynchus rockymontanus.* This *Chonetes* has never been found in the Canyon; while only a single occurrence of the *Leiorhynchus* has been reported from the latter group, and it is known in the northern mid-continent area to have its most typical development somewhat lower than the Canyon equivalents. The Gaptank strata below the *L. rockymontanus* horizon are therefore correlated with the upper portion of the Strawn group of Central Texas, and with the Marathon formation of the northern mid-continent area.

The upper part of the Lower Gaptank is probably of Canyon age. The fauna of bed 10 appears to be a typical Canyon assemblage, since it contains, for example, the characteristic Canyon fusulinid, *Triticites irregularis,* so abundant in the Adams Branch limestone. This part of the Gaptank is probably correlative also with the Kansas City formation of the northern mid-continent area.

The Gaptank above bed 12 of the type section, called the "Upper Gaptank" because of its lithologic differences from the beds below, contains few distinctive fossils, other than fusulinids. Dunbar states that these indicate a Cisco age for the member, since *Triticites moorei* occurs near the base of the division and *Triticites cullomensis* near the top. Near Gap Tank and Wolf Camp there is no evidence of the presence of beds equivalent to the Wabaunsee stage of the mid-continent section.

The higher beds west of Marathon are also of Cisco age for they contain *Triticites secalicus* and *T. cullomensis,* which characterize the middle part of the Cisco group of central Texas, and the middle of the Missouri farther north. The ammonoid fauna from these beds is also Cisco, and from its stage of evolutionary development appears to be younger than the lower Cisco ammonoid fauna of central Texas.

The faunal evidence, particularly that of the fusulinids, indicates that the uppermost Pennsylvanian is absent from the Marathon region, a span of time occupying at least the Wabaunsee stage of the mid-continent section. The faunal and structural evidence thus agree that there is a considerable period of non-deposition, and probably of emergence and erosion as well, following Gaptank time, an epoch probably of upper Cisco age. This period of non-deposition probably corresponds to the culminating phases of the Marathon disturbance.*

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*Miller, A. K., A New Ammonoid Fauna of Late Paleozoic Age from Western Texas. Jour. Pal., 4:383-412, pls. 38-39, 1930.

*It will be perceived that the correlations advanced above are somewhat at variance with those previously made by the writer and his brother, and by others who have written on the correlation of the formation. By the previously accepted correlation, the Gaptank was made to correspond with the Canyon and part of the Cisco of Central Texas, and with the Marmaton to Shawnee formations of the northern mid-continent area. Recent work, notably that of Raymond C. Moore, has, however, shown that the Missouri group is to be correlated, not with the Cisco alone, but with the Canyon and the Cisco. The correlation of the Gaptank formation with the northern mid-continent area has never been in question, but the recent changes in the correlation of the Central Texas section with the northern mid-continent have necessitated an alteration in the correlation of the Gaptank with the nearer area. This revision of the correlation has been made with the suggestions and advice of C. O. Dunbar.

STRATIGRAPHIC RELATIONS

It was the conclusion of Udden, Baker and Bowman (**5**, p. 41; **6**, pp. 107–112) that the major orogeny which disturbed the Marathon Basin was older than the Gaptank, a conclusion more recently restated by Baker (**14**, pp. 1111–1114). On the contrary, other writers, including the author of this paper, have concluded that the disturbance was in reality post-Gaptank and pre-Wolfcamp (**11**, pp. 388–390; **9**, pp. 212–221; **12**, pp. 120–122).

The age of the Marathon disturbance is more fully discussed in the structural chapter, where it is shown to be divisible into three distinct phases: a period of folding beginning early in the Gaptank, and culminating at the end of Gaptank time, a period of overthrusting which came at the close of the Gaptank, and a final period of warping which gently deformed both folds and overthrusts. The succeeding Wolfcamp formation extends unconformably across all these structures. At the west end of the Glass Mountains it rests upon an area of upwarping, so greatly denuded that the pre-Carboniferous rocks of the Dugout Creek overthrust sheet have been partially stripped away, laying bare the deformed and overridden Gaptank formation. At the east end it rests on an area of downwarping, in whose deeper parts the Gaptank is preserved.

The character of the unconformity at various localities is shown on the accompanying map. (Fig. 20.) In the western part of the mountains the unconformity is clearly shown at many places. It is perhaps best developed on the south side of Dugout Mountain, two and a half miles S 40° W of Lenox, where fossiliferous upper Wolfcamp, with 350 feet of coarse basal conglomerate, rests nearly horizontally on fossiliferous Dugout beds, which are overturned and now dip 35° south. These beds have already been shown to belong to the Gaptank formation and not to be older. The rocks forming the lower slopes of Dugout Mountain are basal Gaptank, but not far to the south, still higher strata are involved in the folding, and four and a half miles S 15° E of Lenox, ammonoids of Cisco age were collected from directly beneath the Dugout Creek overthrust.

In the eastern part of the mountains the relations are less clear. The base of the Wolfcamp in this region is the Uddenites member of the Permian, which is older than any fossiliferous beds of this system in the western part of the mountains. In the region of Gap Tank and Wolf Camp this member rests on the Gaptank beds with equal dip and strike. Keyte, Blanchard, and Baldwin (**9**, pp. 212–221) have contended that the Uddenites member is in reality a part of the Gaptank formation, but the unconformity suggested by their sections (**9**, pl. XXXI) is not supported by the observations of the writer, as shown in the accompanying sections (Pl. VIII). Moreover, Smith's[34a] studies have shown that the affinities of the ammonoid fauna are decidedly with the Permian rather than with the Pennsylvanian.

Despite the apparent conformity at Gap Tank and Wolf Camp, the Uddenites member of the Permian appears to rest directly on the Tesnus of the oldest Carboniferous at the east end of Leonard Mountain (though the relations are obscured by talus). Again, at a locality three and a half miles ESE of Gap Tank, the Permian (but not certainly the Wolfcamp) rests directly on the Haymond formation, with the intervening Gaptank missing. At Wolf Camp itself, the Uddenites member thins and thickens irregularly above the uppermost Gaptank limestone, as though it were deposited on the warped irregular surface of the older formation (Section accompanying Fig. 19).

Southward from Gap Tank the folding of the Gaptank formation increases in complexity and passes without apparent interruption into still more strongly deformed Haymond beds to the southeast. It is thought that the northward disappearance of strong folding may be accounted for by the assumption that the folding began earlier in the southern part of the basin and progressed northward, and that the Gap Tank area was involved only in the closing stages of the deformation (Fig. 39). Some explanation of this sort is clearly necessary in view of the conclusive nature of the post-Gaptank age of the disturbance west of Marathon.

CARBONIFEROUS HISTORY

During the early part of Carboniferous time there was no deposition in the Marathon geosyncline and the pre-Carboniferous rocks were probably subjected to erosion. Near the close of Mississippian time, however, the seas again entered western Texas, certainly in the Hueco Mountain area, and perhaps in the Marathon region, and at the

[34a]Smith, J. P., The Transitional Permian Ammonoid Fauna of Texas, Amer. Jour. Sci. (5), Vol. XVII, pp. 63–64, 1929.

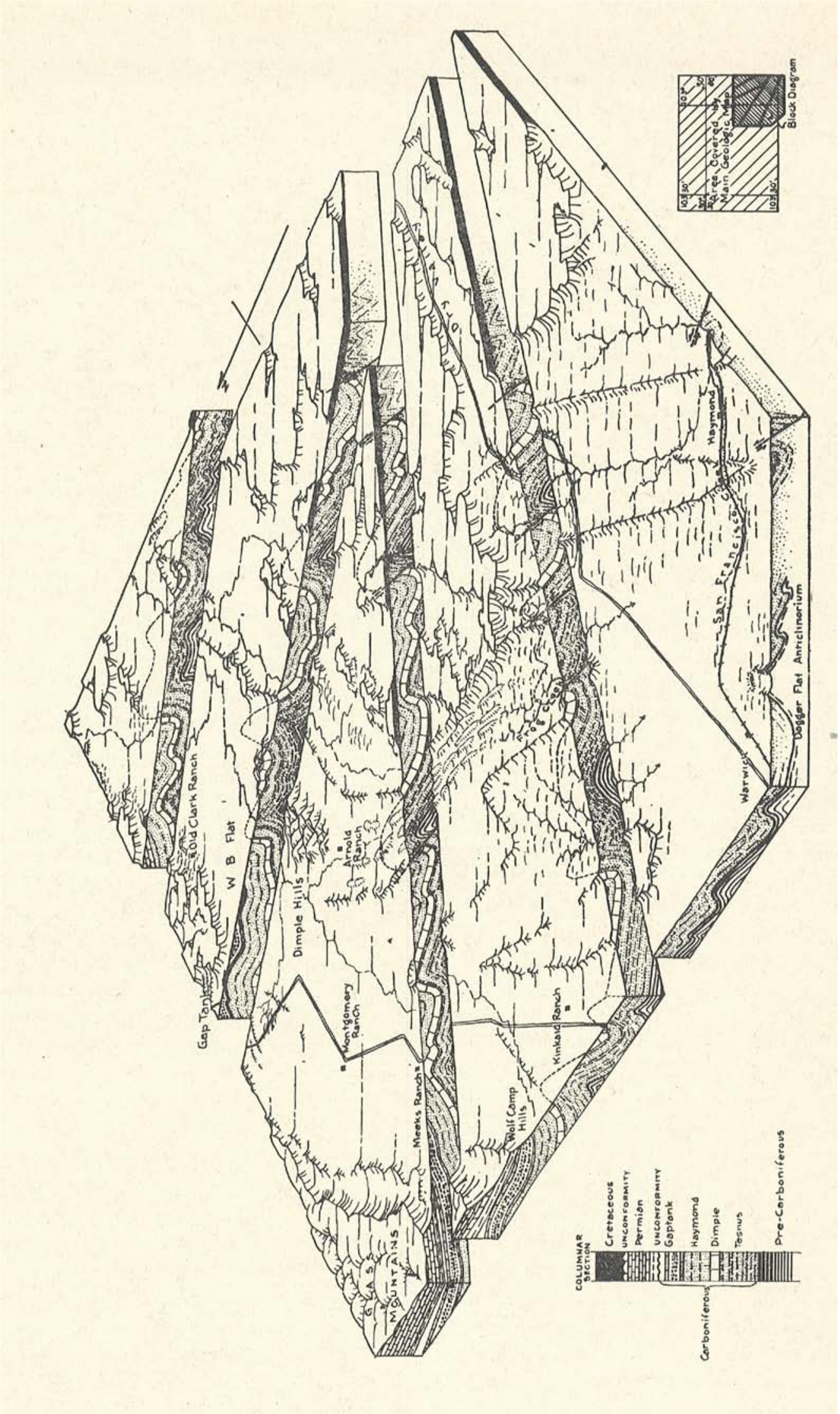

FIG. 16. Block diagram of the Haymond-Gaptank area, as viewed from the southwest. Shows Carboniferous stratigraphy and structure, the relation of the Carboniferous to the Permian (on the left), and its physiographic expression.

same time there was a marked uplift of Llanoris to the southeast, causing a vast amount of clastic material to be eroded from the old land, and to be deposited during Tesnus time in the geosyncline occupying the present site of the Marathon region. In this uplift, the earlier Paleozoic rocks were involved to a certain extent, for chert grains and pebbles are found in the Tesnus, Dimple, and Haymond rocks, but for the most part the sediments were derived from the erosion of igneous and metamorphic rocks, including granites, slates, and phyllites.

The Tesnus deposits were probably deltaic, but the proportion of marine to non-marine deposits is not known. The regularity of the bedding and the occurrence of foraminifers in some of the shales suggest a marine environment. These deposits overlapped northwestward over a warped surface of Caballos chert and novaculite, with the seas appearing first in the southeast, and then spreading more widely until during the latter part of Tesnus time they had covered the whole of the region. At the same time, subsidence was probably taking place most rapidly in the southeastern part of what is now the Marathon Basin.

A pause in the erosion of Llanoris is indicated by the thick, widespread limestones of the Dimple formation, but vigorous erosion was resumed again during Haymond time. The source of these sediments and the environment of their deposition were probably nearly identical to those of Tesnus time, for the character of the two formations is very similar.

In the latter part of Haymond time, some of the unrest which had previously manifested itself only in the hinterland began to be transmitted to the geosyncline itself. At certain places in the geosyncline, probably near the hinterland, folds rose to sufficient height to lay bare the early Paleozoic strata to forces of erosion. This is manifested by the widespread occurrence in the highest Haymond of a thin layer of chert conglomerate. These movements, however, could not have been of very great intensity, and were only a preliminary warning of what was to follow. Gaptank time began quietly with the spreading out of a wide sheet of coralline limestone, but early in the Gaptank, though some time after its commencement, folding commenced again in the geosyncline. The crests of anticlines rose above the sea. The axes of the folds south of Gap Tank had risen several thousand feet by mid-lower Gaptank time, and had contributed boulders of Dimple limestone to the sediments of the region. The folding evidently advanced progressively northwestward for it was not until early upper Gaptank time that the folds had risen sufficiently in the extreme northwest part of the present Marathon Basin to contribute any sediments to the seas of that area; these sediments consist of fragments of Caballos novaculite and Maravillas chert. The finer clastics of the Gaptank may have been largely reworked erosional products of the Tesnus and Haymond shales and sandstones. The folding during the early phases of the disturbance was essentially local, as shown by the variability in character of the Gaptank deposits in various parts of the basin.

The end of Gaptank time, but long before the close of the Pennsylvanian, was marked by the culmination of the Marathon disturbance. Now the folds were tightly compressed, were broken into thrusts, and in places were driven forward many miles in overthrust sheets. The seas were finally driven from the area, the land uplifted, and the folds gently warped before early Permian time, when the waters again returned, spreading over what was now a greatly denuded, folded region.

PERMIAN SYSTEM

GENERAL CHARACTER OF THE PERMIAN ROCKS

Permian rocks make up the bulk of the Glass Mountains, and flank the Marathon Basin on the northwest in southeast facing cuestas. The formations are tilted away from the underlying strongly deformed rocks, so that the upturned edges of the entire sequence are exposed in the twelve-mile width of the range. The most striking feature of the Permian stratigraphy in the mountains is the great lateral variation in the thickness and lithology of the strata from northeast to southwest along the range. Some of the changes are clearly the result of disconformities, either by erosion of pre-existing beds or by overlap of the succeeding beds upon an upraised land mass. Other beds vary by rapid changes from one type of deposit to another, and by peculiar changes in thickness, which the different members of the formation appear to share equally. The result of these variations is to make the successions in the eastern and western parts of the mountains almost totally unlike.

These changes are presented in detail in Plates II, III, and IX showing correlations of vertical sections, and in Figure 17, a stratigraphic diagram interpreting the observations made on the stratigraphy. Unfortunately, our knowledge of Glass Mountains stratigraphy must be in two dimensions only, since each formation is exposed only along a narrow outcropping belt, a condition which may perhaps be remedied in the future, if deep wells are drilled in the vicinity of the mountains.

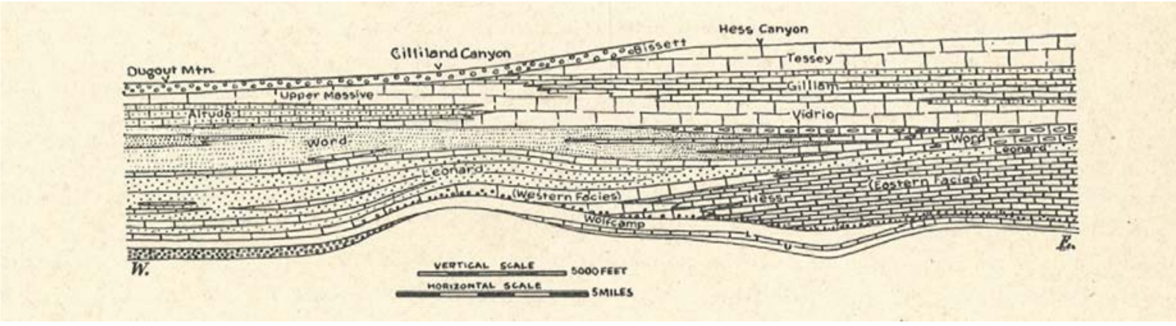

FIG. 17. Stratigraphic diagram to show variations in the Permian rocks of the Glass Mountains along the strike of the range.

The changes in thickness of the formations appear to be closely related to structural trend lines in the mountains, so that, while deposition was going on, subsidence was less active in some areas than others, and thus the more stable areas received less deposit. The ramifications of this problem cannot, unfortunately, be entered into, because our knowledge of the stratigraphy is essentially two dimensional.

It will be noted in the discussion which follows that only incidental reference is made to fossils, and that their significance and zonation is not discussed. This subject is reserved for a companion volume by R. E. King dealing with the faunas and their stratigraphic significance. To this the reader is referred for further information.

The writer has followed Udden's method of studying the formations by the measurement of vertical sections and has supplemented the work as far as possible by tracing out horizons between the sections. About 23 sections were measured in all, of which three embrace the entire Permian column and ten of them showing all the beds below the base of the equivalents of the Capitan. (Fig. 12.) Representative sections are included in the text, and all have been utilized in plotting the vertical section plates.

During the measurement of these sections, specimens of the rocks were collected. It was hoped that a detailed petrographic study of these could be made, but the magnitude of this report has rendered this impossible. It is to be hoped that more work will be done on this aspect of the matter in the future. The writer has contented himself with a study of the microscopic character of the siliceous shales, a large part of which have proven to be radiolarites, and of the sandstones. Udden has studied some of the limestones and has described them in his "Notes on the Geology of the Glass Mountains."

WOLFCAMP FORMATION

HISTORICAL SUMMARY

The Wolfcamp is the oldest Permian formation in the Marathon region, and on paleontological evidence appears to lie very near the actual base of the Permian, including faunas "older and more primitive than any Permian previously known and distinctly younger and more specialized than any known Coal Measures fauna" (**15**, pp. 63–80). As is to be expected of such border-line faunas, they have been the subject of controversy, and for this reason an historical summary is here given.

When the first surveys were made in the region, the unconformity at the base of the Hess was considered to mark the local base of the Permian, and the underlying shales and limestones were placed in the Pennsylvanian. However, "Udden observed in an unnamed place which we afterwards used to call the Wolf Camp . . . that there were certain strata below the unconformity . . ., which contained fossils similar to those of the Word formation. . . . Near Wolf Camp also Udden found a few small cephalopods, apparently belonging to new species" (**7**, pp. 15–16). After an examination of the ammonoid collections, Böse came to the conclusion that there were two formations below the unconformity, one Pennsylvanian, and the other Permian. The latter was named the Wolfcamp formation (**7**, p. 16; **5**, pp. 41–42).

The type locality of the formation is in the foothills of the Glass Mountains north of Wolf Camp, on the present Taylor Ranch, 12 miles northeast of Marathon. Wolf Camp is "the site of an old dwelling place, just to the south of two buttes . . . , and is marked by an old open well some hundred feet deep"[35] (Fig. 18).

The Permian age of the beds above the Uddenites member was ably sustained by Beede's[36] studies of their fusulinid fauna. However, Keyte, Blanchard and Baldwin (**9**, pp. 175–178) concluded that the Uddenites member was of Gaptank age, and that the boundary between the Pennsylvanian and the Permian lay somewhat higher in the section. This conclusion was reached because of the well-recognized Pennsylvanian aspect of most of the fossils associated with the ammonoids, and because of an unconformity believed by them to occur

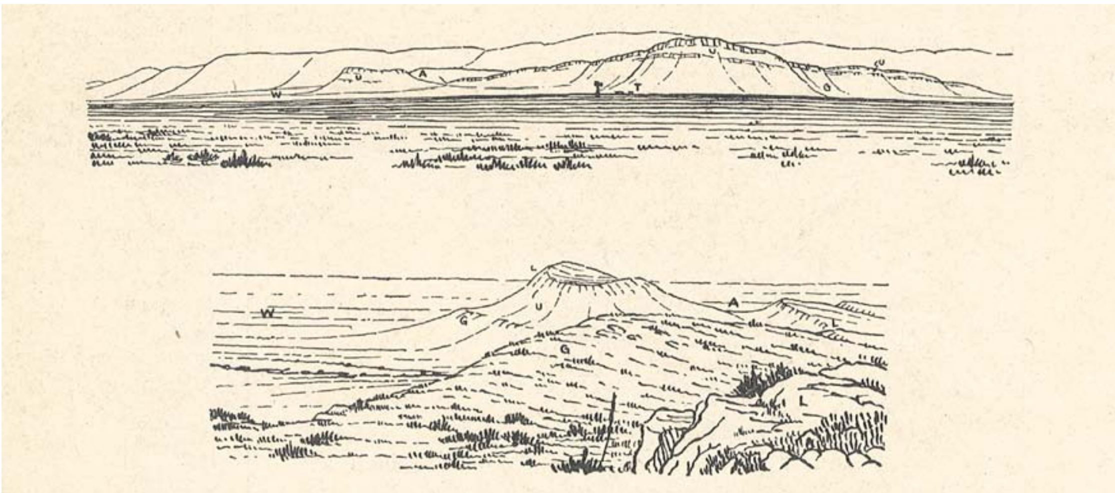

FIG. 18. Two views of the Wolf Camp Hills. *Upper.* From a point one and one-half miles to the south looking north. *Lower.* Looking southwest toward Wolf Camp from a point on the crest of the escarpment above the windmill in the first figure. W—Wolf Camp; T—Taylor Ranch; A—Böse's ammonoid locality; G—Gaptank formation; U—Uddenites member of Wolfcamp formation; L—Gray limestone member of Wolfcamp formation.

The geologic section at Wolf Camp was shown by Udden to consist of shales and limestones of Pennsylvanian age below, succeeded by 100 feet of shale containing the ammonoids described as the *Uddenites* fauna by Böse. These were succeeded by a thick-bedded limestone, above which were some hundreds of feet of shales and thin limestones, capped by the basal Hess conglomerate. Though Udden's intention would seem to be to place the ammonoid zone in the Permian, yet in his section 7 he states that the base of the Wolfcamp formation lies at the base of bed 10, or above the lowest occurrence of ammonoids (p. 34). Apparently this statement is either a typographical error, or represented the expression of an earlier idea left unchanged in final manuscript.

above the Uddenites member, so that five miles northeast of Wolfcamp the zone of *Uddenites* is "over 400 feet below the top of the Gaptank" (p. 176).

Contrary to this interpretation, R. E. King and the writer are convinced of the Permian age of the Uddenites member (**12**, pp. 123–126). The evidence will be set forth below, and in the accompanying paleontological report by R. E. King. Moreover, after a careful review of the ammonoid fauna, J. P. Smith (**15**, pp. 63–65) has concluded that its character is definitely Permian.

GENERAL FEATURES

The formation was believed by Udden to have a restricted distribution, but the present investigation has shown that the Wolfcamp beds are present along almost the whole of the Glass Mountains escarpment, although they are in places mantled

[35]Udden, **5**, p. 42. The old site of Wolf Camp is not shown on the topographic sheet, though the old well still exists. In order to perpetuate the name, the writer has suggested to the United States Geological Survey Board of Geologic Names that the foothills to the north of Wolf Camp be called the Wolf Camp Hills. He has been assured that this name will appear on the next edition of the sheet.

[36]Beede, J. W., Species of the Genus Schwagerina, Univ. Texas Bull. 2433, pp. 54–55, 1924.

by wash, as between Wolf Camp and Leonard Mountain. Near their type locality, they consist in a large part of green or blue clay shales, with rather abundant thin fossiliferous limestone beds, but to the southwest, where the formation encroaches upon the strongly-folded rocks, it becomes coarsely clastic, with several hundred feet of basal conglomerate followed by sandy shales with sparse fossils.

largely of blue and green clay shales, with thin layers of limestone. This part of the formation contains unmistakable Permian fossils, including *Schwagerina*, which first appears at the base of the member.

There is no easily discerned break at the base of the Permian in the Wolf Camp Hills, though at their western end, near the point where the ammonoids were collected, the Uddenites member is

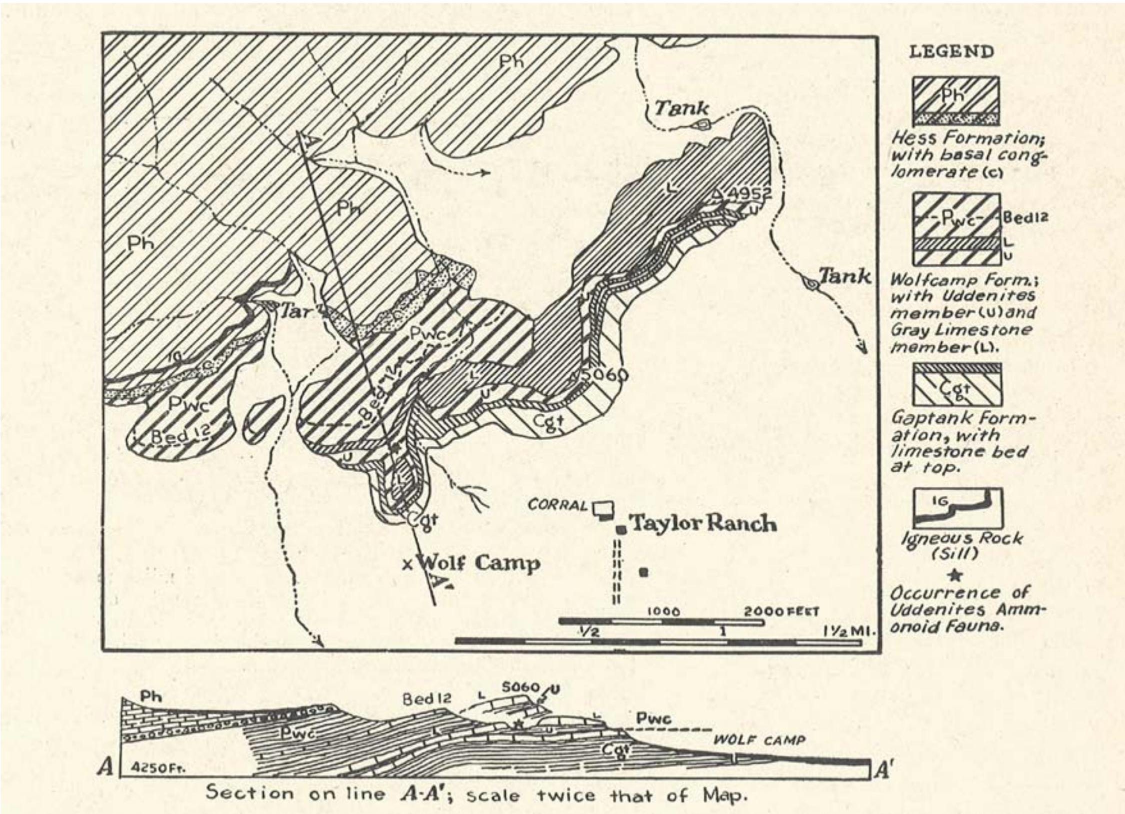

FIG. 19. Map of the Wolf Camp area.

LOCAL FEATURES

Wolf Camp—Gap Tank Area.—At its type locality the beds placed by us in the Wolfcamp formation have a thickness of 700 feet.[37] For convenience of reference, and for units of mapping, the formation is divided into three members. The lower, or Uddenites member, is a shale, with a few thin limestone beds, and it varies in thickness up to 100 feet. It contains the *Uddenites* fauna. This is followed by the Gray Limestone member, a rather thick-bedded, scarp-forming limestone about 50 feet thick, containing only a few fossils. The upper member of the Wolfcamp, which comprises about three-quarters of the total thickness, consists very seen to vary in thickness from a few feet to 100 feet within a short distance, where apparently it is overlapping on a warped, irregular surface of Gaptank limestone (Section accompanying Fig. 19).

Section 24.—Measured at the west end of the Wolf Camp Hills, along the western side of a small canyon draining through the hills from the main scarp of the mountains. Section begins on the north side of an outlying butte capped by the Gray Limestone member, lying directly north of Wolf Camp.

		Feet
	Top of section; basal conglomerate of the Hess formation.	
(21)	Greenish drab shale	57
(20)	Granular brown limestone	1
(19)	Mostly covered, with some greenish shale	56

[37] Udden's measurement for these same beds is 529 feet.

	Feet
(18) Brown, finely granular limestone, containing crinoid stems and limestone pebbles forming a ledge	2
(17) Mostly covered, with a few thin ledges of brown limestone	105
(16) Finely granular brown limestone	2
(15) Covered	38
(14) Granular brown limestone, with some limestone pebbles and crinoid stems	3
(13) Covered, with an indistinct limestone ledge near the middle	38
(12) Granular gray limestone, with limestone pebbles in the upper part. Forms a ledge of considerable prominence, capping the high cuesta between the Gray Limestone member below and the base of the Hess above. *Schwagerina fusulinoides* and *Schwagerina uddeni*	10
(11) Covered	35
(10) Brown granular limestone with scattered fossils	2
(9) Covered where section was measured; a little farther to the east, along the side of a small drainage channel the following were collected: *Teguliferina bösei*, *Parakayserlingina fredericksi*, *Productus* sp., *Aulosteges wolfcampensis* and *Fusulina* sp. (type of *F. elongata*)	19
(8) Irregularly crystalline dark gray limestone, sparingly fossiliferous	3
(7) Shale like 5, mostly covered	103
(6) Brown granular limestone, crowded with crinoid stems and brachiopod fragments	2
(5) Soft blue to black shale, usually thinly laminated	58
Gray limestone member:	
(4) Brown, irregularly crystalline limestone, containing crinoid stems and rounded limestone pebbles. *Schwagerina kansasensis* occurs here	4
(3) Covered, probably limestone	8
(2) Massive, evenly crystalline gray limestone, containing some fossil fragments. Thickness somewhat variable	37
Uddenites member:	
(1) Greenish drab clay shale, in part calcareous, with two thin layers of brown granular limestone in the upper part, and some beds of shaly limestone. This member contains the *Uddenites* ammonoid fauna, *Triticites ventricosus*, an abundance of brachiopods characteristic of the Cisco, and in addition: *Aulosteges wolfcampensis*, *Paraenteletes cooperi*, *Meekella irregularis*, *Martinia wolfcampensis*, and *Spirifer condor*. Thickness at ammonoid locality (maximum)	113
Gaptank limestone at base of section.	
Total	686

The Wolfcamp formation has been traced northeast as far as Gap Tank, as shown in Plate VIII. The Uddenites member and the Gray Limestone member retain much their same character in this direction. The upper Wolfcamp, however, becomes quite sandy and is largely missing as a result of pre-Hess erosion. The *Uddenites* fauna occurs in some abundance, as shown by Keyte, Blanchard and Baldwin, at two localities on the Montgomery Ranch, four and a half and five and a half miles northeast of Wolf Camp. The base of the formation is not exposed over great enough distances in this area to determine with certainty its relations to the Gaptank formation. At Gap Tank, brown limestones along the highway a few hundred yards east of the tank contain *Schwagerina* and other Wolfcamp fossils.

The following section was measured five and a half miles northeast of Wolf Camp, on the Montgomery Ranch:

SECTION 27

	Feet
Conglomerate in a matrix of gray sandy limestone, forming a base of Hess formation.	
Upper member of Wolfcamp formation (?):	
(17) Covered, except for some brown sandstone at base	26
Gray Limestone Member:	
(16) Massive gray crystalline limestone, in part nodular, with a few quartz pebbles	35
Uddenites Member:	
(15) Covered, probably sandstone in part	64
(14) Red brown sandstone	8
(13) Brown sandy limestone, containing small sub-rounded chert pebbles	26
(12) Covered	26
(11) Ledge of brown granular limestone, with abundant shell fragments	1
(10) Covered	25
(9) Dense to finely crystalline dark gray limestone in two ledges. This contains the *Uddenites* ammonoid fauna and other fossils in great abundance	14
(8) Brown, fine-grained sandstone, with some pebbles	26
(7) Covered, evidently mostly shale	35
(6) Granular limestone, with many shell fragments	1
(5) Covered, probably shale	31
(4) Granular limestone, with many shell fragments, and crinoid stems	1
(3) Covered	35

		Feet
(2)	Limestone	1
(1)	Covered	4
	Limestone of the Gaptank formation at base of escarpment, of which 16 feet are exposed.	
	Total	359

Hess Ranch Horst.—The Wolfcamp is exposed in an isolated area, bounded by faults, on the horst north of the Hess Ranch. It is here overlain by Hess limestone, with an angular discordance reaching 10° in places. The following section is exposed at the east end of the uplift:

SECTION 20

		Feet
	Hess conglomerate; limestone cobbles in a matrix of sandy limestone.	
(8)	Marly shale, containing *Schwagerina*	15
(7)	Conglomerate of limestone and chert fragments in a matrix of sandy limestone	60
(6)	Covered	22
(5)	Brown sandy limestone, containing chert pebbles	1
(4)	Sandy shale, with thin beds of sandstone and fossiliferous sandy limestone	45
(3)	Thin-bedded, brown, fine-grained sandstone, with some nodular sandy limestone containing *Schwagerina* and other Wolfcamp fossils	14
(2)	Massive, light gray limestone, containing limestone and chert pebbles in certain layers	153
(1)	Calcareous shale, weathering greenish, containing a few fossils. This is indurated and baked near the igneous intrusion (Uddenites member?)	100
	Intrusive contact; igneous rock of a plug forms base of section.	
	Total exposed	405

To the west, the section changes, as shown in Figure 22. The shales wedge out, and all the beds become conglomeratic, and merge into massive conglomeratic limestone at the west end of the uplift. About a mile west of the measured section, the upper shale (bed 8) attains a greater thickness beneath the unconformity and contains some thin limestone beds with abundant Wolfcamp fossils.

Western Part of Glass Mountains.—The Wolfcamp formation is exposed around the south and east sides of Leonard Mountain, where the formation has been folded into several broad arches not shared by the overlying Hess. Relations are, however, much obscured by landslides of the Hess limestones which form the cliffs above. The Uddenites member, with its characteristic fauna is exposed three-fourths of a mile NE of the summit of Leonard Mountain, as noted by Udden, and a short distance to the south the Wolfcamp beds are seen to rest with basal conglomerate and slight angular discordance upon the Tesnus formation. The basal conglomerate reaches 100 feet in thickness at the south end of the mountain, and its unconformable basal contact is well exposed in several ravines. The upper part of the formation contains *Schwagerina* and consists of several thick limestone beds, separated by shales and sandstones.

The Wolfcamp formation is continuously exposed along the base of the Glass Mountains foothills west of Iron Mountain, as far as Dugout Mountain, except where wash-mantled valleys cut gaps in the escarpment. The Uddenites member is apparently absent west of Leonard Mountain. The basal beds of the Wolfcamp in this area are conglomerates, which thicken westward from a minimum of 10 feet west of Iron Mountain, to 450 feet near Lenox. As shown in Figure 20, the Wolfcamp beds rest on various formations in this area, and at several localities the discordant contact is well exposed. The conglomerates are followed by shale and sandy shale, with thin limestone layers that locally contain *Schwagerina* and other fossils characteristic of the upper part of the Wolfcamp formation of the type section. The thickness of these upper beds is variable because of the unconformity at the top; 160 feet is found one mile southwest of Iron Mountain. Southwest of Lenox these upper beds have been removed by pre-Hess erosion along one and one-half miles of outcrop, so that the Hess conglomerates rest directly on Wolfcamp conglomerates. Below the summit of Dugout Mountain the two conglomerates diverge, as shown in Figure 21, and the upper member of shale and thin limestone appears as a wedge between them. This wedge is 60 feet thick below the summit of the mountain. It includes a limestone layer that contains ammonoids, among which are *Prothallasoceras welleri* and *Perrinites* cf. *cumminsi.*

Relationships of the Uddenites Member.—The evidence for the Permian age of the Uddenites member is very largely paleontological, and this evidence is discussed by R. E. King in the companion memoir. The physical evidence is not in itself conclusive largely because of the discontinuous nature of the exposures of the lower contact. At most exposures it appears to rest on the Gaptank below with nearly equal dip and strike. The available data is shown in Plate VIII, which indicates that the member does not have the relations given it by Keyte, Blanchard, and Baldwin (**9**, pl. 31), who believe it to be 400 feet below the top of the Gaptank four miles northeast of Wolf Camp. These writers give no evidence for the Pennsylvanian age of the strata overlying the Uddenites zone, and field work by the writer and his brother indicates that beds of Hess age were included in their "Gaptank" at this place.[38] Our Plate VIII shows that the Uddenites member is of variable thickness, and it is found that this variability is in places abrupt, as near Wolf Camp, suggesting that this difference is the result of an overlap on a warped surface of the beds beneath. Moreover, at the east end of Leonard Mountain, the Uddenites member appears to rest directly on the Tesnus, though the relations are somewhat obscured by talus.

Stratigraphic Relations.—The Wolfcamp is overlain by the Hess with a well-marked unconformity. The base of the Hess along the entire length of its outcrop from the region east of Gap Tank to the foot of the Del Norte Mountains, some 35 miles, is marked by conglomerate. At many places a perceptible angular divergence between the two formations may be seen, reaching a maximum of 10° (Fig. 21A). Pre-Hess erosion is also indicated by the variable thickness of the upper members of the Wolfcamp formation. Moreover, it will be shown below that there is evidence of extensive overlap of the Hess upon the underlying rocks.

HESS FORMATION

GENERAL FEATURES

The Hess formation was named by Udden (**5**, p. 43) for the Hess Ranch, near which it is well exposed. The formation has not been well understood, because of its great lateral variation in lithology and thickness. In his section on Leonard Mountain (Sec. 4, Bull. 1753), Udden provisionally placed beds regarded by us as Hess in the Leonard formation, though he recognized the possibility that the Hess might be present here. The type sections of the two formations therefore overlap on one another. The contact is now placed at the natural line of subdivision between siliceous shales above and massive limestones below. The Hess is also represented, as suggested by Udden, in the sections farther west. The formation outcrops in a prominent escarpment between the Hess Ranch and Gap Tank, which rises about 1000 feet above the Marathon Basin on the south. It forms prominent cliffs on Leonard Mountain and the mountain west of Iron Mountain, but loses its topographic identity west of this point. The dolomites of the center of the Sierra Madera dome are also probably Hess, as they underlie conglomerates correlated with the Leonard formation.

The Hess strata in the eastern part of the Glass Mountains make a great mass of limestone, reaching 2130 feet in thickness in section 27 (Pl. VII). These limestones are prevailingly thin-bedded, and dolomitic, with a meager fauna in which fusulinids predominate. Toward the east they are partially replaced by varicolored marls and shales. In the western part of the Glass Mountains the formation is much thinner, being less than 100 feet thick in places; it here consists of massive, light gray, pure limestone. Because of these differences the Hess formation may be divided into an eastern and western facies, with the line of division lying on the Hess Ranch east of Leonard Mountain.

LOCAL FEATURES

Eastern Facies.—The eastern facies of the Hess formation consists of limestone, mostly dolomitic, abundant in fusulinids, but barren of other fossils

[38]After this part of the paper was written the writer had the pleasure of visiting some of the critical localities in the field in company with Prof. I. A. Keyte. The locality considered most significant by Prof. Keyte is at the south base of the Glass Mountains escarpment north of the Meeks Ranch and four and one-half miles northeast of Wolf Camp. At this place the section is roughly as follows:

(e) Varicolored marls of undoubted Hess age.
(d) Thickly and regularly bedded light gray limestone capping the outer cuesta of the Glass Mountains. Contains an undescribed species of *Triticites*, similar to *T. ventricosus*. Thickness about 75 feet.
(c) Sandy and shaly beds, with a few layers of brown limestone. Thickness about 150 feet.
(b) Gray limestone member. Thickness about 50 feet.
(a) Uddenites member; shale with limestone layers which contain the *Uddenites* fauna. About 50 feet exposed at base of hill.

Keyte has considered all the strata up to bed (e) to belong to the Gaptank formation, whereas the writers have mapped beds (a) to (c) as Wolfcamp, and beds (d) and (e) as Hess. So far as I have been able to learn, the Gaptank age of the beds above the Gray limestone member is based entirely on the fusulinid of bed (d). Prof. Dunbar, who has identified the writer's collection, states that it is unlikely that this fossil is any older than Wolfcamp. Similar slender fusulinids have been noted elsewhere in the mountains in the lower Hess, but whether they are identical can hardly be determined till Dunbar's monographic study of the Glass Mountains fusulinids is completed.

except in a few zones. These limestones are mostly thin-bedded and dark-colored, weathering dirty gray. The formation is of monotonous character as a whole, and does not lend itself readily to subdivision. There are very few layers traceable for more than a few miles, and of more than local significance.

The Hess formation in the eastern part of the Glass Mountains has a thin but persistent basal conglomerate made up of limestone and chert pebbles and cobbles. These basal conglomerates are well exposed near Wolf Camp and Gap Tank, and are found as far east as the easternmost exposures of the formation, seven miles east of the tank. In

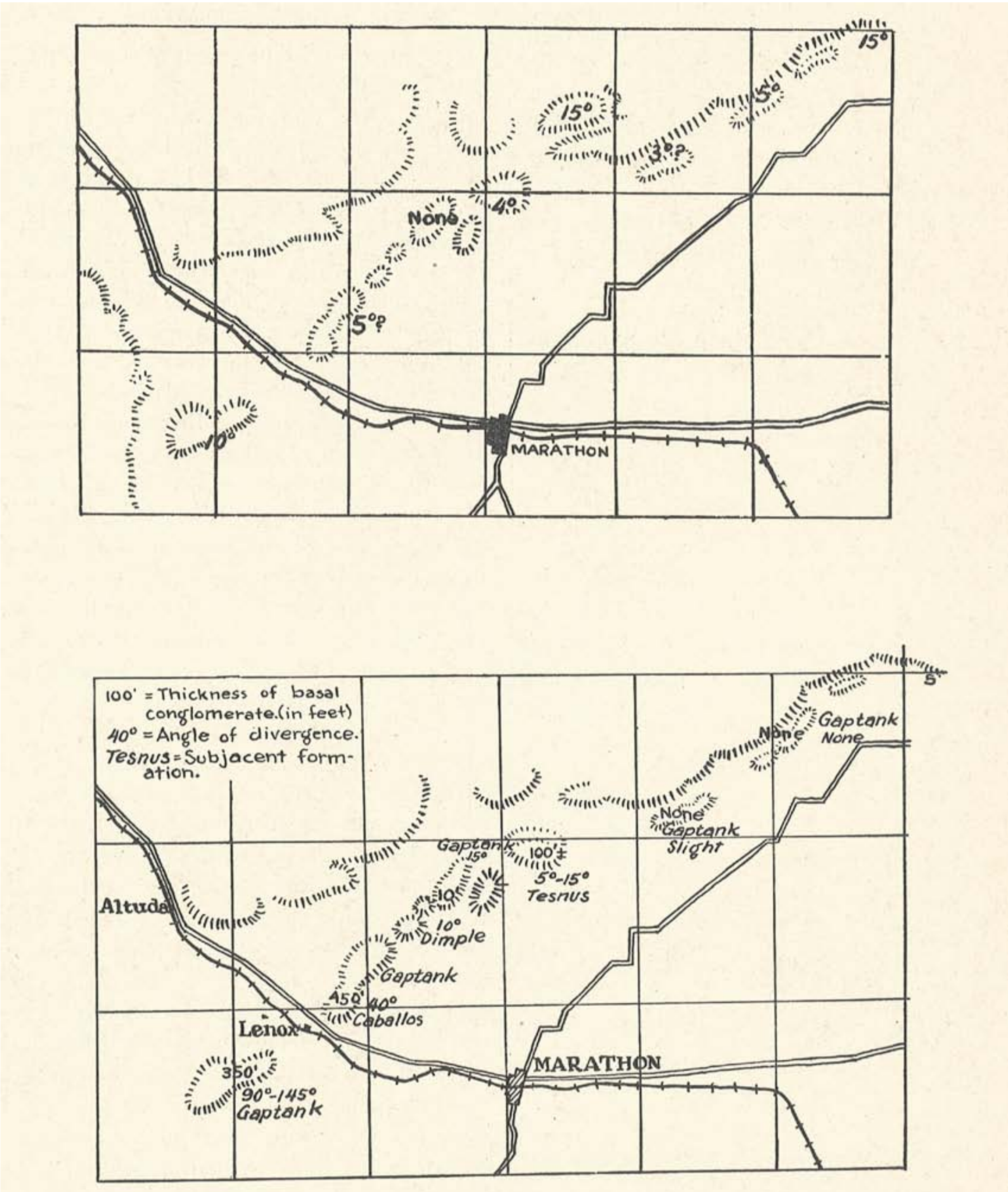

FIG. 20. *Upper.* Map showing amount of angular divergence in dip between the Hess and Wolfcamp formations in various parts of the Glass Mountains. At most places the two formations dip to the northwest, but at different inclinations; however, in some places, as at Leonard Mountain due north of Marathon, the Wolfcamp is irregularly folded, while the Hess maintains a regular northwest dip.
Lower. Map showing character of unconformity at base of Wolfcamp formation.

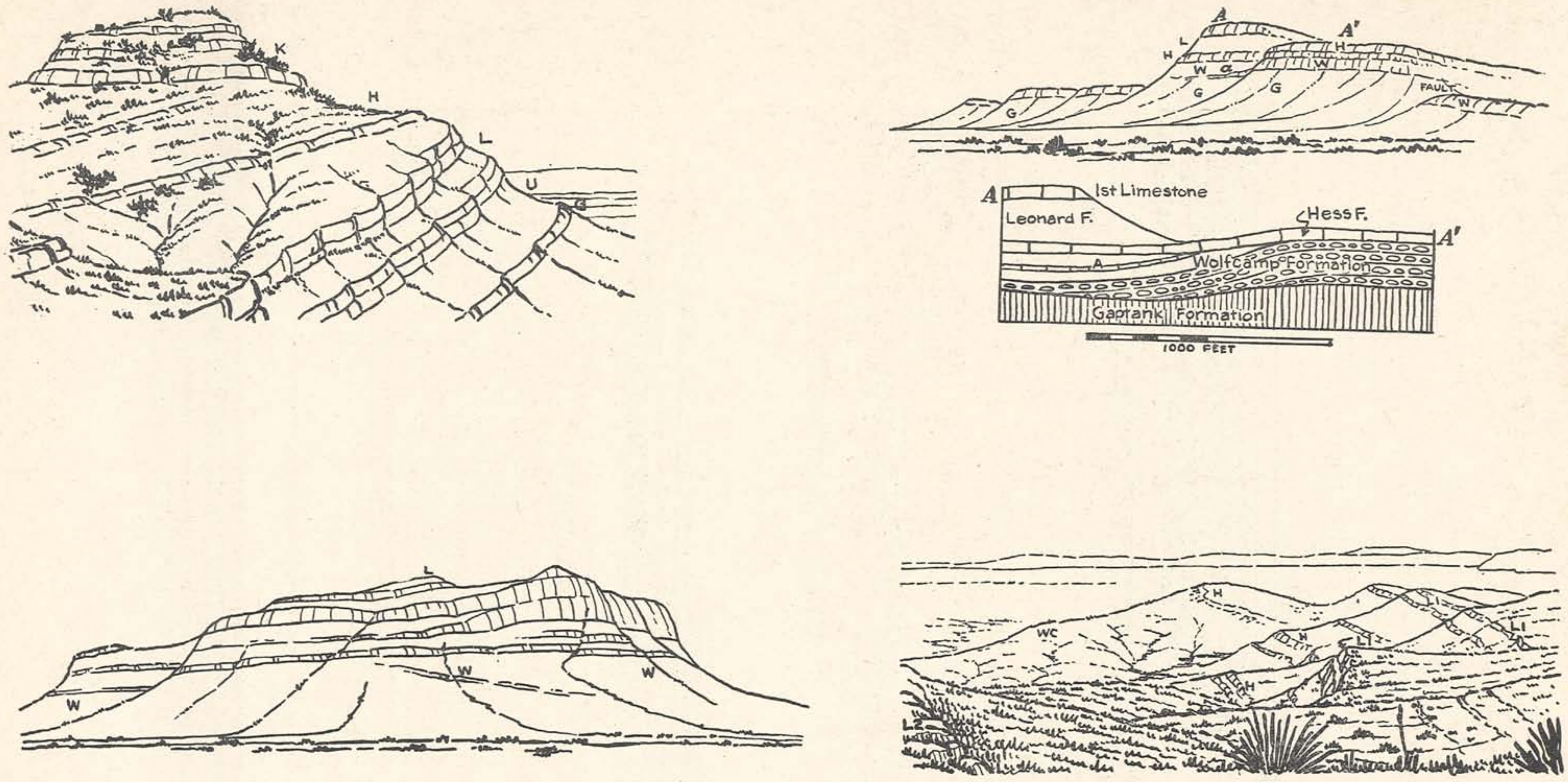

FIG. 21. *Upper left.* View showing two angular unconformities, the lower between the Wolfcamp and Hess, the upper between the Hess and the Comanche series; looking east from a point a mile west of Gap Tank. G—Gaptank; U—Uddenites member of Wolfcamp formation; L—Gray limestone member; H—Hess; K—Comanche series.
Upper right. Sketch looking west toward summit of Dugout Mountain. G—Gaptank; W—Wolfcamp; H—Hess; L—Leonard; a—ammonoid locality. The section below is an east-west section along the face of the escarpment between A and A′ of the previous view.
Lower left. Leonard Mountain from the south, showing outcrop of massive Hess limestones; W—Wolfcamp; L—Leonard.
Lower right. View looking southwest from summit of outer Permian cuesta from a point two miles northeast of Lenox. WC—Wolfcamp conglomerate; H—Hess limestone; L1—First limestone member of Leonard formation; L2—Second limestone member of Leonard formation. Del Norte Mountains in distance, across Marathon basin.

the region north of the Meek Ranch, however, along one and a half miles of outcrop, the basal conglomerates pass into a massive gray limestone without fragmental material which rests directly on the Wolfcamp formation.

East of Wolf Camp, in the lower half of the formation, varicolored marls, sandstones, and shales replace the limestones in an easterly direction. Some of these beds are red, others are buff, orange, brown, or greenish. They are conspicuously developed northwest of Gap Tank. In the area of the Meek and Montgomery ranches, within the marly group and 900 feet above the base of the formation, there is a persistent double ledge of white limestone 30 feet in thickness which has been traced for about three miles (Fig. 24).

In the upper part of the formation north and northeast of Wolf Camp, a cherty fossiliferous bed has been traced for over 10 miles; this may be named the *Perrinites compressus* horizon, for a rare but characteristic ammonoid. The beds above this layer consist of thick-bedded dolomite, which thins from 250 feet in the easternmost section to less than 100 feet northwest of Wolf Camp. These upper beds form the prominent ledges which cap the escarpment north of the camp.

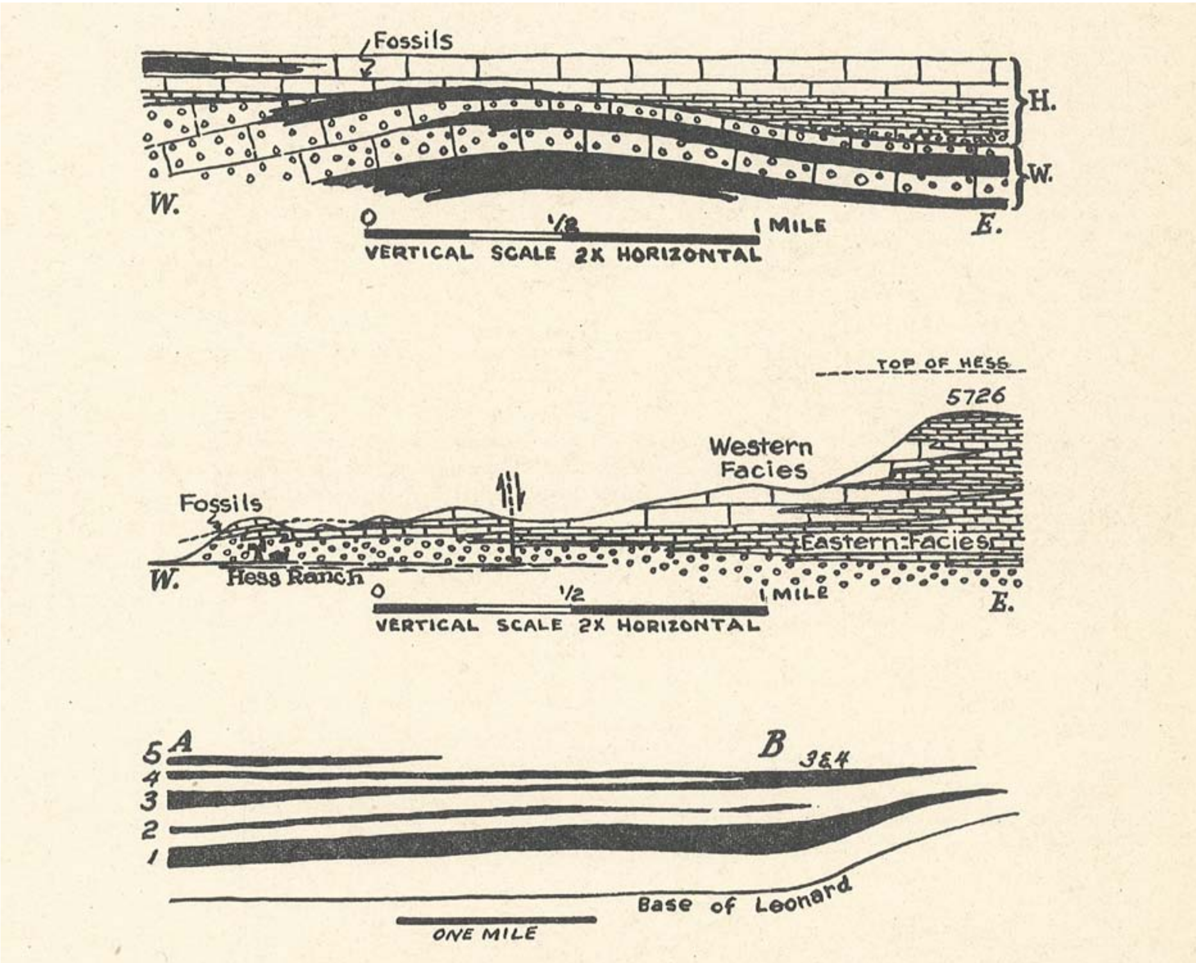

FIG. 22. *Upper.* Stratigraphic diagram showing lateral variation in Wolfcamp (W) and Hess beds (H) on the Hess Ranch horst; shale beds are shown in black.
Middle. East-west profile along the Glass Mountains escarpment for about two miles east of the Hess Ranch, showing observed stratigraphic changes in the Hess: *a*, a change from massive light-gray limestone of the western facies into thin-bedded, dirty-gray, dolomitic limestone of the eastern facies, and *b*, the westward rise in the stratigraphic position of the lower conglomerates, indicating a westward overlap of the formation.
Lower. Stratigraphic diagram showing lateral variation of basal Leonard limestones between Sullivan Peak and Dugout Mountain; A—Dugout Mountain; B—Meridian or Sullivan Peak. Limestone beds in black; siliceous shales in white; limestone members are designated by number.

The following section, measured on the escarpment north of Wolf Camp, shows the character of the eastern facies of the Hess formation:

SECTION 24

	Feet
Limestone with abundant quartz pebbles (Leonard).	
(22) Cherty limestone, locally developed, containing abundant silicified fossils, including: *Composita mexicana, Pugnoides texanus, Perrinites* cf. *vidriensis, Stacheoceras* sp.	30
(21) Brown, finely crystalline, dolomitic limestone in 2-foot to 5-foot beds, weathering to an irregular pitted surface. Fusulinids abundant	120
(2) Two massive ledges crowning the Hess escarpment in this region. Fusulinids are abundant in this layer, some being covered with a concentric algal growth, probably *Osagia encrustens*	70
(19) *Perrinites compressus horizon:* Gray cherty limestone with abundant silicified fossils including: *Enteletes dumblei, Rhipidomella hessensis, Aulosteges medlicottianus, Composita subtilita, Hustedia meekana, Productus ivesi, Heterocoelia* sp., massive sponges, *Omphalotrochus* sp., and *Perrinites compressus* (rare). This is the chief fossil horizon of the Hess and forms a persistent layer traceable for nearly ten miles	43
(18) Limestone containing abundant rounded limestone pebbles. This bed is very persistent and has been traced for several miles to the east and west	2
(17) White, fine-grained dolomitic limestone in 1-foot ledges, with much marl and soft limestone between in 5-foot layers	173
(16) Similar to underlying member, with thinner bedding	190
(15) Dense, finely crystalline light gray dolomitic limestone in 1-foot beds. Fusulinids very abundant in some layers	147
(14) Irregularly crystalline, pockety, white dolomitic limestone in 1-foot to 4-foot ledges, with some marly beds. Weathered surfaces of ledges are deeply pitted	175
(13) Dense gray dolomitic limestone in 1-foot to 3-foot ledges, with thinner bedded pink dolomitic limestone between	208
(12) Marly limestone and sandy limestone	18
(11) Dense gray and brown dolomitic limestone, breaking into sharp-angled chips, and forming 1-foot to 3-foot ledges. Some intercalated marly limestone in upper part	85
(10) Granular gray-brown limestone, containing crinoid stems, fusulinids, and fragments of bryozoans	18
(9) Irregularly crystalline, pockety, gray-brown, dolomitic limestone, weathering to a pitted surface. Forms 1-foot to 5-foot ledges	62
(8) Dense gray limestone in massive ledges, breaking into angular chips, with thinner beds of dense brown dolomitic limestone between	112
(7) Poorly exposed, probably marly	20
(6) Dense gray limestone in 1-foot beds, with some marl between the ledges. Fusulinids abundant in some beds	43
(5) Buff or pink dolomitic limestone in thin beds. Some of the beds are sandy	58
(4) Covered, probably limestone	70
(3) Dense brown dolomitic limestone, in 1-foot to 4-foot ledges, containing some fusulinids, and interbedded with purplish and greenish shale in thicker layers	65
(2) Covered	260
(1) Conglomerate in 3-foot beds. Fragments consist of rounded cobbles of chert and limestone, the latter being of various types, some of which suggest the Dimple formation; there are also some pebbles of green chert from the Ordovician. The matrix is a hard gray limestone, in part sandy	50
Wolfcamp shales beneath.	
Total	1839

Transitional Area.—Near the Hess Ranch the thin bedded, dolomitic facies interfingers with massive, light gray, non-dolomitic limestone of the western facies. The relationships are complicated by the faulting of the Hess Ranch horst, and by considerable areas masked by alluvium. Consequently there is a four-mile gap in which a complete section of the formation is not exposed, this gap coinciding with the critical portion of the transitional area.

The interfingering relationships of the two facies are well shown two miles N 65° E of the Hess Ranch, where several tongues of massive, light gray limestone extend eastward into thin-bedded dolomitic limestone, decrease in thickness, and finally merge into the surrounding rock (Fig. 22). Conversely, on the east side of Leonard Mountain, a tongue of the eastern facies 150 feet thick in the midst of massive limestone merges westward into the western facies. In the intermediate area, in the hills immediately to the north of the Hess Ranch (west end of Fig. 22), and on the Hess Ranch horst farther north (Fig. 22), the two rock types are interbedded. The limestone of the western facies in this area is characterized by *Scacchinella gigantea*, which is particularly abundant one-half mile north of the Hess Ranch on the east side of the road to the Word Ranch.

Not only is there a change in facies in this area, but also a notable decrease in the thickness of the formation westward. Three miles east of the Hess Ranch the formation is 1500 feet thick and one mile southwest of the ranch on Leonard Mountain, it is 700 feet thick. This thinning is interpreted to be a result of overlap of the Hess on the Wolfcamp beds, an interpretation which is supported by observations on the Hess Ranch horst, where 300 feet of beds forming the base of the Hess at the eastern end of the horst pass out by overlap on the Wolfcamp formation at the western end of the horst (Fig. 22 and Sections 19 and 20, Pl. VII). Moreover, in the hills immediately to the north of the Hess Ranch, conglomerates lie progressively higher in the section toward the west, replacing the limestones (Fig. 22 and Secs. 21 and 22, Pl. VII).

Western Facies.—The 700 feet of Hess on Leonard Mountain is a massive light gray limestone, outcropping in bold cliffs (Fig. 21). The following section was measured at the south end of the mountain:

SECTION 17

	Feet
Leonard siliceous shales above.	
(7) Thin-bedded, light gray, finely crystalline limestone, containing fossils near top	20
(6) Massive, light gray, coarsely crystalline limestone, forming a prominent cliff at the top of Leonard Mountain, which appears reddish at a distance. Bedding places are indistinct	187
(5) Poorly bedded, coarsely crystalline, light gray limestone, with some shell fragments and a few chert pebbles. This bed merges eastward around Leonard Mountain into dirty gray dolomitic limestone of the eastern facies	175
(4) Mostly covered, with a few ledges of conglomerate	74
(3) Calcareous conglomerate, of limestone and chert pebbles in a gray limestone matrix. This forms a prominent ledge around the east end of Leonard Mountain, but thins and becomes less conglomeratic westward	136
(2) Covered	80
(1) Poorly bedded, gray, finely crystalline limestone, with a few crinoid stems	74
Wolfcamp beds below, poorly exposed.	
Total exposed	646

To the southwest the formation thins progressively apparently by overlap on the Wolfcamp formation, for its upper contact is a continuous ledge as far as it could be traced. In the region northeast of Lenox the Hess is only 50 feet in thickness (Fig. 21). The base of the formation is in all places conglomeratic; on the mountain west of Iron Mountain there are thick basal layers of cobble conglomerate in a limestone matrix. The limestones above the conglomerate however, contain few clastic fragments, and are almost completely soluble in hydrochloric acid. The beds of the western facies contain various characteristic Hess fossils, including *Scacchinella gigantea*, *Rhipidomella hessensis*, and *Enteletes lioumbonus* which are also found in fossiliferous beds of the upper part of the Hess of the eastern facies.

Stratigraphic Relations.—The contact of the Hess and Leonard formations is here interpreted as a conformable one, though many puzzling features of it remain to be explained. The contact between the two formations is well exposed southwest from Leonard Mountain to Dugout Mountain, where the Leonard is 900 to 1800 feet in thickness and the Hess only a few hundred feet thick. It is also well exposed northeast from the Word Ranch, as far as the outcrop extends, where the Leonard is but 250 feet in thickness and the Hess more than 2000 feet thick. In neither area is there evidence of erosion at the contact and in each area individual layers above and below the contact may be traced for comparatively long distances.

Unfortunately, in the most critical area, in the vicinity of the Hess Ranch, neither the Hess-Leonard contact nor any part of the Leonard formation is exposed for a distance of five miles. In this distance the Leonard thins eastward from 800 feet to 250 feet, and the Hess thickens from 700 to 1500 feet.

The faunas of the two formations are similar, thus indicating that if they are separated by a break or time interval, it is very slight. In spite of their similarity, however, the two faunas contain characteristic elements in each not shared by the other, though both are of the same facies. Although the maximum thickness of each formation appears to be mutually exclusive of the other, the distinctive quality of the two faunas seems to argue against an intergradational relationship.

As a result of evidences of overlap seen west of Leonard Mountain on the Hess Ranch horst, and in the transgressive conglomerate beds of the hills north of the Hess Ranch, it is concluded that the marked westward thinning of the Hess formation is the result of an overlap on uplifted Wolfcamp beds, and is not the result of pre-Leonard erosion, or the intergradation of Hess and Leonard facies.

LEONARD FORMATION

GENERAL FEATURES

The Leonard formation was named by Udden (**5**, p. 46) for Leonard Mountain, nine miles north of Marathon, on whose north slope the formation is well exposed. As already stated, in his type section (Sec. 4), he included in the Leonard the massive limestones which outcrop on the south face of Leonard Mountain, and which have been shown by the writer to correspond to the upper part of the Hess at its type locality. Since there is an overlap

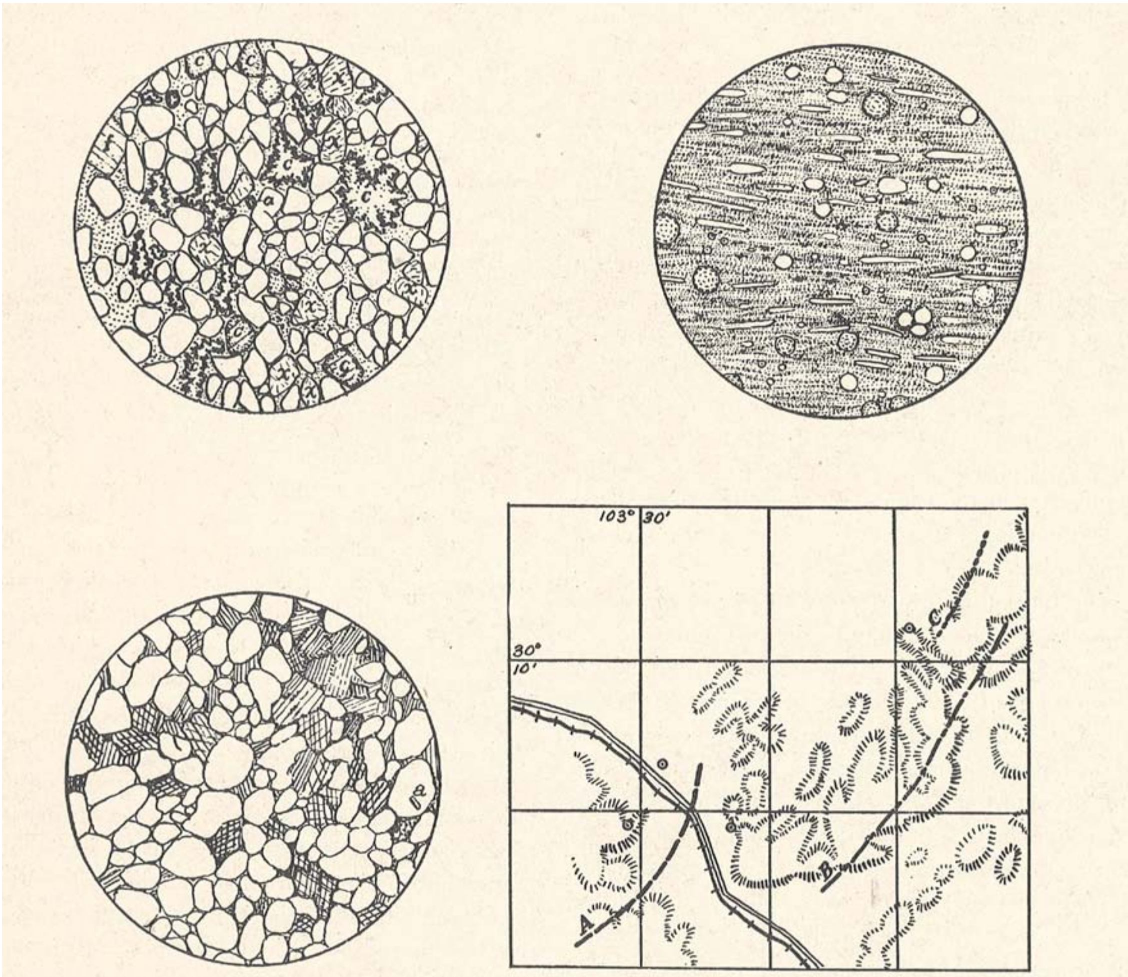

FIG. 23. *Upper left.* Thin-section of Word sandstone from bed 11, section 12. The sand grains consist of quartz (unshaded), chert (x), calcite (c), feldspar (f), and apatite (a). These are set in an argillaceous matrix containing irregular areas of finely crystalline calcite (c).
Upper right. Thin-section of radiolaria-bearing siliceous shale from the Leonard formation, section 12, bed 21.
Lower left. Thin-section of calcareous sandstone from Leonard formation, bed 18d, section 12; the clear grains are quartz, one of which contains an included crystal of apatite (a). The shaded areas are calcite crystals, which form the matrix of the rock.
Lower right. Map of the western half of the Glass Mountains to show: A—Northwest limit of Lower Massive member; B—Southeast limit of Altuda member; C—Northwest limit of Gilliam member. Small circles indicate the observed occurrence of the Papery limestone bed.

of the type sections of the two formations, the contact is placed at the natural line of subdivision beween the siliceous shales above and the massive limestones below. Evidently this was also Böse's interpretation, for he writes (**7**, p. 15):

> Below the . . . . Word formation there is a mass of shales, alternating with rather thin or medium-bedded gray limestones and thinly bedded cherts which we call the Leonard formation.

The Leonard outcrops in a belt extending in a northeasterly direction across the Glass Mountains from the region southwest of Lenox to a point eight miles S 25° W of the summit of Sierra Madera, where it plunges beneath the Comanche series. However, for a space of five miles northeast of Leonard Mountain, the formation is cut out by a faulted uplift and does not outcrop at the surface, except for a small, isolated, infaulted wedge one and a half miles N 50° E of the Hess Ranch. The Leonard is also exposed in an encircling belt around the center of the Sierra Madera dome, and in the center of the uplift south of Altuda Mountain where it is in contact with an igneous plug.

The formation thins from west to east across the Glass Mountains and may be divided into a western and an eastern facies. The western facies attains a thickness of 1800 feet in the vicinity of Lenox, where it consists of limestones, mostly in thin beds, of radiolaria-bearing siliceous shales and cherts, and of sandstones and shales. The limestone and sandstone beds are nearly all conglomeratic, the fragments consisting of chert and limestone derived from pre-Permian rocks. Many of the limestone beds are rich in fossils. The eastern facies of the formation, as exposed east of Hess Canyon, resembles the western facies, but is only 300 feet thick. It contains several beds of sandy limestone crowded with small quartz and chert pebbles, and these characteristic beds continue as far northeast as the Sierra Madera where the remainder of the Leonard formation has changed into massive dolomite.

LOCAL FEATURES

Western Facies.—The thickest sections of the Leonard formation were measured on Dugout Mountain three miles southwest of Lenox and south of Sullivan Peak four miles northeast of Lenox (Secs. 7 and 12, Pl. VII), where the formation is 1800 feet in thickness. The formation thins to the northeast, and is 900 feet thick north of Leonard Mountain. The western facies consists of siliceous shale, limestone, and sandstone.

The radiolaria-bearing siliceous shales and cherts make up nearly half of the section in the western part of the mountains, and occur in ten to sixty-foot beds associated with thin beds of fine-grained quartz sandstone, and lying between thin limestone layers. Megascopically, they consist of thinly laminated, well-indurated, brown, finely granular rocks breaking into thin chips and plates, or of brown vitreous cherty rocks in beds several inches thick. In places they are stained by secondary color bands. They closely resemble the Mowry shale of Wyoming. Interbedded with these rocks are thin, sandy seams now altered to firmly cemented quartzites. Thin sections were made of a number of samples from different beds, which were carefully selected from varieties of type, and for lateral and vertical distribution. All of these sections showed an abundance of radiolaria, and some also contained sponge spicules. Although the number of thin sections was not great enough to show with certainty that the whole of the siliceous shale series are radiolarites, yet the lithologic resemblance of all these rocks to those of which sections were made, and the abundance of radiolarians in all sections examined, make this conclusion a likely one.

The limestone beds are cherty, and are granular, crystalline, or dense in texture; some of the denser layers are bituminous. Many of the beds contain abundant fossils, and also pebbles of chert and limestone. Most of the layers are only a few feet in thickness, and lie between thicker beds of siliceous shale. Near Lenox, however, there are several thick limestone layers which can be traced for considerable distances; two of these beds exceed 50 feet in thickness. They are here designated as the First, Second, Third, Fourth, and Fifth limestone members of the Leonard formation. These limestones outcrop in conspicuous cuestas northeast and southwest of Lenox. Their variation as observed along the outcrop is shown in Figure 22. South of Sullivan Peak, the Third and Fourth Limestone beds join into a single bed, and in this area contain a great abundance of *Perrinites vidriensis*. These layers lens out east of the meridian of Sullivan Peak.

The upper fourth of the formation contains few limestone layers, and is of variable character, in places consisting of siliceous shale, in others of conglomeratic sandstone, and in others of soft clay shale. The clay shale phase is well exposed at the so-called Clay Slide two miles west of Iron Mountain. At several localities near the base of the Clay Slide, shaly limestones contained an abundant fauna, including *Perrinites vidriensis*, *Medlicottia whitneyi*, and *Productus ivesi*.

Two zones in the Leonard formation are characterized by a great abundance of *Perrinites vidriensis*. One of these is at the top of the Fourth Limestone, and the other outcrops at the base of the

FIG. 24. *Upper*. Lower beds of Hess formation three miles northeast of Wolf Camp. Basal conglomerate of Hess formation outcrops on bench in foreground. The conspicuously outcropping layer is the Double ledge

Lower. Butte three miles north of the mouth of Gilliland Canyon, on the north side of the road to the Warren Ranch. The butte is capped by rudistid-bearing Edwards limestone; the ledges below are the Basement Sands (BS), and the lower slopes are composed of the calcareous conglomerate and red beds of the Bissett formation.

Clay Slide. These two definite levels are found at many places in the western part of the Glass Mountains, and are recognizable as far east as Leonard Mountain.

As already stated, the Leonard formation thins from 1800 to 900 feet in the seven miles between Sullivan Peak and Leonard Mountain. As shown in the sections (Pl. VII), this change is accompanied by a convergence of the limestone members, and of the *Perrinites* zones as though there was a difference in the amount of synchronous deposition in the two areas.

The following section, measured south of Sullivan Peak, is typical of the Leonard formation in the western part of the mountains:

SECTION 12

		Feet
	Word bituminous limestone at top of section.	
(38)	Friable sandstone, passing upward into platy siliceous shale	300
(37)	Brown, coarse-grained sandstone with rounded and polished quartz and chert pebbles. Some of the beds are calcareous and contain ammonoids	100
(36)	Soft marly limestone, containing abundant *Perrinites*	3
(35)	Clay shale, and some indurated shale	90
(34)	Coarsely fragmental limestone, made up of bryozoa, brachiopod, and fusulinid fragments. Contains abundant rounded pebbles of clear quartz and darker colored chert	3
(33)	Siliceous shale, passing up into softer shale. A few thin beds of sandstone	133
(32)	Dense bituminous limestone	1
(31)	Shale	20
(30)	Fine-grained sandstone and siliceous shale	82
(29)	Brown siliceous shale, weathering into plates and flakes	46
(28)	Limestone with *Perrinites*	2
(27)	Brown sandy siliceous shale	16
(26)	Sandy gray limestone in about eight ledges, each of which is several feet in thickness, separated by buff siliceous shale. *Perrinites vidriensis* is abundant in tho limestones	75
(25)	Covered, probably shale	5
(24)	*Third and Fourth Limestone Members:* Fine-grained gray sandy limestone, passing upward into conglomeratic limestone containing rounded chert and limestone fragments	105
(23)	Covered; may be sandy	27
(22)	Saccharoidal, fine-grained white or buff sandstone, in part calcareous	25
(21)	Brown siliceous shale, in part vitreous and flinty, and in part dull and platy. Thin sections show this rock to contain a great abundance of radiolarians and sponge spicules. These beds cap the highest part of the outer Permian cuesta	54
(20)	*Second Limestone Member (?):* Finely crystalline gray limestone in thin ledges, interbedded with some siliceous shale	29
(19)	Siliceous shale, in part flinty, with some thin layers of quartzitic sandstone	129
(18)	*First Limestone Member:* In which the following beds may be distinguished:	
	(e) Cherty limestone containing fossils and pebbles, forming a prominent ledge near the top of the outer Permian cuesta	27
	(d) Pink, fine-grained, quartzose sandstone	10
	(c) Finely crystalline, light gray limestone, containing, in the upper part, limestone boulders reaching 1 foot across	20
	(b) Poorly exposed limestone	40
	(a) Massive, gray, crystalline limestone, with poorly marked bedding planes, and weathering to a rough pitted surface. Contains occasional pebbles. Forms a prominent ledge	103
(17)	Covered	2
(16)	Dense, nodular limestone, in part bituminous	1
(15)	Gray, finely granular limestone, made up of fossil fragments and small calcite crystals	2
(14)	Buff, platy siliceous shale. A thin section of this rock contains abundant radiolarians	7
(13)	Granular limestone, resting on a discontinuous nodular dense limestone	2
(12)	Buff siliceous shale, with some interbedded thin limestone in the upper part	49
(11)	Dense bituminous limestone, weathering to a smooth buff surface	1
(10)	Buff, platy siliceous shale, weathering into flakes	53
(9)	Gray limestone	3
(8)	Buff, platy siliceous shale	18
(7)	Gray limestone, made up of fossil fragments and small calcite crystals. At the base it contains rounded and polished chert pebbles reaching 1" in diameter	2
(6)	Buff, platy siliceous shale	13
(5)	Ledge of gray-brown, finely crystalline limestone, in places changing into breccia of crinoid stems, bryozoans, etc.	1
(4)	Covered	29
(3)	Gray crystalline limestone, containing angular chert and limestone pebbles	

	Feet
reaching ½" in diameter. Some fusulinids noted	2
(2) Poorly exposed limestone ledges, apparently with more interbedded shale than before	29
(1) Gray crystalline limestone in 1-foot to 3-foot beds containing frequent chert pebbles. There are beds of shale and fossiliferous marly clay between	32
Hess limestone at base of section.	
Total	1682

Eastern Facies.—Northeast of Leonard Mountain, as stated above, the outcrop of the formation is cut out by a faulted uplift for a distance of five miles. When again exposed, two miles southwest of the Word Ranch, it has its eastern facies. From here northeast, as far as its outcrop extends, the thickness does not exceed 300 feet. Udden (**5**, p. 34), believed that the lower part of the formation was cut out by faulting, but this is clearly disproved by a wider study of exposures. The lower part of the formation consists of limestone containing abundant, well-rounded quartz pebbles, which passes upward into fossiliferous limestone, interbedded with marl and siliceous shale. The siliceous shale is well-exposed along Hess Canyon, where it contains large limestone nodules. Toward the east the shales and marls lens out, and the limestones change to dolomite. At the easternmost point at which the formation is exposed, its dolomites differ from those of the Hess and Word only in their content of sand and pebbles. This same facies is exposed in the Sierra Madera, where the content of clastic material is inconstant, and passes laterally into featureless dolomite. The conglomeratic phase is well-developed in a valley eight-tenths of a mile N 50° E of the summit of Sierra Madera.

The following section, measured two miles east-northeast of the Word Ranch is typical of the eastern facies of the formation:

SECTION 26

Section measured one-fourth mile east of the "Split Tank," two miles east-northeast of the Word Ranch.

	Feet
Word bituminous limestone above.	
(13) Siliceous brown shale	15
(12) Dark gray, crystalline limestone in a massive bed, containing abundant silicified fossils and cherty masses	4
(11) Siliceous shale, with some cherty beds. There are a few interbedded layers of sandy limestone	80
(10) Gray, granular limestone, containing silicified fossils	3
(9) Siliceous brown shale, breaking into small flakes. There are some thin interbedded layers of shaly limestone	50
(8) Gray crystalline limestone, full of silicified fossils	6
(7) Siliceous shale	6
(6) Dense gray limestone, with silicified fossils	3
(5) One-foot beds of fossiliferous crystalline limestone, interbedded with siliceous shale	32
(4) Massive bed of gray crystalline fossiliferous limestone	6
(3) Brown, platy siliceous shale, with some thin interbedded layers of dense tan limestone, and gray crystalline, cherty fossiliferous limestone	56
(2) Cherty gray crystalline limestone in 2-foot beds, containing abundant silicified fossils and a few small rounded chert pebbles	16
(1) Calcareous conglomerate. Consists of gray crystalline limestone, containing scattered chert and quartz pebbles. Locally these are very abundant, and the matrix is quite sandy	20
Hess dolomitic limestone at base of section.	
Total thickness	297

MICROSCOPIC CHARACTER

Six thin sections were examined of sandstone and siliceous shale from the Leonard formation in the western part of the Glass Mountains.

A thin section of sandstone from the lower part of the Leonard formation south of Sullivan Peak (bed 18d, Sec. 12) consists very largely of subrounded quartz grains, a few of which show strain shadows (Fig. 23). A few of the quartz grains contain minute inclusions of apatite. There are also a few grains of chert and plagioclase feldspar, and some of calcite. The matrix consists of crystalline calcite, in which the diameter of some of the crystals equals that of the quartz grains which they inclose. In a few places the matrix is siliceous; in these areas the secondary quartz is oriented in optical continuity to the grains inclosed by it, so as to form an interlocking mass of quartz crystals.

Several distinctions between the Permian and the Carboniferous sandstones are worth noting at this place. These are based on observations in the Marathon region alone and may be of only local significance, but they might prove of value in the study of well cuttings. In the Carboniferous sandstones the majority of the grains are quartz, but an important number are composed of metamorphic rocks and various minerals derived from granitic rocks, such as microcline, muscovite, biotite, and apatite. Chert grains are also common. In the Permian sandstones the grains are almost wholly quartz, with a small amount of chert and a few of feldspar. The matrix in most of the early Carboniferous sandstones is an iron-rich chlorite; in the Permian it is either calcite or silica. The Carboniferous sand grains nearly all show crushing and granulation and the quartz grains show strain shadows; no such deformational effects were seen in the Permian. These distinctions are the result of the different structural and depositional history of the two groups of rocks. The Carboniferous sediments were probably largely derived from the crystalline land mass of Llanoris and the Permian sediments were derived almost wholly from the folded Paleozoic strata of the geosyncline.

Four thin-sections of siliceous shale were examined. A relatively soft platy siliceous shale from bed 14, section 12, was found to contain abundant, well preserved sponge spicules and tests of radiolarians (Fig. 23). These remains make up about 25 per cent of the rock. The radiolarians show the lattice structure of the interior of the test, and are composed of radiating fibers of chalcedony, which have a black cross under crossed nicols. The sponge spicules are tubular, the longitudinal sections being rod-like and the cross-sections being circular, though smaller than the circular sections of the radiolaria. A circular hole is always found in the center of each spicule cross-section; the spicules are composed of radiating fibers of chalcedony, and under crossed nicols the spicule cross-section shows a black cross. The matrix of the radiolarite, comprising about 75 per cent of its volume, consists of minute, feebly birefringent grains of chalcedony, much stained by limonite, with which are mingled minute scattered crystals of calcite and siderite.

Thin-sections were also studied of the stony and sub-vitreous phases of the siliceous shales. The same structure and mineral content was found in these rocks as in the rock type just described. However, the radiolarian tests and sponge spicules were rarely well preserved, and seldom retained any of their more minute structure. Possibly these rocks have been subject to a greater amount of secondary alteration by percolating ground water than the rock type first described.

ORIGIN OF THE RADIOLARIAN ROCKS

Previous Work.—There is an extensive literature on the origin of siliceous rocks containing radiolarians, but not a great deal of unanimity in their interpretation. The writings on the subject, to 1918, have been summarized by Davis;[39] a recent paper on one of these siliceous formations is by Rubey.[40]

Radiolarian rocks have been considered by some geologists to be deep-sea oozes. Davis, however, concludes that those in the Jurassic Franciscan group of California are of shallow water and near-shore origin, because of their close association with terrigenous deposits, both laterally and vertically. He believes that the occurrence of radiolarians, even in some abundance, does not indicate that the whole of the rock is of this origin, for the radiolarian remains are always well-preserved, and are not ordinarily broken or crushed. If the matrix had been derived from fragmented tests, it is hard to see how so many of the tests could be so well-preserved. If it were derived from the replacement of some original deposit by silica leached from radiolarian tests, or by the alteration by percolating ground water of a rock made up wholly of tests, the radiolarian remains which now occur in the rock would likewise show the effect of this alteration. He concludes, therefore, that the occurrence of radiolarians in the rock is incidental to the deposition of the main mass of siliceous material, and he suggests that this was derived from submarine volcanic eruptions, either directly from the erupted material, or through the agency of siliceous springs.

A somewhat different interpretation is made by Rubey for the Mowry shale. He believes that the siliceous rocks of this formation were formed by the diagenetic alteration of volcanic ash by sea-water accompanied by a secondary silicification of associated shale beds by silica leached from the ash. Radiolaria and other siliceous organisms are reported from the formation though apparently not

[39]Davis, E. F., The Radiolarian Cherts of the Franciscan Group, Univ. Calif. Dept. Geol. Bull., Vol 11, pp. 353-402, 1918.

[40]Rubey, W. M., Origin of the Siliceous Mowry Shale of the Black Hills Region, U.S. Geol. Surv. Prof. Paper 150-D, 1929.

in great abundance, but he considers these to be merely incidental constituents.

In both these interpretations, the control by contemporaneous igneous activity is an important feature.

Origin of the Glass Mountains Radiolarian Rocks.—That the Permian radiolarites of the Glass Mountains are certainly not of deep-sea origin is clearly borne out by their field relations. Those in the Word formation in the Del Norte Mountains are replaced southward by sandstones and conglomerates which are clearly near-shore deposits. Toward the northeast, the radiolarian rocks of both the Leonard and Word are replaced by limestone beds whose faunas, including the thick-shelled brachiopod, *Productus ivesi,* suggest a shallow water origin. Moreover, the radiolarian series contains thin intercalations of sandstone, and interbedded layers of thin limestone, which contain chert pebbles and wave-fragmented brachiopod shells, crinoid stems, and bryozoans. From the close association of the radiolarites, both laterally and vertically, with shallow-water deposits it is safe to conclude that they themselves were not deposited in very deep water.

The thin sections of the Glass Mountains Radiolaria-bearing rocks show that radiolarian tests and siliceous spicules of sponges make up over half of their volume. The remainder is composed of crypto-crystalline silica. Many of the slides show beautifully preserved lattice structure in the Radiolaria. There thus appears to be considerable merit in Davis's contention that the siliceous matrix had some source other than from radiolarian tests.

There is some possibility that the radiolarian rocks of the Glass Mountains were related to volcanic activity as in the case of the Franciscan cherts and the Mowry siliceous shale. In Leonard and Word time, when these rocks were forming in the Glass Mountains, there is known to have been volcanic activity in Mexico. At Las Delicias, Coahuila, 250 miles south of Marathon, a great thickness of ellipsoidal andesitic lavas, pyroclastics, and tuffs, is shown by ammonoids and other fossils in interbedded limestones, to be Leonard and Word age. No beds of ash, tuff, or bentonite have been found in the Glass Mountains section. The volcanic areas may, however, have extended closer to the mountains than Las Delicias, though no intervening Permian exposures are known. It is not unlikely that these volcanic eruptions made available a large supply of silica for use by the radiolaria in constructing their tests, and may even, as Davis suggests for the Franciscan, have supplied a large amount of silica directly to the deposit.

After the formation of the deposits, there was probably local alteration by percolating ground waters, for the firm siliceous cement of the intercalated sandstones attests the movement of such silica-rich waters. This is probably the cause of the imperfect preservation of the radiolaria in a few of the thin sections. The silicification of fossils in the interbedded limestones is probably partly the result of silica-bearing waters derived from the radiolarites. The brown color of the siliceous radiolaria-bearing shales is probably original with the deposit.

STRATIGRAPHIC RELATIONS

The contact between the Leonard and Word, well-exposed northeast of the Word Ranch, is apparently a conformable one, showing no evidence of subaerial erosion. West of Leonard Mountain, however, the contact is not continuously exposed over great enough distances to furnish decisive evidence as to the nature of the contact.

WORD FORMATION

GENERAL FEATURES

The Word formation was named by Udden (**5**, p. 46) for the Word Ranch.[41] The Word outcrops in a belt extending northeast across the Glass Mountains. In the western part of the mountains it forms smooth shaly slopes below the cliff-making dolomites of the lower part of the Capitan formation. In the eastern part of the mountains, it has no distinctive topographic expression. The formation is also widely exposed in the Del Norte Mountains, and is brought to the surface in the Altuda Mountain uplift and the Sierra Madera uplift.

The Word formation as well as the Leonard is characterized by great lateral variations in thickness and lithology. When these thicknesses are plotted (Fig. 25), it is seen that the southernmost sections are the thickest and that the formation thins toward the north and northeast. On the basis of changes in thickness and lithology, it is possible

[41]Incorrectly spelled *Ward* Ranch on the Hess Canyon topographic sheet. The writer has been assured that this will be corrected on the next edition of the sheet.

to divide the formation into an eastern and a western facies, with the zone of transition between Hess and Gilliland Canyons.

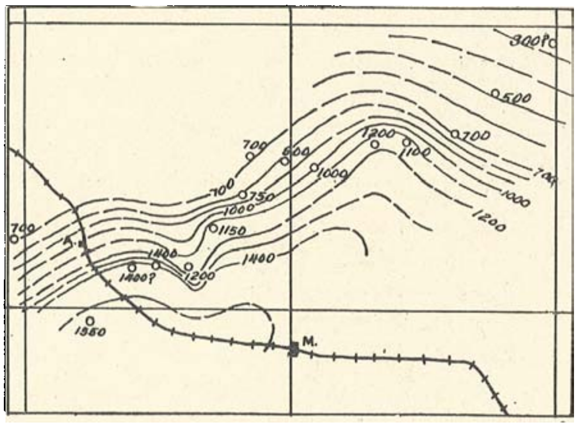

Fig. 25. Map showing variation in thickness of Word formation in the Glass Mountains, Contour interval, 100 feet.

The formation reaches a thickness of 1500 feet in the western part of the mountains and consists mostly of siliceous shale, clay shale, and beds of sandstone. The only limestone bed of any importance and the only abundantly fossiliferous layer is at the base. The formation may be distinguished from the underlying Leonard formation along most of its outcrop in that it contains no pebbles of quartz, chert, or limestone. On the east side of Gilliland Canyon, wedges of limestone appear in the middle and upper parts of the section, which thicken eastward. Toward the east the intervening shale layers disappear, and in the eastern part of the mountains the Word formation is a cherty fossiliferous dolomite about 500 feet in thickness.

LOCAL FEATURES

Western Facies.—In the region between Sullivan Peak and the Del Norte Mountains west of Lenox, the Word beds have a thickness of from 1200 to 1500 feet. The base is marked by a bed of cherty fossiliferous limestone about 100 feet in thickness. In part, this is a compact bituminous limestone, weathering to smooth light gray surfaces. Other beds are coarsely crystalline, light gray, and contain abundant fossils. South of Sullivan Peak the basal limestone reaches a thickness of 340 feet, but the upper limestone beds of this section are seen to interfinger westward with siliceous shales, intercalated with several limestone layers, which are fingers of the overthickened limestone of the Sullivan Peak section.

The upper part of the Word formation in the western part of the Glass Mountains consists very largely of siliceous shale, with some beds of clay shale, and of sandstone. The most conspicuous sandstone bed is about 300 feet below the top, and was traced along the escarpment of the Glass Mountains west of Sullivan Peak, and was also recognized in the Del Norte Mountains. It thickens southward in the Del Norte Mountains at the expense of the siliceous shale, and is 500 feet thick on the high peak of the Del Norte Mountains six and a half miles S 75° W of Lenox. In the upper part of the formation are beds of dense, yellow or pink dolomite, without fossils, but containing small chert nodules.

The following section, measured up the slope of Sullivan Peak, is typical of the Word formation in this area:

SECTION 12

	Feet
Massive Capitan dolomite (Lower Massive Member) above, in sharp contact with the beds beneath.	
(19) Yellow porous dolomitic limestone in thin regular beds	53
(18) Platy shaly buff limestone	16
(17) Dense buff limestone with small chert nodules	10
(16) Platy buff calcareous shale	16
(15) Dense brown or dark gray cherty limestone in six-inch beds	25
(14) Platy siliceous shale	147
(13) Buff shaly nodular limestone	3
(12) Platy siliceous shale	24
(11) Fine-grained, buff to pink calcareous sandstone in a prominent ledge, with a few nodular limestone layers	45
(10) Buff nodular clay shale	60
(9) Platy buff siliceous shale, with a few bituminous limestone layers	140
(8) Nodular dense bituminous limestone	1
(7) Platy buff siliceous shale, with some sandy beds, and some layers of dense yellow limestone. Radiolaria in the siliceous shale	303
(6) Massive, dark gray, finely crystalline limestone, containing fine fossil fragments	8
(5) Limestone interbedded with brown calcareous shale	20
(4) Massive, light gray, finely fragmental limestone, outcropping in a prominent ledge	49
(3) Massive, finely crystalline, dark gray fossiliferous limestone in beds 10 feet thick	60

	Feet
(2) Dense shaly bituminous limestone, in thin regular beds, weathering to a smooth light gray surface. Contains some thin elongate chert lentils	218
(1) Massive, light gray, fossiliferous limestone, with calcite crystals 2 mm. across. Forms a conspicuous ledge, but is of variable thickness	12
Base of section; Leonard sandstones and siliceous shales below.	
Total	1210

The southernmost exposures of the Word formation are in the Del Norte Mountains three miles south of the latitude of Marathon. In this area there are three layers of rather coarse conglomerate, made up of chert and limestone pebbles and cobbles, indicating an approach to the source of the sediments in this direction. In this section, the intervening beds are sandstones, rather than siliceous shales. The uppermost of these conglomerates extends north as a bed of small chert pebbles to a point north of the Old Payne Ranch, four miles west of Lenox. At its southernmost exposures the Word is in contact with fossiliferous Gaptank sandstones, but this relationship is probably the result of post-Cretaceous thrust faulting along the overturned monocline of the Del Norte Range; three miles to the south the Gaptank is thrust in contact with the Glen Rose formation.

In the more northern sections in the western Glass Mountains, in Gilliland Canyon, and on the Altuda Mountain uplift, the formation thins to 700 feet, but retains its sandy and shaly character. In both localities its basal limestone contains the ammonoid *Waagenoceras.*

Transitional Area between Gilliland and Hess Canyons.—In the region of Road and Gilliland canyons the Word formation is about 1100 feet in thickness, and contains four thick limestone beds, here called the First, Second, Third, and Fourth Limestone members of the Word formation. The First Limestone member is apparently laterally continuous with the basal limestone farther west in the mountains. The Second Limestone is not exposed for more than a few miles to the west of Hess Canyon. The Third Limestone member outcrops as far west as the east side of Gilliland Canyon, where it caps the summits of the mountains south of Road Canyon. This limestone is light gray, is commonly oolitic, and contains abundant fossils, including *Waagenoceras* and other ammonoids. It is the bed from which Böse's fauna from the "junction of Road and Gilliam Canyons" was collected. At its westernmost exposures it is interbedded with sandstone and siliceous shale by which it is apparently replaced westward, for it is not present on the west side of Gilliland Canyon, two miles to the west. The Fourth Limestone member forms the top of the Word formation. It thickens eastward, apparently replacing siliceous shales, and reaches a thickness of 300 feet on the west side of Hess Canyon. It is quite cherty, and abundantly fossiliferous.

The two lower limestone members change over into dolomite near Hess Canyon. This is the westernmost extension of dolomitic rocks in the formation; toward the east all the limestones are altered to dolomites.

The following sections show the character of the Word formation in the transitional area:

SECTION 18

	Feet
Measured on the hills to the north and south of Road Canyon, at a point directly north of the east end of Leonard Mountain.	
Massive dolomite of the Vidrio member of the Capitan formation.	
(21) Thick-bedded, very cherty, dirty gray dolomite, interbedded with calcareous shale	30
(20) Siliceous shale, with thin limestone beds	23
(19) Cherty, irregularly crystalline, gray dolomitic limestone, with some fossils	10
(18) Brown siliceous shale	69
(17) Medium crystalline, light gray limestone, with abundant fossils	12
(16) Brown siliceous shale, with a thin bed of cherty limestone near the middle	18
(15) Cherty gray limestone	3
(14) Siliceous shale, with lenticular masses of cherty limestone	23
(13) Finely crystalline, gray, thin-bedded limestone	3
(12) Brown siliceous shale, with thin beds of brown limestone	42
(11) Gray fossiliferous crystalline limestone	19
(10) Mostly covered; probably siliceous shale	138
(9) Fine-grained brown sandstone	4
(8) Mostly covered; poor exposures of clay shale and siliceous shale	138
(7) *Third Limestone Member:* Divided into the following layers:	
(d) Oolitic gray limestone in thin ledges	69
(c) Gray limestone, containing fossils, and several seams of small quartz pebbles	11

	Feet
(b) Brown calcareous sandstone	10
(a) Light gray oolitic limestone, containing some chert masses and fossils, including *Waagenoceras, Prorichthofenia*	218
(6) Brown siliceous shale in 10-foot to 50-foot beds, separated by 1-foot layers of dense or finely crystalline limestone	344
(5) Lenticular bed of gray limestone, crowded with silicified fossils	2
(4) Brown siliceous shale	36
(3) Abundantly fossiliferous gray crystalline limestone	2
(2) Brown siliceous shale	8
(1) *First Limestone Member:* Light gray oolitic limestone, with abundant fossils, forming a massive ledge. The layer is over a hundred feet thick toward the west	50
Total	1222

SECTION 23

	Feet
Section measured along the west side of Hess Canyon.	
Vidrio dolomite above.	
(17) *Fourth Limestone Member:* Dense, thin-bedded, dark gray, cherty limestone, with abundant fossils. Some of the beds near the middle of the member are oolitic	200
(16) Not exposed	35
(15) Like bed 13	30
(14) Poorly exposed	35
(13) Buff, calcareous shale, and nodular limestone	28
(12) Covered by wash; probably mostly siliceous shale	290
(11) Brown, platy, siliceous shale, with thin limestone beds	31
(10) *Third Limestone Member:* Finely to coarsely crystalline gray limestone in thick ledges. Fossils are abundant, particularly in the upper part, and include *Waagenoceras,* and other ammonoids	95
(9) Siliceous shale, with a few thin beds of limestone	126
(8) Siliceous shale, with three ledges of limestone, one of which is oolitic	41
(7) *Second Limestone Member:* Gray, porous, finely crystalline dolomite, in 2-foot to 5-foot beds, weathering to deeply pitted surfaces. Fossils are abundant, and are silicified on the surface. In the upper part is a 10-foot bed of siliceous shale	113
(6) Brown siliceous shale	22
(5) Finely, regularly crystalline gray-brown limestone containing fossils	4
(4) Brown siliceous shale, with a thin bed of crystalline limestone near the middle	51
(3) Irregularly crystalline gray-brown limestone, with pockets filled by crystalline calcite	2
(2) Brown siliceous shale	2
(1) *First Limestone Member:* Gray pockety finely crystalline dolomite in a massive bed, weathering to a pitted surface. Contains abundant imperfectly preserved fossils	56
Leonard siliceous shales below.	
Total thickness	1243

Eastern Facies.—East of Hess Canyon the siliceous shale layers lens out, and the limestones change into dolomites; the formation thins in this direction. The base is marked by a thin layer of platy bituminous limestone, which, with an overlying layer of massive dolomitic limestone, makes up the First Limestone member. The siliceous shale between the First and Second Limestones disappears half a mile east of Hess Canyon, but the other siliceous shale members persist for two or three miles northeast of the Word Ranch. The Fourth Limestone member may be distinguished from the immediately overlying Vidrio in being less massive and dolomitic, and in having a great abundance of fossils and chert concretions. Udden in his type section of the Word formation at the ranch drew the Word-Vidrio contact at the base of this member. Since the member is replaced to the west by sandy and shaly beds which lie below the natural dividing line at the base of the dolomite cliffs, the writer feels justified in accepting the upper contact drawn by Udden in the western part of the mountains, rather than that at the Word Ranch, and therefore he would place this member in the Word formation. This usage is further justified by the fact that the fauna of the Fourth Limestone has been shown by R. E. King's studies to be very closely related to the fauna of the upper limestone of the Delaware Mountain formation, so that in placing the top of the Word at the top of the Fourth Limestone member its limits are made to conform with those of the Delaware Mountain formation. At the northeasternmost exposures of the formation in the Glass Mountains it consists of about 300 feet of cherty dolomite, which locally contains fossils.

The following section was measured four and a half miles northeast of the Word Ranch:

SECTION 27

	Feet
Massive dolomite of Vidrio member of Capitan formation, without chert.	
(7) Massive, dirty gray dolomite, in thick ledges, texture very irregular, with large	

	Feet
masses of crystalline calcite. Contains abundant chert nodules near top	84
(6) Thin-bedded dolomite	42
(5) Massive dolomite	263
(4) Thin-bedded dolomite	53
(3) Siliceous shale, with a few thin dolomite beds	33
(2) Dense, dirty gray dolomite, full of earthy cavities, weathering to a deeply-pitted surface	45
(1) Dense, thin-bedded or platy bituminous limestone, weathering to smooth white surfaces	30
Leonard siliceous shale below.	
Total thickness	550

The same facies is also exposed in the Sierra Madera uplift, where the Word formation consists of thick-bedded dolomite, some of whose beds are crowded with fusulinids. Several of the layers are cherty, and contain fossils at several localities on the mountain.

MICROSCOPIC CHARACTER

Two thin sections of Word sandstones were examined, one from bed 11, Section 12, south of Sullivan Peak, the other from the thick sandstone beds at the crest of the Del Norte Range south of Sullivan Peak. In both sections the sand is quite fine-grained and sub-angular. The section south of Sullivan Peak (Fig. 23) consisted largely of quartz grains, but with many grains of chert and calcite, a few of plagioclase, and occasional minute grains of apatite. In the section from the Del Norte Range, chert grains are an important minor constituent. The matrix in the Sullivan Peak section is clay containing much calcite in irregular masses.

A thin-section from bed 7, Section 12, is a typical radiolarite. It is composed of minutely granular, feebly birefringent chalcedony, in which are well preserved radiolarian tests, making up about 10 per cent of the rock. A few sponge spicules were also noted. Minute rhombic crystals of calcite are abundant in some parts of the section, and a few crystals of siderite are also present.

STRATIGRAPHIC RELATIONS

Some suggestions of unconformity between the Word and Capitan formations are seen in the correlation of the vertical sections, but on the whole the lateral changes in the formation may be most satisfactorily explained by differences in the amount of synchronous deposition in different places. The Word formation is thickest in the south where it contains the coarsest clastic materials, and is nearest the source of supply of sediments.

At several places in the neighborhood of Cathedral Mountain, the Capitan dolomites appear to extend down irregularly across 40 or 50 feet of Word beds within short distances, and there may actually be an erosional unconformity between the two formations at this point. It is improbable, however, that this is of any more than local importance. Where the rock facies of the two formations are the same, they appear to possess gradational relationships. This is true in the dolomitic rocks northeast of the Word Ranch, and in the siliceous shales and thin limestones of the Del Norte Range, in which in some localities the Altuda member rests directly on the Word formation.

CAPITAN FORMATION

HISTORICAL SUMMARY

The strata herein referred to the Capitan formation were originally divided by Udden into three units which he named, in ascending order, the Vidrio, Gilliam, and Tessey formations. They were subdivided along Gilliland Canyon where the group is separable into massive dolomite below, thin-bedded dolomite in the middle, and massive dolomite above.

The Vidrio took its name from the Spanish word for glass, the mountains being known among the Mexicans as the Sierra del Vidrio; the Gilliam is named for Gilliland Canyon,[42] and the Tessey for a "post-office now defunct, but once located about two miles north of the mouth of Gilliam Canyon" (**5**, p. 53).

The work of R. E. King and the writer has shown that the three subdivisions established by Udden are local phases of the interfingering of different facies. The natural units in the western portion of the Glass Mountains do not correspond in age to those in the east, and neither those in east or west have any more than a local significance. For this reason it is here proposed to use the general term Capitan formation for these rocks, and to

[42]This name from which the formation name *Gilliam* is derived is pronounced "Gilliand" by the inhabitants of the region. The name is correctly spelled on the Hess Canyon and Altuda topographic sheets. The United States Geological Survey Committee on Geologic Names states, however, that it is inadvisable now to change the name of the formation to conform with the spelling of the type locality.

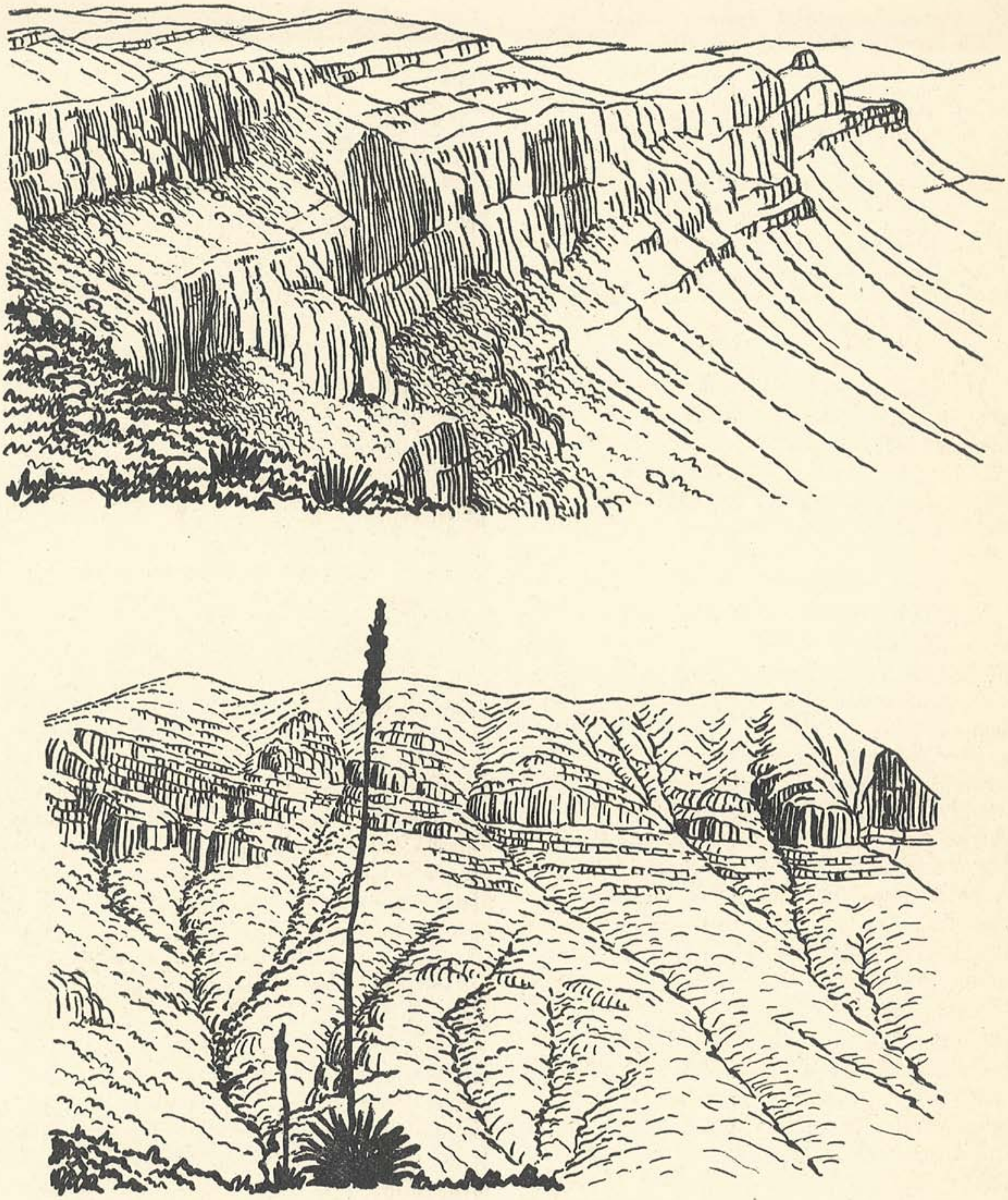

FIG. 26. *Upper*. The dolomite cliffs of the Lower Massive member of the Capitan capping Cathedral Mountain, part of the crest of the western part of the Glass Mountains. The slopes below the dolomite cliffs are made up of sandy and shaly beds of the Word formation, thinly sheeted with talus.

Lower. East face of Old Blue Mountain, showing cross-bedded structure (übergus-schichtung), with foresets dipping northwest. The Altuda member occupies the smooth-contoured slopes below the cliffs.

reduce the Vidrio, Gilliam, and Tessey to the rank of members of this formation.

The Capitan formation was named by Richardson[43] for El Capitan, the high peak of the Guadalupe Mountains and its fauna was described by Girty. Several lines of evidence indicate that the group of dolomites at the top of the Glass Mountains section is of the same age as the typical Capitan. Aside from the strong lithologic similarity, there is a resemblance in faunas; for although fossils are not as abundant in the Glass Mountains dolomite as in the type section in the Guadalupe Mountains, those which do occur are identical with Capitan species. Moreover, the fossils of the uppermost Word limestones along Hess Canyon indicate a correlation with the "upper dark limestone" of the Delaware Mountain formation, showing that the top of this division is of the same age as the top of the Word. If the base of the dolomites in the Glass Mountains is of the same age as the base of the Capitan formation, then the rocks of the two areas cover approximately the same span of time, for both are composed of the same type of rock and the thickness of both is about 3000 feet.

GENERAL FEATURES

The Capitan formation outcrops on the crests and back slope of the Glass Mountains. West of Gilliland Canyon its basal members form bold cliffs at the top of the main escarpment of the range. The lower part of the formation is also exposed on the flanks of the Sierra Madera dome, in the northern Del Norte Mountains, and along the north and west sides of the Altuda Mountain uplift.

The maximum thickness of the formation in the Glass Mountains was measured along Hess Canyon, where 2800 feet of beds were found. The formation thins to about a third this amount in the western part of the mountains, probably as a result of pre-Bissett erosion. The thickness of 4300 feet measured by Böse (**5**, pp. 21–22) along Gilliland Canyon is believed to be excessive, due allowance not having been made for faults and other structural complications which are determinable only with difficulty in this area.

In Gilliland Canyon, and to the east, as Udden has shown, the Capitan is divisible into three members, the Vidrio massive dolomite below, the Gilliam thin-bedded dolomite in the middle, and the Tessey massive dolomite above. Toward the west, however, the Gilliam passes into massive dolomite and loses its identity.

At about the same point where this change takes place, another distinctive member appears at a lower level; this member (the Altuda) disappears toward the east. The section in the western Glass Mountains may therefore be divided into a Lower Massive member at the base, the Altuda member in the middle, and the Upper Massive member above. The Altuda member consists of thin-bedded dolomitic limestone, sandy limestone, and siliceous shale. The Upper Massive member is believed to correspond to the upper part of the Vidrio and the lower part of the Gilliam at their type localities, the equivalents of the Tessey and upper Gilliam having been removed by pre-Bissett erosion.

Deep wells in Pecos County, to the northeast of the Glass Mountains, show that beneath the surface the Capitan formation changes over very largely into anhydrite and red beds. As shown below, in the Vacuum Oil Company well on the Elsinore Ranch, about one-third the formation, comprising parts of the Gilliam and Tessey members has changed to anhydrite.

LOCAL FEATURES

Eastern Part of the Glass Mountains.—As already stated, the section of the Capitan dolomites measured by Böse on Gilliland Canyon is unsatisfactory because of structural complications. A section measured by R. E. King and the writer on Hess Canyon is apparently free from such difficulties, and is therefore used here as the standard section of the eastern part of the Glass Mountains. This section begins at a point a few miles northwest of the Word Ranch, and continues northwest to the hills north of the Warren Ranch, at the north edge of the mountains.

SECTION 24

	Feet
Bissett calcareous conglomerate above.	
Tessey member:	
(33) Dense, dark gray, dolomitic limestone, with some chert concretions. Bedding planes poorly developed	420
(32) Massive gray dolomite, weathering into broad smooth surfaces	50
(31) Brown sandy marl	10
(30) Massive, dirty gray dolomite, with indistinct bedding planes	570

[43]Richardson, G. B., Report of a Reconnaissance in Trans-Pecos Texas North of the Texas and Pacific Railway, Univ. Texas Bull. 23, p. 41, 1904.

	Feet
Gilliam member:	
(29) Fine-grained brown sandstone, some of which is cross-bedded	21
(28) Dolomite	3
(27) Brown, fine-grained sandstone, with limonite nodules	12
(26) Thin-bedded, light gray dolomite	8
(25) Fine-grained brown sandstone	31
(24) Dolomite like bed 22	16
(23) Brown, fine-grained sandstone, and brick-red shale	31
(22) Dense, light gray dolomite, breaking into sharp, angled chips. Beds 1-foot in thickness	23
(21) Poorly exposed sandstone and red shale, with a thin dolomite bed near the middle	70
(20) Dense, light gray dolomite in beds a few inches in thickness	4
(19) Gypsum, weathering to white gypsite on the surface	3
(18) Friable, fine-grained, brown sandstone, with interbedded brick-red shale	20
(17) Light gray, thin-bedded dolomite	5
(16) Fine-grained brown sandstone, and red shale	21
(15) Dense, light gray, thin-bedded dolomite, weathering to smooth white surfaces	14
(14) Fine-grained, brown sandstone, with small limonite nodules	21
(13) Dense, pale brown dolomite in 2-inch beds	35
(12) Fine-grained, brown sandstone, weathering to smooth rounded surfaces	5
(11) Finely crystalline, light gray dolomite, somewhat porous in 1-foot to 3-foot beds. Weathers to a deeply pitted, dirty gray surface	140
(10) Fine-grained, brown sandstone, with small limonite nodules, containing a thin layer of dolomite near the middle	9
(9) White or dirty gray, dense dolomite, in 1-foot beds	90
(8) Prominent bed of friable, brown, fine-grained sandstone	16
(7) Thin-bedded, dirty gray dolomite	4
(6) Platy brown sandy dolomite	6
(5) Thin-bedded, dirty gray dolomite	26
(4) Prominent bed of brown, calcareous fine-grained sandstone	5
(3) Dirty gray, thin-bedded dolomite, with some pockets filled by calcite	25
(2) Alternating beds of thin-bedded dolomite in 5-foot members and friable, buff, fine-grained sandstone in 15-foot members	205
Vidrio member:	
(1) Massive dolomite, with few bedding planes, weathering to a dirty gray, pitted surface	900
Word cherty limestone at base of section.	
Total thickness	2820

The total thickness of the Vidrio member in this section is 900 feet, of the Gilliam 870 feet, and of the Tessey, 1050 feet.

The Vidrio member becomes more thin-bedded east of Hess Canyon but, except in the extreme northeast part of the mountains, it is always more distinctly thick-bedded than the Gilliam. North of the Word Ranch it is moderately thick-bedded dirty gray dolomite containing beds crowded with very large fusulinids, whose tests are in places all oriented in a single direction, probably by the action of currents. In Sierra Madera the thin-bedded strata begin with the base of the Capitan, and the Vidrio and Gilliam members are not distinguishable as such. At a locality six miles N 40° E of the Word Ranch, a single bed in the Vidrio member contains small, well-rounded quartz and chert pebbles widely scattered in a dolomite matrix. So far as known, this is the only occurrence of such materials in the Capitan formation.

The Gilliam member, as shown in the section, consists of three main divisions, a medial group of thin-bedded dolomites, with sandy beds above and below. The upper sandy beds are more conspicuous than the lower, and give rise to subsequent valleys along about ten miles of their outcrop in the eastern part of the mountains. They are best exposed two and a half miles southeast of the Warren Ranch. These sandstones contain much interbedded red shale, a lesser amount of blue shale, and a few thin gypsum beds. The top of the Gilliam in this region is drawn at the top of a persistent sandstone layer.

West of Hess Canyon the Vidrio and Gilliam members undergo a change. The Vidrio dolomites become more massive and nearly all bedding planes disappear. Careful estimates indicate that the Vidrio thickens to about 1200 feet on the west side of Gilliland Canyon, whereas the Gilliam thins to 500 feet. The sandstones of the Gilliam member disappear toward the west. Along the east side of Gilliland Canyon, a single sandstone bed is present near the top of the member, and another occurs about 200 feet lower down, outcropping conspicuously on some hilltops two miles south of the Warren Ranch. The upper sandstone of the Gilliam appears to mark a continuous horizon. The reciprocal variation in thickness of the Vidrio and Gilliam members, the constancy of their total thickness, and the apparently continuous character of the sandstone at the top of the Gilliam indicate that the lower part of the thin-bedded facies is replaced westward by massive dolomite of the Vidrio facies. (Pl. XIV.)

West of Gilliland Canyon the Gilliam formation changes over very largely into massive dolomite. The following section shows the thin-bedded facies of the Gilliam one and a half miles southwest of the mouth of Gilliland Canyon.

SECTION 17

	Feet
Tessey member:	
(16) Massive dolomite; this is the last outcrop of this formation toward the southwest	100
Gilliam member:	
(15) Moderately thick-bedded dolomites forming back slope of cuesta; similar to beds beneath	150
(14) Finely crystalline, light gray dolomite in a prominent ledge capping the mountain. About a mile to the west it contained *Productus capitanensis* and various poorly preserved gastropods	35
(13) Dolomite ledges, with some fusulinids	81
(12) Poorly exposed; brown sandstone in float	10
(11) Prominent ledges of dense, light-gray dolomite, with some members crowded with large fusulinids	55
(10) Not exposed	26
(9) Thinly laminated, dense reddish dolomite	2
(8) Dense, light gray, porous dolomite in 1-foot ledges, with a 5-foot member near middle crowded with fusulinids	27
(7) Poorly exposed; some marly sandstone	7
(6) Thin-bedded dolomite	8
(5) Dense, light gray porous dolomite, with no fusulinids, forming a prominent ledge	10
(4) Dolomite in 1-foot ledges, with fusulinids abundant in the upper part	52
(3) Covered, except for a marly sandstone bed near the middle	12
(2) Thin ledges of light gray, dense, porous dolomite, over half of which are made up almost wholly of the tests of fusulinids, now diagenetically altered. Weathered surface is jagged and pitted, and the fusulinids mostly standing in relief	29
Vidrio member:	
(1) Massive, irregularly crystalline gray dolomite, outcropping in broad formless bare-rock surfaces, weathering jagged and dirty gray. Exposed:	100
Total thickness of Gilliam member	504

The great abundance of fusulinids in these beds is notable. Other poorly preserved fossils are common, including gastropods, brachiopods and possibly ammonoids, but only a single specimen, a *Productus capitanensis*, was specifically determinable. Along the face of the escarpment to the west, in a distance of a mile, all the thin-bedded strata below bed 14, totaling a thickness of about 300 feet, merge into massive, featureless dolomite (Fig. 28). West of this point, the Gilliam member as such is not certainly known, but some thin-bedded strata directly beneath the Bissett formation in some hills four miles east of Bissett Mountain are possibly the western extension of the upper part of the Gilliam.

The Tessey member outcrops east from Gilliland Canyon to the hills southwest of Sierra Madera. Near the canyon it disappears under alluvial deposits and does not come to the surface again to the west. As shown in the section, the Tessey is a group of poorly bedded dolomites and dolomitic limestones about 1000 feet in thickness. In some of the exposures, bedding laminae are rather well marked, but few ledges stand out on weathering, and none of these are traceable for any great distances. Some of the dolomitic limestones have an oolitic texture. North of Sanderson Cabin, the upper part of the member contains great numbers of brown chert nodules, which show indistinct imprints of fossils. A bed in this locality contained an abundance of *Pleurophorus*. An exposure in an arroyo seven and a half miles S 75° W of the summit of Sierra Madera shows a coarsely brecciated mass of dolomite, sandstone, and gypsum, which passes laterally into undisturbed, Tessey strata, doubtless representing a slump into a leached out gypsum bed underground. There are probably other occurrences of gypsum in the Tessey strata, but exposures are not good enough to determine the quantity of this material in the outcropping areas.

In the upper part of the Tessey member, angular limestone and dolomite cobbles are scattered rather abundantly in the dolomite matrix, which makes it difficult to distinguish this member from the Bissett conglomerates above.

Relations to the Anhydrite and Red Bed Series of Pecos County.—Evidence from deep wells suggests that toward the northeast, the Capitan formation changes over very largely into red beds and anhydrite. However, with a single exception, no deep wells have been drilled within 20 miles of the Glass Mountains. This exception—the well of the Vacuum Oil Company on the Elsinore Ranch—demonstrates with such clearness the relation of the various members of the Capitan to the anhydrite beds, that a discussion of its correlation is given here.

The following abstract of the formations penetrated is derived from a study and description of samples by Miss O. M. Richey for the Bureau of Economic Geology. Samples were collected at frequent intervals, usually every five feet. The correlations given are those of the writer.

SECTION 31

Condensed log of the Vacuum Oil Company, Elsinore No. 1 well. Located in Section 60, Block B, G., C. and S. F. R. R. Co. Survey.

	Depth in Feet
Comanche series:	
(11) No log	0– 295
(10) Red-brown sandstone	295– 450
Bissett formation:	
(9) Red-brown, micaceous sandy shale, with some shaly sandstone; in the lower part are thin beds of gypsum	450– 950
Tessey member:	
(8) Dolomitic limestone, in part oolitic, in part sandy	950–1150
(7) Anhydrite in beds 80 to 100 feet thick, with thin layers of dolomitic limestone between	1150–1930
Gilliam member:	
(6) Anhydrite alternating with dolomitic limestone. A number of layers of red sandstone, in part micaceous	1930–2140
(5) Dolomitic limestone, in thin beds, alternating with layers of red and gray sandstone 10 to 25 feet thick	2140–2430
(4) Dolomitic limestone, with thin layers of anhydrite	2430–2545
(3) Dolomitic limestone, with thin layers of sandstone in lower part. There is a considerable gap in the sample record within this member	2545–2880
Vidrio member:	
(2) Uninterrupted sequence of dolomitic limestone	2880–3665
Word formation:	
(1) Non-dolomitic, cherty limestone, passing downward into shaly and sandy beds	3665–4465

The total thickness of the Capitan formation as revealed by the log is 2715 feet. The Vidrio member is 765 feet thick, the Gilliam 950 feet, and the Tessey 980 feet. These measurements agree very closely with those made on the outcrop of the formations on Hess Canyon (Pl. XIV). A total thickness of 4015 feet of Permian was penetrated in this well.

The base of the Capitan in this log is drawn at the top of the cherty, non-dolomitic limestones, which change upward abruptly into dolomite at a depth of 3665 feet. The Gilliam member is separated from the Vidrio and Tessey on the basis of its sandstone layers. The correlations show that the dolomites of the lower part of the Tessey member and those of the upper part of the Gilliam, comprising about 1000 feet of strata, have changed over into anhydrite in this area.

Western Part of Glass Mountains.—As shown above, on the west side of Gilliland Canyon, the Gilliam thin-bedded facies has very largely merged into massive dolomite, and surmounts about 1200 feet of dolomites of the Vidrio facies, embracing the equivalents of the Vidrio member and the lower half of the Gilliam member of the Hess Canyon section.

At about the same point where the Gilliam loses its identity, another distinctive member appears at a lower level, making possible a tripartite subdivision in this area, which, however, does not correspond to the subdivision in the eastern part of the Glass Mountains. The three divisions are here called, from below upward, the Lower Massive member, the Altuda member, and the Upper Massive member.

The Lower Massive member has a maximum thickness of 300 feet, and consists of two or more dolomite beds, each 50 or 100 feet in thickness, which have no bedding planes, and which outcrop in bold cliffs capping the higher escarpments of the Glass Mountains. They are well exposed at the top of Cathedral Mountain. This member thins to the west (Fig. 27 and Pl. XIV). On the escarpment one mile southeast of Altuda it is 90 feet in thickness. It is about the same thickness in the Del Norte Range, but thins out to the north, and is absent on the Altuda Mountain uplift.

Overlying the Lower Massive member is the Altuda member, named by the writer in 1927 (**10**, p. 217) for its good exposure in the vicinity of Altuda section house. It outcrops in the Del Norte Mountains, on the slopes of Altuda Mountain, and extends northeast from Altuda in an irregular belt along the back slope of the Glass Mountains as far as the west side of Gilliland Canyon. The Altuda member is about 450 feet in thickness, and consists of thin-bedded, brown sandy dolomitic limestone, siliceous shale, and thin- to thick-bedded dolomite. Although no thin sections were made of the siliceous shale, it is of the same lithology as that in the Word formation beneath, and is probably also a radiolarite. At the top of the Altuda member, a very thin-bedded, fine-grained, gray limestone occurs at several places; this limestone is capable of splitting into very thin sheets, and is herein referred to as the papery limestone. Its observed occurrences are shown in Figure 23.

In the western part of the Glass Mountains the limestones of the Altuda member are less dolomitic than in the east, and here they contain fossils. On the slopes of Altuda Mountain, bryozoa are abundant in these layers. At two localities, one a mile east of Altuda, and the other four and a half miles north-northwest of Altuda, brachiopods were collected from near the top of the Altuda member; the species are all identical with Capitan forms described by Girty. The most abundant shell is *Squamularia guadalupensis*.

The Altuda member merges into massive dolomite a short distance east of Old Blue Mountain, and is not represented as such east of Gilliland Canyon. Somewhat farther southwest, in the projecting angle of Capitan exposure northeast of Sullivan Peak, the thin-bedded, sandy layers of the Altuda member are seen to go over into thick-bedded dolomite, not easily distinguishable from the massive beds above and below. The line of transition from the Altuda facies to the Vidrio facies, appears therefore to be directed northeast-southwest. (Fig. 23.)

The Upper Massive member consists of thick-bedded or non-bedded dolomites. It outcrops on the back slopes and outer foothills of the western Glass Mountains, and forms the conspicuous cliffs at the top of Altuda Mountain. As a result of its generally massive character and the wide areas in which it is masked by valley fill, its entire thickness is not certainly known. Careful estimates indicate that its thickness is about 800 feet four miles east of Bissett Mountain. To the west it apparently thins out, and on a hill four miles west of Bissett Mountain and four and a half miles north-northwest of Altuda, only 215 feet of Upper Massive strata intervene between the Bissett formation and the Altuda member, evidently as a result of pre-Bissett erosion. On Altuda Mountain the Upper Massive member is a non-dolomitic limestone.

A peculiar feature in the Upper Massive member is the presence of a type of gigantic cross-bedding, whose foresets dip toward the northwest, depart as much as 10° from the normal dip of the strata below, and extend through hundreds of feet of section. At their bases the thick foreset layers flatten abruptly and pass into thinner bottomset beds which interfinger with thin-bedded and sandy dolomitic limestone layers of the Altuda member. This cross-bedded structure was found on Old Blue Mountain (Figs. 26 and 28) and the mountain two miles northwest of Sullivan Peak. It was also noted in the Vidrio member at several places east of Gilliland Canyon, and in the Lower Massive member on the mountain one and a half miles northeast of Sullivan Peak. Ruedemann[44] has suggested to the writer that it is analogous to the *übergussschichtung*, that is, the steep bedding of material poured over the outer slopes of reefs, such as are observed in the dolomite masses of southern Tyrol.

The following sections show the character of the Capitan formation in the western part of the Glass Mountains:

SECTION 16

	Feet
Section at the south end of Old Blue Mountain.	
Upper Massive member:	
(8) Massive dolomite, with large-scale cross-bedding in places. Total thickness exposed on the upper part of Old Blue Mountain	600
Altuda member:	
(7) Dolomitic limestone, in 5-foot beds. At the north end of the mountain, papery limestone occurs at the top of this member	40
(6) Brown, sandy, thin-bedded limestone, with some layers of gray dolomitic limestone	21
(5) Gray crystalline dolomitic limestone, with small cherty masses, and some pockets filled by calcite; the member outcrops in 2-foot ledges. Toward the top are some buff sandy beds. Near the base is a fossiliferous layer, containing massive and ramose bryozoa, fusulinids, echinoid spines and plates, and a *Composita*	97
(4) Brown, sandy, thin-bedded, dolomitic limestone	163
(3) Gray, dense, massive dolomite, weathering with deeply pitted surfaces. There is no bedding between the upper and lower contacts	114

[44]Ruedemann, R., Letter to the writer, 1927.

		Feet
(2)	Buff, finely crystalline, thin-bedded dolomitic limestone, with cherty layers	57
Lower Massive member:		
(1)	Massive gray dolomite in two cliffs, separated by thinner beds. Thickness estimated	250
	Total thickness exposed	1342

SECTION 9

		Feet
Section measured along the escarpments at the western end of the Glass Mountains, from the vicinity of Altuda to Bissett Mountain.		
Upper Massive member:		
(8)	Massive dolomite, not continuously exposed; without bedding planes. Thickness estimated; is only a rough approximation	500
(7)	Prominent ledge of dolomitic limestone	15
Altuda member:		
(6)	*Papery limestone:* Fine-grained limestone splitting into sheets a few millimeters thick	2
(5)	Thin-bedded, gray limestone, with some interbedded siliceous shale. The uppermost beds contain rather abundant brachiopods, including *Squamularia guadalupensis*. Lower down bryozoa are abundant, including *Fenestella* and *Acanthocladia*	200
(4)	Massive gray dolomitic limestone, with some chert	40
(3)	Thin-bedded, brown, flaggy limestones, in part sandy, with some chert lentils	74
(2)	Flaggy, sandy limestone	153
Lower Massive member:		
(1)	Gray crystalline dolomitic limestone in 5-foot ledges	85
Word formation below.		
	Total thickness	1069

ORIGIN OF THE CAPITAN FORMATION

The Capitan dolomites are evidently the result of diagenetic alteration of an original deposit of limestone. That they are the result of secondary alteration shortly after the time of original deposition is suggested by the imperfect preservation of their fossils, and by their generally porous texture, which indicates a change from a limestone deposit of greater volume.[45] They are clearly not the result of alteration by igneous intrusions, because of the wide distribution of the dolomitic facies of the formation, and its lack of relationship to any igneous bodies in the area. Moreover, on Altuda Mountain, where the Capitan limestones are least dolomitic, there is a large group of igneous intrusions, some of which have produced ore deposits.

The differences in bedding, such as the thin-bedded character of the Gilliam and the massive or non-bedded character of the Vidrio and Tessey, are believed to be original in the deposit, and are not the result of diagenetic alteration. The diagenetic changes are of about equal rank in both types of rock, though the rocks themselves are of different character. The thin-bedded strata in places contain a great abundance of fusulinids, and in others are associated with sandstone and red beds. On the other hand, the massive strata show none of these features; when the bedding planes are discernible, they are irregular, and in places even possess a cross-bedded structure. In view of these facts, it may be concluded that the two types of rock are fundamentally different, and were produced under different environments of deposition.

In a general way, a progressive sequence of facies may be discerned in the Capitan strata in a northeasterly direction along the strike of the mountains:

Southwest:
(a) Thin-bedded, cherty limestone, sandy limestone, and siliceous shale, with fairly abundant fossils, of the normal marine type (Altuda facies).
(b) Massive, dolomitic limestone, in places with a cross-bedded structure, whose foreset beds dip toward the preceding facies; fossils uncommon (Vidrio facies).
(c) Thin-bedded dolomite, with abundant fusulinids (Western Gilliam facies).
(d) Thin-bedded dolomite, with beds of sandstone and red shale (Eastern Gilliam facies).
(e) Anhydrite and red beds.
Northeast

All the members of the Capitan formation in the Glass Mountains pass through these changes of facies but the boundaries of the facies do not form vertical planes. Instead they pass upward across the bedding in zig-zags which offset the facies to the northeast or southwest by as much as ten miles along the strike of the rocks. It is this zig-zag boundary of facies which gives rise to the local members of the Capitan formation in the Glass Mountains, for different facies may either rest one upon the other or grade laterally into each other.

[45]Twenhofel, W. H., Treatise on Sedimentation, p. 261, Baltimore, 1926.

(Fig. 27.) On the west side of Gilliland Canyon, the Gilliam member with facies *c*, rests upon dolomite of facies *b*, which in turn rests on the Altuda member of facies *a*.

It should be noted that the Hess formation has a comparable sequence of facies changes; the western facies of the Hess corresponds to facies *b*, the thin-bedded dolomite above Wolf Camp resembles facies *c*, and the Hess beds in the eastern part of the Glass Mountains correspond to facies *d*.

These changes in facies appear to be the result of the conditions under which the deposits were laid down. During Capitan time the open seas were restricted to a narrow embayment in western Texas. These seas merged northeastward into lagoonal areas interspersed between low-lying flats receiving sub-aerial red-bed deposits from the surrounding lands. Excessive evaporation in the lagoonal areas resulted in the precipitation of salt and anhydrite beds, and likewise caused a concentration of the dissolved salts in the marginal seas. It is probable that this highly saline sea water combined with its rapid evaporation was in a large part responsible not only for the diagenetic changes of the newly deposited subjacent strata, but as well for the very rapid lime precipitation.

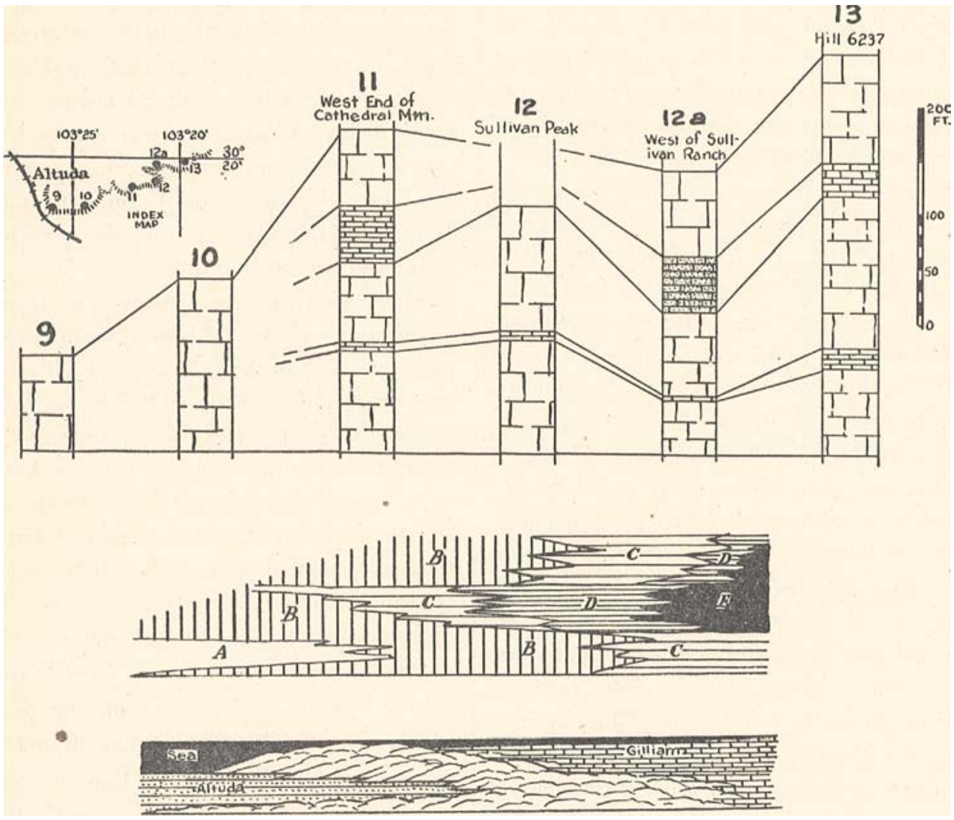

FIG. 27. *Upper.* Sections showing variations in lower massive beds of Capitan formation in western part of Glass Mountains. A general thinning of the member toward the west is shown, but there is also a pinching and swelling of individual layers.
Middle. Diagram showing arrangement of facies in Capitan formation in the Glass Mountains. The letters correspond to the table in the text (p. 80).
Lower. Diagram showing possible conditions in Middle Gilliam time, with the massive dolomites interpreted as reef deposits.

An inspection of the sequence of facies suggests that the massive dolomite (facies *b*) may have stood as a barrier between the normal marine waters (a) and the thin-bedded dolomite and anhydrite deposits (c, d, and e). The thin-bedded dolomite and the anhydrite may therefore be lagoonal deposits. The cross-bedded and foreset structures of a considerable part of the dolomites show that they stood at some height above the areas receiving normal marine deposits (Fig. 27). The precise character and position of this barrier is not certain, for the dolomites have been greatly altered by diagenetic processes.

In the massive dolomites north of Sullivan Peak, in the western part of the Glass Mountains, David White and the writer have observed a great abundance of remains of lime-secreting algae, both of massive and scale-forming type. In some layers identifiable algal remains make up over half the volume of the rock. Mingled with them are cup corals, echinoid spines, fusulinids, and a few brachiopod shells, set in a matrix of obscure structure which is probably composed of fine calcareous debris. Algal remains are common elsewhere in the massive Capitan dolomites of the Glass Mountains, but in many places are so comminuted or so altered by diagenesis as to escape the untrained eye. Ruedemann[46] has also noted spherical algal remains in the Capitan limestone of the Guadalupe Mountains, which Lloyd[47] states are most abundant "in the lagoonal limestones immediately adjacent to the reef," but are represented "very sparingly, if at all, in the reef rock itself." These fossil associations are typical of both modern and ancient reef deposits known elsewhere; algae predominate over corals even in many reefs being formed today.

Since the preliminary copy of this paper was prepared, several articles have appeared in which the reef origin of the Capitan dolomite of the Guadalupe Mountains is discussed.[49] Interpretations very similar to those of the writer are made with regard to the various rock facies. These writers believe that the Capitan dolomites of the Guadalupe Mountains are but a northward equivalent of the upper part of the Delaware Mountain sandstone of the Delaware Mountains, and that they in turn grade northward into the thin-bedded dolomites of the Carlsbad member. Gigantic, southeast dipping foreset structures are described along the southeast flank of the Guadalupe Mountains within the massive dolomite facies (Fig. 28). It may be readily perceived that the three facies enumerated correspond to facies (a), (b), and (c) of the sequence described in the Glass Mountains, and these authors have placed the same interpretation on them that the writer has. In other words, the upper Delaware, like the Altuda is the open sea facies; the massive Capitan like the Vidrio is the reef; and the Carlsbad, like the Gilliam is the lagoon.

In the Glass Mountains it has been possible, on account of the persistence of the Lower Massive member, to distinguish the Altuda member from the Word formation, which it resembles, and this has made the Glass Mountains stratigraphy somewhat more simple than that in the Guadalupe Mountains area, where the Delaware Mountain and Capitan formations are shown not to be time units but to possess an interfingering relationship. In the Glass Mountains, the Capitan formation, as delimited in the present work is essentially a time unit, rather than a lithologic one.

The massive dolomite facies (b) bears a certain resemblance to the Schlern dolomite masses of Triassic age of Southern Tyrol, whose characteristics have recently been summarized by Ogilvie-Gordon.[50] In this region are found scattered areas of massive Schlern dolomite, reaching over 3000 feet in thickness, which pass laterally into marls and tuffs of the Buchenstein, Wengen, and Cassian beds, with normal marine faunas. The dolomites themselves contain a fauna of calcareous algae (diplopores) and a lesser number of coral remains. Mrs. Ogilvie-Gordon objects to the term "reefs" for these deposits, though she admits that they were elevated platforms, standing somewhat higher than their surroundings. She states that the gradient of their sideward slopes is more gentle than modern reefs, and seldom exceeds 30°. This objection seems to be hardly valid; if it is correct it would also be applicable to the massive Capitan dolomites, whose cross-beds never exceed a dip of 20°.

Field[51] has recently contributed observational data on the subject of the origin of reef limestones in his description of the characteristics of the Great Bahama Bank, and has shown that over large areas of its surface it is receiving fine structureless calcareous deposits, either of inorganic origin, or resulting from the metabolism and putrefaction of benthonic organisms. It may also be due in part to evaporation in these shallow and slow moving waters on the banks. Reef-living organisms are

[46]12, 139, and Ruedemann, R., Coralline Algae, Guadalupe Mountains, Bull. Amer. Assoc. Petrol. Geol., pp. 1079-1080, Vol. 13, 1929.

[47]Lloyd, E. Russell, letter to Prof. Schuchert, 1929.

[49]Lloyd, E. Russell, Capitan Limestone and Associated Formations, Bull. Amer. Assoc. Petrol. Geol., pp. 645-659, Vol. 13, 1929.

Crandall, K. H., Permian Stratigraphy of Southeastern New Mexico and Adjacent Parts of Western Texas, Bull. Amer. Assoc. Petrol. Geol., pp. 927-945, Vol. 13, 1929.

Blanchard, W. G., Jr., and Davis, Morgan J., Permian Stratigraphy and Structure of Parts of Southeastern New Mexico and Southwestern Texas, Bull. Amer. Assoc. Petrol. Geol., pp. 957-997, Vol. 13, 1929.

[50]Ogilvie-Gordon, Maria M., Das Grödnes-, Fassa, und Enneberggebeit in der Südtiroler Dolomiten, Abh. der Geol. Bundesanstalt, Band XXIV, Heft 1, pp. 157-161, Vienna, 1927.

[51]Field, R. M., The Great Bahama Bank; Studies in Marine Carbonate Sediments, Amer. Jour. Sci., (5), Vol. 16, pp. 239-246, 1928.

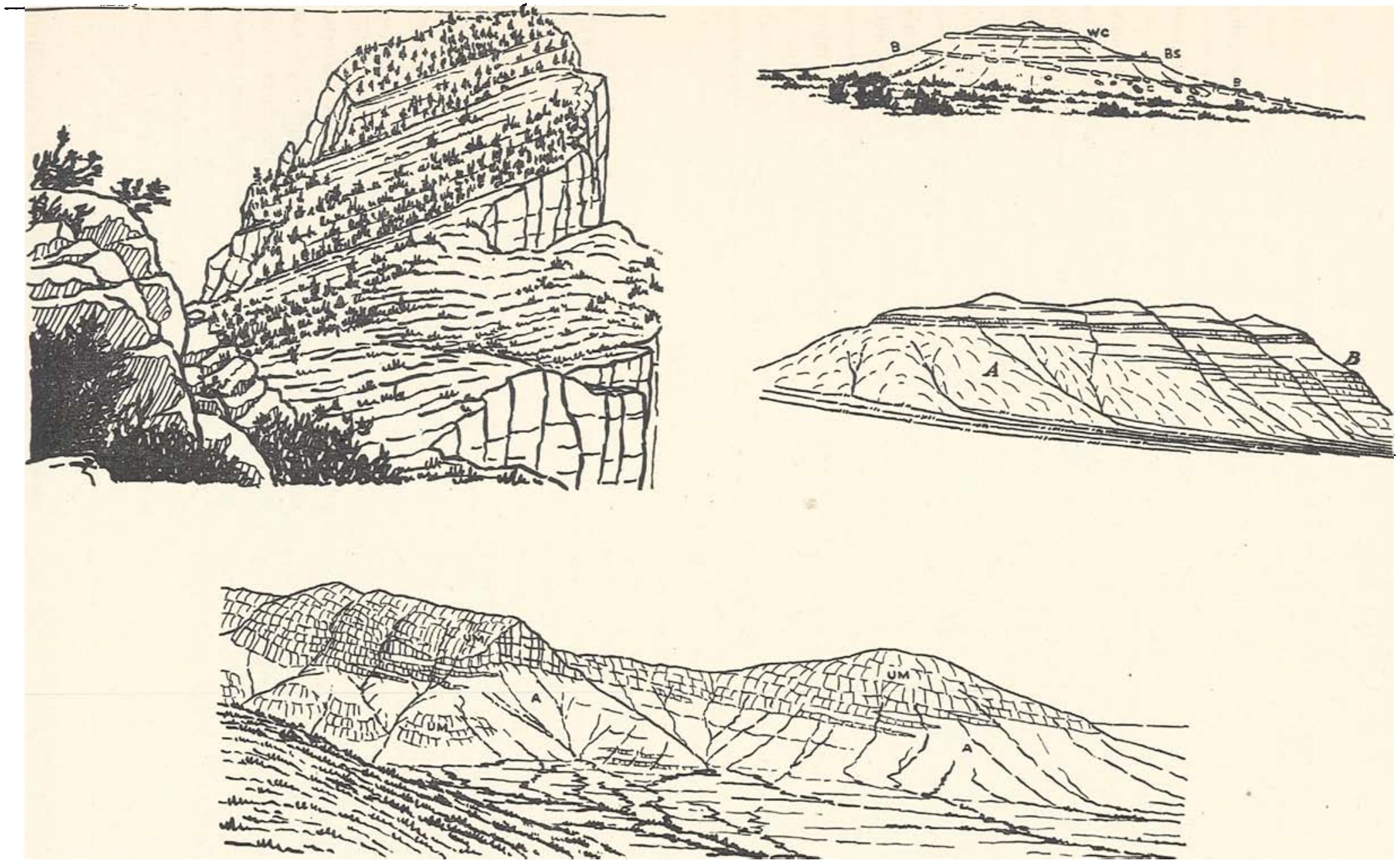

FIG. 28. *Upper left.* View looking down on Guadalupe Point from the summit of El Capitan, Guadalupe Mountains, to show cross-bedded structure in the Capitan limestone. As seen from the opposite side, from below the peak, the base of the Capitan is nearly horizontal, yet steep dips to the left (west) are shown in the picture. (Drawn from a photograph by Willis T. Lee, from Nat. Geogr. Mag., Vol. 53, p. 660, 1928.)

Upper right. View showing angular unconformity between the Bissett formation (B), and the Comanche series, represented by the Basement Sands (BS) and Walnut (?) clay (WC), at the locality of section 34, four miles northwest of the mouth of Gilliland Canyon. The prominent ledge in the Bissett formation is a layer of dolomite, beneath which are red shales.

Middle right. View showing abrupt change of Gilliam thin-bedded facies (B), into massive dolomite (A), on mountain one and one-half miles south of the mouth of Gilliland Canyon.

Lower. View looking southwest toward summit of Old Blue Mountain to show interfingering of Upper Massive member (UM) with the Altuda member (A). A fault runs along the nearer spurs of Old Blue Mountain, bringing the Upper Massive members to the valley level. The mountain stands 1,250 feet above the level of the valley.

nearly absent, and make only a negligible contribution to the volume of the sediments. The Bahama Bank is covered by very shallow water, and stands as a platform 600 feet or more above its surroundings. Under such circumstances, an inorganic precipitation of calcium carbonate is theoretically possible. If cool sea water from the surrounding depths, saturated with calcium bicarbonate, were to be carried to these warm shallow seas there would be a supersaturation of this salt, and some of it would precipitate out. Furthermore, the abrupt slopes of the limestone platform of the bank, would permit some of the precipitated material to be swept over the edges during great storms, producing bedded deposits with steep original dips. Field mentions that great amounts of the freshly deposited calcium carbonate are stirred up by agitated storm waters.

Thus, given a pre-existing platform, calcareous deposits might well be produced without the aid of reef-dwelling organisms. The platform itself might be formed either by tectonic forces, or by the growth of reef societies. In the Capitan of western Texas, it seems hardly likely that tectonic forces could have produced a barrier so far-flung as this one must have been, for it extended at least from the Glass Mountains to the Guadalupe Mountains. It is therefore possible that the dolomite masses were formed from a combination of the growth of reef societies and of the inorganic precipitation of calcium carbonate.

In summary, the Capitan formation consists of a normal marine facies, bordered by higher-standing deposits of massive dolomite, which separate it from lagoonal deposits, consisting of thin-bedded dolomite which abounds in fusulinids on its seaward side, and which passes inland into anhydrite deposits and interfingering red-bed layers. The massive dolomite platforms were either initiated by tectonic forces or by the growth of reef organisms, and were probably continued after their formation by the combined action of reef societies and inorganic precipitation.

STRATIGRAPHIC RELATIONS

As will be shown below, the Capitan formation is separated from the Bissett formation above by a considerable erosional and structural unconformity. Since several pertinent facts relating to the evidence of this unconformity are given in the description of the Bissett formation, a detailed discussion of the stratigraphic relations of the two formations is reserved for later pages.

BISSETT FORMATION

(Permian? or Triassic?)

GENERAL CHARACTER

The Bissett formation was named by the writer in 1927. Its type locality is Bissett Mountain, six miles north-northeast of Altuda, on whose north slopes the formation is well-exposed. The formation outcrops in a belt along the northwest flanks of the Glass Mountains extending from the Southern Pacific on the west to a point 13 miles west-southwest of Sierra Madera on the east. In this belt its exposures are in many places widely separated by strips of wash.

The Bissett formation is for the most part a conglomerate of rounded dolomite fragments derived from the beds beneath, set in a calcareous matrix. There are also some interbedded layers of sandstone and limestone, and lenticular layers of red shale. The maximum observed thickness of the formation is 720 feet. It rests with nearly equal dip and strike on the underlying formations, and is overlain with angular unconformity by the Comanche series.

LOCAL FEATURES

In the region northeast and northwest of Bissett Mountain the formation consists in the lower part of red shales interbedded with conglomerate, and overlain by 200 feet of conglomerate composed of well-rounded limestone and dolomite pebbles several inches in diameter in a sandy calcareous matrix of varying hardness. In the conglomerate all the common types of material found in the limestones and dolomites beneath may be recognized. Rarely, in the upper portion, pebbles of chert, quartzite, and quartz are also found. In the higher parts of the formation the conglomerates are interbedded with dense yellow limestones and fine-grained brown sandstones in layers several feet in thickness. The conglomerates weather with smooth or slightly knobby surfaces and in some parts possess well-delevoped bedding planes. Where the matrix is of soft material the pebbles weather free and lie on the slopes in great abundance. These pebbles are always distinguishable from those of normal slope wash deposits because they are much more rounded.

The following sections were measured north of Bissett Mountain:

SECTION 9

	Feet
One and one-quarter miles northwest of summit of Bissett Mountain.	
Edwards Limestone of the Lower Cretaceous at top of section.	
(8) Calcareous conglomerate in which the fragments are rounded to sub-rounded pebbles and cobbles of limestone and the matrix is a hard limestone in which the fragments are closely packed. One pebble of pink quartzite, very similar to pink quartzites of the Word formation, was noted in the upper part. Near the top some thin layers of yellow sandstone are interbedded	200
(7) Yellow-brown, fine-grained friable sandstone with a few small disseminated limestone pebbles. Bedding poorly developed	15
(6) Thinly-bedded vermilion-red to maroon-red shale containing scattered limestone pebbles	60
(5) Calcareous conglomerate with a moderately soft limestone matrix. Pebbles are of limestone, of all sorts, thinly laminated, massive, dense, and finely crystalline gray and brown limestone. This bed is of lenticular character, and thins out to the west	15
(4) Red shale like bed 6	30
(3) Conglomerate like bed 5	12
(2) Red shale like bed 6; contains a few lenses of conglomerate in a red matrix	45
(1) Conglomerate consisting of angular blocks of limestone of similar composition to those in bed 5. These are closely packed together, so that the matrix, which is of red calcareous material, is of small amount	55
Massive gray dolomitic limestone below.	
Total thickness	532

SECTION 49

	Feet
Two and one-half miles north of summit of Bissett Mountain.	
Edwards Limestone at top of section.	
(14) Massive ledges of calcareous conglomerate	30
(13) Brown limestone with a few thin layers of calcareous conglomerate	8
(12) Calcareous conglomerate	26
(11) Brown limestone	11
(10) Calcareous conglomerate	3
(9) Brown limestone	10
(8) Calcareous conglomerate	15
(7) Dense brown limestone with a conchoidal fracture; containing a few scattered pebbles	6
(6) Massive ledges of gray calcareous conglomerate	43
(5) Gray calcareous conglomerate, interbedded with brown calcareous sandstone, the former in 3-foot and the latter in 1-foot layers	8
(4) Massive ledges of gray calcareous conglomerate. Pebbles reach 3 inches in diameter and are well rounded	48
(3) Brown sandy limestone, gray calcareous sandstone, and gray calcareous conglomerate, interbedded in 1.5-foot layers	10
(2) Gray and buff limestone containing well rounded limestone pebbles up to 2 inches in diameter	45
(1) Red indurated shale containing a few well rounded and polished limestone pebbles	20
Base of formation not exposed.	
Total thickness	283

At the locality of section 9, the dip of the Bissett diverges westward at an angle of 5° with the overlying Comanche, so that all but 50 feet of the topmost member have been removed by erosion at the eastern end of the section. At section 49, where both the Bissett and Comanche have been tilted northward, dips in the lower formation are several degrees steeper than those in the higher one. In the mesas three miles east of Bissett Mountain, where the angular divergence between the Bissett and Comanche is 10°, the basal beds of the Edwards limestone rest on the upturned and eroded edges of the Bissett conglomerate to the north, but overlap across them to lie on the Gilliam and Upper Massive members of the Capitan at the south end of the mesa. Even more striking are the relations on Bissett Mountain itself, for the conglomerates have been removed by erosion from the crest of the dome, so that the Edwards limestone rests on the Upper Massive member of the Capitan. On the flanks of the mountain, the Bissett conglomerates wedge in between, and pitch off the sides of the dome at angles of as great as 35°. Field observations indicate that the Bissett Mountain dome, a post-Cretaceous structural feature, had been previously uplifted in pre-Comanche and post-Bissett time, a conclusion also suggested by a comparison of structure contours on the base of the Bissett formation, and on horizons in the Edwards limestone (Plates X and XI).

In the hills four miles west of the mouth of Gilliland Canyon, a small thickness of the Bissett formation is exposed. The following section was measured on one of these hills, and shows a non-conglomeratic facies of the formation. An angular divergence of 5° between the Basement sands and bed (5) is admirably shown on the east side of the butte. (Fig. 28.)

SECTION 34

	Feet
On a small butte about four miles northwest of mouth of Gilliland Canyon.	
Basement sands of Comanche series, resting on Bissett formation with angular unconformity.	
(5) Dense, dark gray limestone, with a peculiar lumpy weathering surface. In places its weathered surface is covered with an ash-like powder	4
(4) Bluish and reddish clays, poorly exposed	21
(3) Limestone, full of rounded and polished quartz grits. An abraded and silicified crinoid step noted	1.5
(2) Brick-red, indurated shale, with some lavender shale	16
(1) Hard dense dolomitic limestone, of light gray and dark gray color, in thin and thick beds	15
Base of formation not exposed.	

In the hills north and northeast of the mouth of Gilliland Canyon, the Bissett consists of thick beds of calcareous conglomerate, near the middle of which, two to three miles north of the mouth of the canyon, there are conspicuous red-bed layers. Farther east, along the west side of Hess Canyon north of the Warren Ranch, the red layers are absent, and the lower 500 feet of the formation are a single mass of conglomerate. This is overlain by buff shale with thin interbedded dolomite layers containing ostracods and the casts of pelecypods and gastropods. At this locality, in 1930, Sidney Powers and party have in addition collected large vertebrate bones.

The following sections were measured in this area:

SECTION 17

	Feet
Section measured along the western edge of the hills lying from 2 to 4 miles north of the mouth of Gilliland Canyon.	
Basement sands of Comanche series at north end of section.	
(8) White nodular limestone	10
(7) Red shale	10
(6) Yellow limestone	10
(5) Calcareous conglomerate	5
(4) Red shale, with some purplish shale	140
(3) Calcareous conglomerate, like bed 1	66
(2) Red shale, with several interbedded 5-foot layers of calcareous conglomerate	42
(1) Calcareous conglomerate, forming massive gray ledges. The conglomerate consists of rounded pebbles of limestone, with rarer ones of chert and quartz. The matrix is a sandy limestone. The contact with the Tessey below is determined by the fact that the fragments in the Tessey are fewer and more angular	250
Tessey dolomites beneath.	
Total thickness	533

SECTION 24

	Feet
Section measured along the west side of Hess Canyon north from the Warren Ranch.	
Basement sands of Comanche series overlying north end of section.	
(6) Calcareous conglomerate of limestone and dolomite pebbles, with a few of quartz, quartzite, and chert	100
(5) Gray and brown, dense to finely crystalline dolomitic limestone, with platy or splintery fracture, in 2-inch to 2-foot beds, interbedded with buff shale. The limestone contains the casts of pelecypods and gastropods, and also very abundant well preserved ostracods, including the genus *Bairdia*	50
(4) Calcareous conglomerate	10
(3) Covered, probably calcareous conglomerate	160
(2) Similar to bed 1. In some beds the matrix is very sandy, and there are several layers of fine-grained, calcareous sandstone and sandy dolomite	240
(1) Calcareous conglomerate, consisting of rounded dolomite pebbles, in a calcareous matrix. There are also rather abundant well rounded pebbles of quartz and chert, some of which reach 2″ in diameter. Some of the chert is fossiliferous and is probably derived from the Word formation	240
Tessey dolomites beneath.	
Total thickness	800

At the locality of section 17, the Basement sands of the Comanche overlap across all the members of the Bissett succession; they rest on the topmost members at the north end of the section, on member 4 on the butte just north of the gap on the road to the Warren Ranch (Fig. 24), and on member 1 in the mesas to the south. A mile or so to the south of these, outliers of the Basement sands rest on the Tessey member. At the locality of section 24 the unconformity is not so clearly displayed; the Basement sands overlie the Bissett on the north, but no longer cover the rest of the section. They are well exposed, however, resting on the Tessey member three miles to the south in an infaulted wedge half a mile northwest of the Warren Ranch.

A somewhat dubious exposure nine miles north of Bissett Mountain on the Stroud Ranch has also been included in the Bissett formation. Here about 150 feet of red and yellow marl underlie a thin Cretaceous conglomerate, which is in turn succeeded by fossiliferous marls and rudistid limestones of Fredericksburg age. The marly beds contain a few small scattered dolomite pebbles. The inclusion of these rocks in the Bissett has been based on the red color of some of the strata, and an apparent divergence in dip between them and the Fredericksburg at the south end of the hills. It is reported, however, that geologists for the Humble Company have found *Miliolina* and *Chara* seeds in identical strata in a well two miles to the north, so that a Cretaceous age for these beds is not unlikely.

STRATIGRAPHIC RELATIONS

Relations to Underlying Beds.—The Bissett formation apparently rests unconformably on the older rocks of the region. Its conglomerates, which make up the greater part of the mass of the formation, consist almost exclusively of dolomite cobbles which are the erosional products of the immediately subjacent Capitan rocks. The pebbles of fossiliferous chert and quartzite may have been derived from the Word formation, but the occasional quartz pebbles probably had a more distant source.

The Bissett formation rests on the Tessey member of the Capitan east of Gilliland Canyon. Four miles east of Bissett Mountain it overlies a few hundred feet of thin-bedded strata at the top of the Upper Massive member, which is correlated with some part of the Gilliam. Near Bissett Mountain it rests on a considerable thickness of the Upper Massive member, but four miles west of the mountain only 215 feet of this member intervene between the Bissett formation and the Altuda member (Pl. XIV). This appears to represent a downward overlap across nearly 1800 feet of strata in a distance of 17 miles, or an angular divergence of 100 feet per mile.

Relations to overlying beds.—Although, to judge by the overlap relations of the Bissett with the underlying Capitan, as demonstrated above, there is an angular divergence between the two formations of 100 feet per mile, no appreciable difference in dip is to be found in local exposures. On the other hand, the Bissett appears to share the post-Permian pre-Cretaceous folding equally with the rocks beneath. At nearly every locality, as noted in the local descriptions, the Bissett is separated from the Comanche series by a perceptible angular unconformity.

Even though at first sight it might appear to be merely the basal clastic deposit of the succeeding series, the unconformity between them is demonstrated not only by single exposures but by its regional relations as well. The Bissett formation thickens away from the Glass Mountains, but wedges out and disappears toward them beneath the Comanche series, along a line which trends northeast parallel to the lines of truncation of the Permian rocks of the mountains (see Geologic Map). The Basement sands, which are the true basal clastics of the Comanche, also disappear mountainward, but along a line trending west-northwest, which is the result of overlap rather than truncation (Fig. 29).

The overlap of the Comanche is not shared by the Bissett, but is across its truncated edges, for though it is overlain by the Basement sands near the mouths of Gilliland and Hess canyons, the sands disapepar toward the southwest where the Fredericksburg marls and limestones succeed the Bissett conglomerates. Identical sections of Fredericksburg strata, in which conglomerate is nearly absent, are found resting indiscriminately on both Bissett and older Permian rocks in the western Glass Mountains (as, for example, sections 37 to 41, top of Plate XV). Similarly, in the eastern part of the mountains, the Basement sands extend across a variety of formations ranging in age from Bissett on the northwest to Haymond east of Gap Tank.

On the basis of the truncation of members of the Bissett by the Comanche rocks, and of differences in dip between them to be noted in local exposures, and because the Comanche overlap is across not only the older rocks but the Bissett as well, it is concluded that the two series represent distinct epochs of sedimentation separated by an unconformity.

AGE OF THE BISSETT FORMATION

The age of the Bissett formation is not certainly known. To judge by the limiting fossiliferous strata above and below, it is either of late Permian, Triassic, Jurassic, or early Cretaceous age.

The few fossils discovered have furnished no decisive clue regarding the age. The ostracod *Bairdia* is a meagerly ornamented genus ranging from the Silurian to the Recent, though with its greatest expansion in late Paleozoic time. It shows so few evolutionary changes as to be of little value for purposes of correlation. The gastropods and pelecypods are probably not even generically determinable.

Lithologically the marine fossiliferous dolomitic limestones of the Bissett closely resemble those of the undoubted Permian below and are unlike any rocks known from the Triassic Dockum group of the Staked Plains. The Bissett red beds are rather similar to red beds of various ages to the northwest, and the calcareous conglomerates are obviously of such local character as to furnish no evidence for comparison with rocks of other regions.

Perhaps the strongest argument for the Permian age of the Bissett formation lies in the nature and magnitude of the various periods of diastrophism in the region. It will be seen from the foregoing discussion that the unconformity at the base of the formation represents a gradual overlap upon the older formations, with little apparent divergence in dip, thus suggesting a broad uplift. On the other hand, it has been shown that the unconformity at the top of the formation shows a decided tilting of the Bissett and earlier formations before the deposition of the Comanche series, resulting in an angular unconformity, usually of several degrees, but occasionally much more. Thus it is evident that the greatest pre-Cretaceous orogeny of the Glass Mountains is post-Bissett. In nearby areas toward the northwest, and for some hundreds of miles beyond in the same direction, it is found that the Triassic is folded somewhat more than the overlying Cretaceous, but that the greatest folding is consistently pre-Triassic and post-Permian, thus suggesting a correlation of the post-Bissett movements with the pre-Triassic disturbance of the Staked Plains.

The character of the erosion surfaces above and below the formation tends to confirm this reasoning. The Bissett conglomerates are derived from the immediate erosion of a gently upraised land mass, on which they overlap irregularly. The erosion surface at their base is in striking contrast to that at the base of the Comanche series, which is a peneplain produced by long-continued erosion of a stable region. In the Marathon area this ancient peneplain transects all the formations from the Ordovician to the Bissett, with practically no irregularity, save for a very negligible rise in surface in the vicinity of the present Glass Mountains. This same peneplain comes to the surface in Sierra Diablo, where it bevels across all the formations from the Hess to the Delaware Mountain; it is also found at many other localities in Trans-Pecos Texas. The basal Comanchean deposits seldom contain much conglomerate, save for a few well-rounded pebbles of the most resistant rock types; instead they are sands, and in places even marl and limestone.

It seems clear from this evidence that the Bissett formation cannot be as young as the Jurassic or Cretaceous, and is possibly not as young as the Triassic. The post-Bissett movements, if late Triassic or Jurassic would find little counterpart in adjacent provinces and their equivalent is more probably to be sought for in the Appalachian movements of the eastern part of the continent.

In spite of this, there is nevertheless a certain amount of evidence accumulating which would suggest a correlation of the Bissett formation with the Dockum group, as has been suggested by Adams.[52] Rocks of this age are known in the Fort Stockton district, not more than 60 miles northeast of the Glass Mountains, and well log correlations suggest the possibility that these are laterally continuous with the Bissett. The marine dolomites of the latter formation are, however, quite unlike anything found in the Dockum, and if they are Triassic, a connection must be found with Triassic deposits farther west, such as the Moenkopi (Lower Triassic) of northern Arizona, or the beds at Antimonio, Sonora (Upper Triassic). So far, no such connection has been suggested by intervening sections. At most places the Cretaceous rests directly on the Paleozoic, as in southern New Mexico and Arizona; though at Malone, Texas, the Kimmeridgian (Upper Jurassic) overlies the Permian.

There is scant likelihood that the Bissett formation is in any way related to the Malone formation

[52]Adams, J. E., Triassic of West Texas, Bull. Amer. Assoc. Petrol. Geol., Vol. 13, p. 1047, 1929.

farther west in Trans-Pecos Texas. As is well known, the Jurassic portion of the Malone beds passes without apparent interruption into the lowest members of the Cretaceous system. Although Baker[53] reports a conglomerate (Etholen) at the base of the Trinity group near Malone, which rests on the Permian, this is believed to be a marginal rather than a basal deposit, and no exposure of it is known to rest on the Malone formation, either unconformably or otherwise. It is therefore concluded that the Malone beds pass in conformable succession up into the Cretaceous, and have nothing in common with the Bissett formation, which is separated from the Cretaceous by a great unconformity and period of erosion.

The available data do not indicate the age of the Bissett formation with certainty. Formations of known age above and below show that it was deposited at some time between upper Permian and lower Cretaceous, but the structural and erosional history of the region make it unlikely that the formation is any younger than Triassic. It is the conclusion of the writer that it is probably of upper Permian age, but with the possibility not denied that it may instead correlate with some part of the Triassic.*

PERMIAN HISTORY

During Permian time an embayment from the Gulf of Mexico extended inland through Mexico into western Texas, where it divided into two branches, one of which reached northeast into the mid-continent region beyond Nebraska, and the other penetrated the Cordilleran region of New Mexico, Arizona, and Utah. These two branches exhibited opposite characteristics. The mid-continent trough had its maximum extent at the beginning of the Permian, and retreated gradually southward during Permian time, with deposits of salt and red beds laid down in its wake. The Cordilleran trough, on the other hand, was an advancing sea, which spread progressively inland until middle Permian time, when it became connected with another seaway extending down from the Arctic. Toward the close of Permian time, North America was wholly a land area, with the exception of western Texas, in which the last remnant of the dwindling Permian embayment going out through Mexico still remained, and in which the Capitan formation was deposited.

In the Marathon region, the Permian period began with the advance of the Wolfcamp seas over rocks freshly deformed by the Marathon disturbance. The area was in places rugged, and here coarse, thick conglomerate beds were deposited in the hollows of the sea. Farther away from the uplifted area there were deposits of shale and limestone. At the close of Wolfcamp time, there was a slight recurrence of crustal movement, the final phase of the Marathon disturbance, causing the Wolfcamp beds to be tilted and partially eroded before Hess time.

The Hess was a time of quiescence. During this time thick deposits of limestone accumulated in the eastern part of the Glass Mountains area. These overlapped westward on an uplifted area of Wolfcamp rocks, which was only covered at the end of Hess time by the uppermost limestones of that formation. These areas of uplift and depression appear to be genetically related to the cross-warping which closed the Marathon disturbance. The area of thickest Hess deposit lay directly north of the axis of downwarping in the Carboniferous rocks, and the area of thinnest deposit corresponded to the upwarped area in the western part of the Marathon Basin. From the beginning of Hess time to the close of the Capitan, there was apparently continuous deposition in the Glass Mountains area.

During Leonard and Word time there was apparently a renewal of movement in the area to the south of the geosyncline, an upward movement reflected in the Glass Mountains by beds of sandstone and conglomerate. Igneous activity also took place in Mexico during Middle Permian time, and its siliceous ash was probably in some way responsible for the Radiolaria-bearing siliceous shales which characterize these formations. The sandstones, conglomerates, and radiolarites were thickest toward the uplifted area to the south. Toward the northeast and north, they thinned out, and were replaced by a lesser thickness of limestone.

With the beginning of Capitan time there was a change in the conditions. The seas, which had been slowly retreating southward from the continent, now remained as a narrow embayment reaching only as far inland as western Texas. The faunas of this sea, which heretofore had had free communication with the other Permian shelf seas of the

[53]Baker, C. L., Exploratory Geology of Southwestern Trans-Pecos Texas, Univ. Texas Bull. 2745, pp. 15-18, 1927.

*In December, 1930, fossil plants were obtained from the Bissett formation by E. H. Sellards, C. L. Baker, and M. B. Arick. These plants are regarded tentatively as Upper Permian by David White and by E. H. Sellards.

world, now received no additions of new forms from the other areas, and developed into a distinctive but localized fauna. At the same time, along the margins of the embayment limestone barriers developed, which intermittently shut off the last remnants of the interior seas from the ocean, allowing them to be desiccated to produce the great salt deposits of western Texas and New Mexico. These limestone barriers may have been initiated by tectonic forces, or by the growth of reef-dwelling organisms, most probably the latter.

After the final Tessey layers were deposited, the Permian rocks of the Glass Mountains were tilted and partially eroded and the Bissett conglomerates, derived from their erosion, were laid down on top of them. The time when this last event took place is not certain, but evidence indicates that it was either late in the Permian, or at some time during the Triassic.

CRETACEOUS SYSTEM

THE COMANCHE SERIES

The Comanche series rests unconformably upon all the older rocks of the region; it is the deposit of a gradually overlapping sea, which advanced upon a region worn down nearly to a peneplain. In comparison with the Carboniferous and Permian formations, the series is relatively thin, being nowhere more than 1000 feet thick; it is very largely limestone. Over a large part of the Marathon

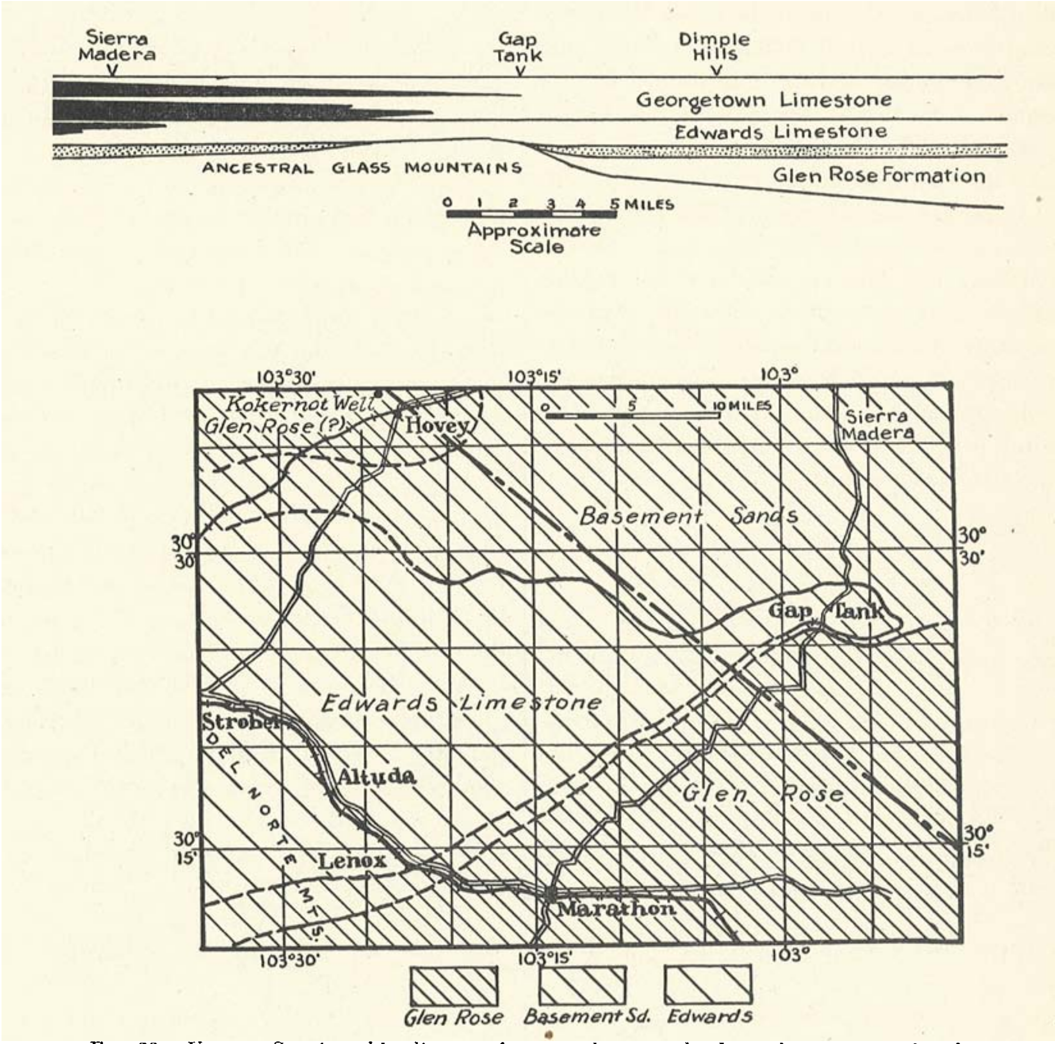

FIG. 29. *Upper.* Stratigraphic diagram from north to south along the eastern side of the area mapped, to show overlaps of Comanche series. Sandstone is indicated by stippled pattern, and shaley beds by black.
Lower. Map showing overlaps of Comanche series; the map shows area in which different formations are the basal deposits. It is also to a certain extent a paleogeographic map, though the Basement sands may not be everywhere of the same age.

region these sediments have been stripped away, and they remain in scattered remnants only over the Glass Mountains.

The overlap relations of the Comanche rocks serve to explain the distribution of its basal formations (Fig. 29). Though the region was lacking in abrupt hills and deep valleys at the time of the advance of the Cretaceous seas, the area of the Glass Mountains rose as a low ancestral range of asymmetrical form. South of the Glass Mountains the basal formation is the Glen Rose marl and limestone. This ends abruptly northward against the Permian. The next higher formation is a sandstone, which, to the south, lies between the Glen Rose and the Edwards limestone, but all about the flanks of the mountains north of the Glen Rose outcrop it forms the base of the Comanche. On the crests of the range, however, this is absent and the Edwards limestone rests directly upon the Permian. The succeeding Comanche formations and the upper Cretaceous beds as well, were laid continuously across the present Marathon region.

The following units were differentiated in mapping the Comanche series:

Comanche series:

Washita group	Georgetown limestone, subdivided into:	Mainstreet (Upper Cap Rock) Weno-Pawpaw Denton (Middle Cap Rock) Fort Worth Duck Creek Kiamichi
Fredericksburg group	Edwards limestone, including, at the base, Comanche Peak limestone and Walnut clay.	
Trinity (?)	Basement sands (in north)	Maxon sandstone (in south)
Trinity group	Glen Rose formation	

The areal mapping was supplemented by the measurement of about thirty sections, which were correlated as far as possible in the field by both lithology and faunas. (Pl. XV.) Unfortunately, most of the work was done without the aid of critical paleontological studies, and for this reason some of the minor problems of the stratigraphy remain unsolved.

For details regarding the zoning of the Comanche in this general region the reader is referred to the work of Adkins[54] in the Fort Stockton district. Stanton[55] has also published some reconnaissance observations on the region.

GLEN ROSE FORMATION

The Glen Rose formation outcrops along the bounding scarps of the Marathon Basin on both east and west sides as far north as the Glass Mountains where it ends abruptly by overlap. On the eastern side it extends as far as Gap Tank, and on the west, in the Del Norte Range, nearly to the latitude of Marathon. As here mapped, the formation includes all those beds between the base of the Comanche series and the base of the Maxon sandstone and is believed to be very nearly the equivalent of the Glen Rose at its type locality in Central Texas. The term has been given the same scope in this region by Stanton.[56]

In the region south of the Dimple Hills, in the eastern part of the Marathon Basin, the Glen Rose is two or three hundred feet thick, and it probably becomes still thicker toward the south. According to Stanton,[57] the zone of *Orbitolina texana,* with an abundant and characteristic fauna is well developed at many localities from the Southern Pacific railway near Maxon and Tesnus northward to near Gap Tank. At the railroad the zone of abundance of *Orbitolina* is about 100 feet below the base of the Maxon sandstone; to the north the interval becomes somewhat less. At Gap Tank and for about two miles to the south, the Glen Rose has a thickness of 50 feet or less. One and one-half miles south of Gap Tank (Sec. 61), it is made up of buff marls, in part sandy, interbedded with thin ledges of white marly limestones. The limestones contain oysters and rudistids. There are a few feet of conglomerate of small rounded limestone pebbles at the base of the formation. In the hills at Gap Tank, the lithology resembles that to the south, except that there are great numbers of limestone cobbles derived from the Permian not far to the north. The formation disappears abruptly by overlap against the Hess formation about a mile north of the tank.

[54]Adkins, W. S., The Geology and Mineral Resources of the Fort Stockton Quadrangle, Univ. Texas Bull. 2738.

[55]Stanton, T. W., The Lower Cretaceous or Comanche Series, Amer. Jour. Sci. (5), Vol. XVI, p. 404, 1928.

[56]Stanton, *op. cit.*, p. 404.

[57]For this and other information quoted below the writer is indebted to Dr. Stanton, who has generously furnished much unpublished material.

In the Del Norte Range the formation is very much the same; at the base of the Comanche is a conspicuous ledge of conglomeratic limestone, succeeded by marls and intercalated thin limestones. The upper part of these are probably of Walnut and Comanche Peak age, and they are succeeded by massive rudistid-bearing ledges belonging to the Edwards limestone. The Glen Rose thins northward from 250 feet to nothing in a mile and a half along the range. It is not unlikely that the formation was at one time continuous along the entire southern edge of the Glass Mountains, against which it overlapped.

For the most part, the Glen Rose rests upon the strongly folded Carboniferous with even contact, which is well exposed along the bare escarpments surrounding the basin (Fig. 31). Even the Dimple limestone, a ridge maker of some prominence under present conditions, does not break the regularity of the contact.

Well records indicate that the Glen Rose is also developed to the northwest of the Glass Mountains, though it is not known to be exposed at any place in this area. In samples from the Twin City Oil Company, Kokernot No. 1 well, north of Hovey, Udden and others report *Orbitolina* and *Chara* seeds in limestone at a depth of 3270 feet.[58] Since *Orbitolina* is not known to occur at any higher level than the Walnut clay, these beds may be of Glen Rose age.

MAXON SANDSTONE

This sandstone outcrops in a prominent ledge midway up the scarps along the east side of the Marathon Basin. It extends southward from the vicinity of Gap Tank at least as far as the southeast corner of the Marathon Basin; its southernmost observed outcrop is one mile north of the Jones ranch house. It was first described by Baker and Bowman,[59] though its age was not discussed, and later mentioned by Stanton,[60] who noted that it has much the same age and relationships as the Paluxy sand of north-central Texas.

Hill[61] cites Parker, Hood, Somervell, Erath, Bosque, Comanche, Hamilton, and Coryell counties as containing the most typical exposures of the Paluxy, though he also applied the name to the basal sand further west along the Callahan divide, the border of the Staked Plains, and the Fort Stockton region. This more extended usage is hardly justifiable, as these sands are but a portion of a transgressive series of basal sands of indefinite stratigraphic position. For this reason, within the area of this report, the basal sands in the north are termed the Basement sands. Those to the south, however, occurring at a definite level between rocks of Fredericksburg and Trinity ages are deserving of a formational name. The term Paluxy cannot be appropriately applied here because the two sands are now widely separated, and probably were never a continuous deposit. A new name, Maxon, is thus necessary.[62] The type locality of the formation is at Maxon Station, near the point where the Southern Pacific leaves the Marathon Basin. It outcrops in rather prominent ledges about 100 feet above valley level east of the station, and caps several buttes of Glen Rose formation to the west of it.

The sandstone outcrops in one or more conspicuous massive ledges cut by vertical joints which run through 25 feet or more of strata and cause the rock to break off in great cubical blocks. It is a brown, well indurated, coarse to medium-grained sandstone, with prominent cross-bedding. In some places there are one or more thin, shaly layers. One and one-half miles south of Gap Tank (Sec. 61), the sandstone is 90 feet thick. According to Stanton it is 145 feet thick in the scarps immediately to the north of Tesnus Station. Near the tank it loses its massive character and is interbedded with conglomerate and sandy marl. It passes out by overlap about a mile north of this place.

In the mesas from five to eight miles east of Gap Tank, this sandstone may be traced northward, overlapping beyond the point of disappearance of the Glen Rose formation, to form the Basement sands of that area.

No fossils were noted in the formation. Stanton[63] writes:

[58]From the files of the Bureau of Economic Geology. The portion of the record which describes probable Trinity is quoted by Adkins, *op. cit.*, pp. 34-35.

[59]Baker, C. L., and Bowman, W. F., Geological Exploration of the Southeastern Front Range of Trans-Pecos Texas, University of Texas Bull. 1753, p. 114, 1917.

[60]Stanton, *op. cit.*, p. 404.

[61]Hill, R. T., The Geology and Geography of Black and Grand Prairies, 21st Ann. Rept. U.S. Geological Survey, part VII, p. 167, 1901.

[62]For suggestions regarding this discussion, the writer is indebted to Dr. Stanton.

[63]*Loc. cit.*

Whether it should be classified as Trinity or Fredericksburg is largely a matter of personal preference. Following the precedent established in classifying the Paluxy sand of north-central Texas, which is in approximately the same stratigraphic position, it would be placed in the Trinity, but it may well be in part at least of Fredericksburg age.

BASEMENT SANDS

The Basement Sands form the basal Comanchean around the north, northeast, and east flanks of the Glass Mountains. At the east end of the mountains they are laterally continuous with the Maxon sandstone, with which they are in part at least contemporaneous.

These sands vary in thickness from 25 to 75 feet, but do not exceed that amount near the Glass Mountains. They consist generally of several layers of coarse, brown, cross-bedded, friable to quartzitic sandstone, interbedded with softer, more shaly, bluish to pinkish sandstones. In some sections there are beds of impure brown or red limestone. Some of the sandstone beds are full of small spherical iron concretions. The beds are lenticular in character as a rule, but certain characteristic members are in some places to be found over several square miles of area.

Pebbles are small in size and are rare. They consist of quartz and chert in small, well rounded, and in part highly polished fragments. In places more angular pebbles of limestone are seen, which are probably of local origin. This characteristic is in great contrast to the thick, coarse, lenticular conglomerates of the Bissett formation which underlies it in some places.

The formation thins out up the flanks of the Glass Mountains and disappears by overlap, so that the Edwards limestone rests directly on the Permian on the crests of the range.

In the Del Norte Mountains, for about three miles northward from the point of disappearance of the Glen Rose, the basal Comanchean consists of about 50 feet of clastic materials here mapped as the Basement Sands. These deposits consist of beds of limestone crowded with angular fragments of sandstone and limestone, interbedded with very fine-grained calcareous pink sandstone.

Adkins[64] suggests that in the Fort Stockton district the sand may be wholly or in part of Fredericksburg age, since it contains, near the top, a characteristic Fredericksburg fossil, *Exogyra weatherfordensis*. Farther south, where it passes over into the Maxon sandstone, it is probably all of Trinity age. It is possible that sands of several ages have been included in the unit as mapped, though extensive replacements of the Fredericksburg limestone by sandstone seem hardly probable, since no such change in lithology was observed in the tracing of its outcrops, and the Edwards limestone contains only insignificant sandstone members.

WALNUT AND COMANCHE PEAK FORMATIONS

At the typical sections of the Comanche series in Central Texas, the Edwards limestone is separated from the Trinity group beneath by a thin group of marls and soft limestones, constituting the Walnut clay and Comanche Peak limestone. The recognition of the equivalents of these beds in the Marathon region is one of the outstanding problems yet to be solved. In Central Texas the type sections are characterized by *Oxytropidoceras, Gryphaea marcoui, Exogyra texana,* and several other fossils, and are succeeded by the rudistid reef facies of the Edwards limestone. The abrupt change from a normal to a rudistid facies makes it easy to recognize the top of the Comanche Peak beds in that region, but elsewhere, where the rudistid facies is lacking, these same fossils are found to have continued through the whole of Fredericksburg time. The two oysters are of no value as zone markers, and a zonation based on ammonoid and rudistid ranges is yet to be established. For this reason, in outlying areas, such as the Glass Mountains, clays and marls beneath the Edwards rudistid facies cannot be definitely correlated with the Walnut and Comanche Peak without critical paleontological studies.[65]

Rocks certainly of this age are probably to be found in the Gap Tank area and to the south, since the succession here is known to extend from Trinity to Washita. The fifty feet of marls, sandy marls, and thin limestones which lie between the Maxon sandstone and limestone of the Edwards facies near Gap Tank are tentatively correlated with the Comanche Peak and Walnut formations.

[64]Adkins, *op. cit.*, p. 33.

[65]For a discussion of the zonation of the Fredericksburg, see Adkins, W. S., Handbook of Texas Cretaceous Fossils, Univ. Texas. Bull 2838, pp. 10-12, 1928.

Other marly beds of more doubtful character occur farther north. In some places they lie between limestone of the Edwards facies and the Basement sands; in others directly upon the Permian; while at many localities rocks of Edwards lithology rest directly on the Basement sands with no intervening clay. It may be that these clays and marls were local deposits laid down in the lower places of the sea bottom, or that they grade laterally into the Edwards facies.

Clays and marls occur over a considerable area near the mouth of Gilliland Canyon, where they directly overlie the Basement sands and are overlain by rudistid-bearing ledges of the Edwards facies. They were noted in the infaulted wedge of Comanche rocks one-half mile northwest of the Warren Ranch and in the buttes two miles north of the mouth of Gilliland Canyon (Sec. 33, Pl. XV). In three buttes about the same distance northwest of the mouth of the Canyon (Secs. 36, 35, and 34) the clays reach 90 feet in thickness, their maximum for the Glass Mountains; *Gryphaea marcoui, Exogyra texana*, and other species are abundant here.

A conspicuous outcrop of clay, resting directly on the Permian occurs on the summit of the Glass Mountains three miles north-northeast of Sullivan Peak and contains abundant casts of gastropods.

The clays may intervene between the Edwards limestone and the Basement sands in other places, but they are then either thin or concealed by talus. In the Sierra Madera area the sandstone is succeeded directly by rudistid-bearing massive limestones.

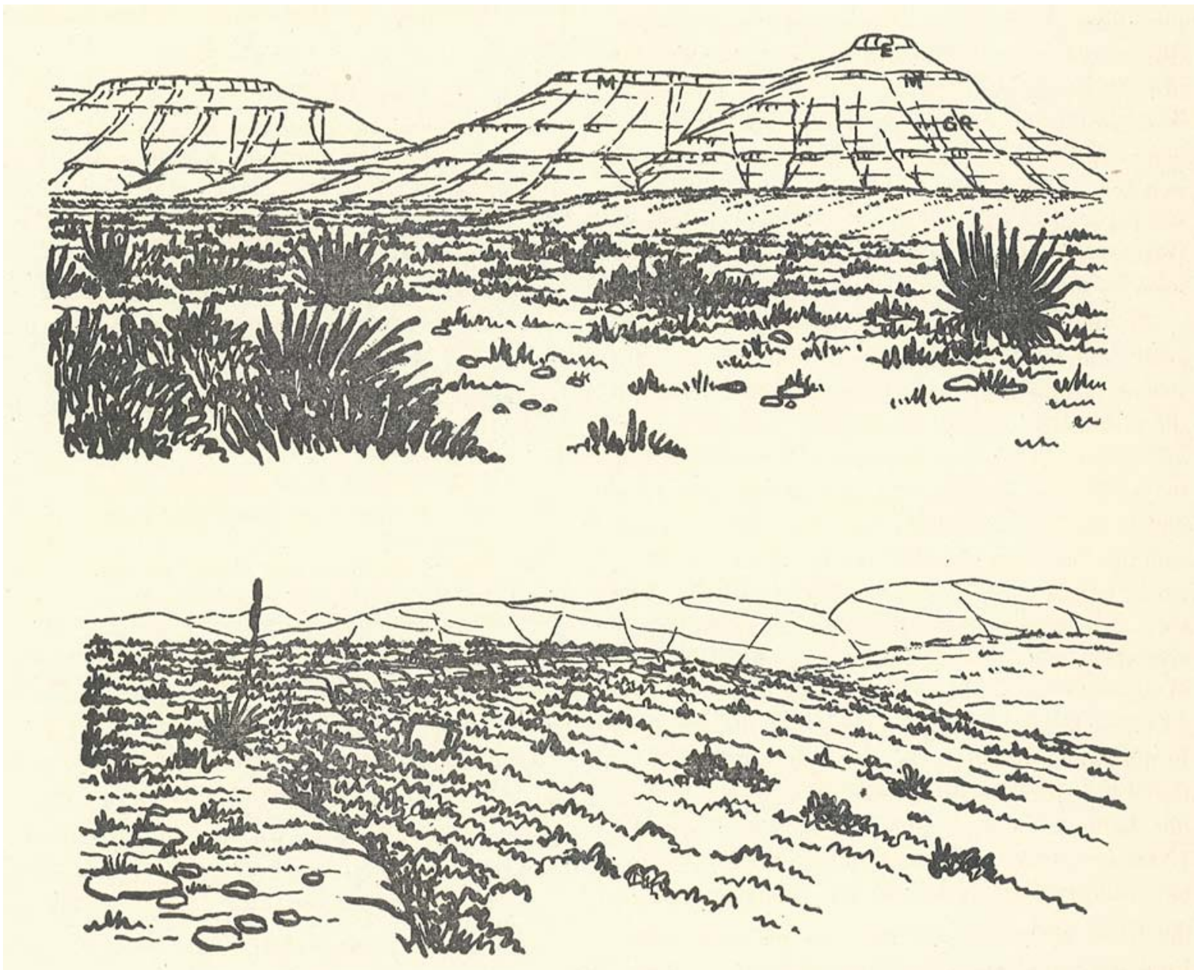

FIG. 30. *Upper.* Gap Peak, an escarpment of the Comanche series on the south side of the Marathon-Sanderson highway, twenty miles east of Marathon. Carboniferous rocks extend to the base of the steep slopes; the lower beds of the slope are Glen Rose (GR), and the top of the mesas is Edwards (E). The Maxon sandstone (M) forms the first ledge below the top of the Edwards. *Lower.* Edwards limestone on the crest of the Glass Mountains three miles north-northeast of Sullivan Peak. Capitan dolomites form the slopes below the ledge. The summits in the distance, which stand at a higher elevation, have been brought to their present position by faulting.

EDWARDS LIMESTONE

The Edwards limestone is the most extensively exposed formation of the Comanche series in the region. It varies in thickness up to 225 feet, and consists of resistant massive ledges of limestone, alternating with more marly strata, which outcrop as flat-topped buttes with terraced slopes.

The formation is predominantly a light gray, finely crystalline or dense limestone in layers from a few feet to ten or more feet in thickness. These beds always contain considerable quantities of brown or gray chert in the form of ovoid masses commonly arranged in continuous zones. These concretions average six inches in width, but a few masses several feet in thickness and many feet in width were noted. The massive ledges contain various types of rudistids and chamids which must have been of considerable importance in the formation of the rock. Between the more massive strata are others, usually thin, of more marly character; some are white marly limestones, but others are soft, argillaceous marls. Several of the cherty, massive, rudistid-bearing ledges are traceable over several square miles of area, as shown in the correlated sections, but none of them are continuous over the entire region.

The upper 50 to 80 feet of the formation is generally more marly than the rest and forms a persistent member, increasing in prominence toward the northeast. This is overlain in the western part of the mountains by a massive, rudistid-bearing ledge. In the northeastern part of the mountains and in the Sierra Madera area the marly member contains thin interbedded layers of brown limestone, and is capped by a thicker bed of the same sort. It is apparently of the same age as the "Fredericksburg clay" described by Adkins in the Fort Stockton district where it contains upper Fredericksburg fossils. The lower part of the Edwards formation is therefore doubtless the equivalent of the "Fredericksburg limestone" of that area, though the latter does not contain abundant rudistids. (Note correlation of section 56 with the Fort Stockton district, Plate XV.) In the northeast part of the Glass Mountains a thick, very massive, cherty limestone, with abundant rudistids lies beneath the shaly member and caps most of the mesas of the area. Over a wide region in the central and western part of the mountains the Edwards limestone rests directly on the Permian. At its base there are local thin sandstones and conglomerates, but in many places limestone lies in contact with the eroded surface of the Permian. Near the Sibley Ranch there is a five-foot bed of saccharoidal sandstone 30 feet above the base of the formation, and a sandstone was seen in the same position on the east flank of Sierra Madera.

The thickness of the Edwards limestone is variable, though it averages about 200 feet; it thins slightly toward the crest of the mountains by overlap. On the Sibley Ranch (Sec. 32), it was only 130 feet in thickness though it is here underlain by the Basement sands. At Gap Tank and toward the south it appears to thicken and one and one-half miles south of the tank, it reaches 220 feet in thickness (Sec. 61).

The following three sections are selected to show the character of the Edwards in various parts of the area:

SECTION 61

In the eastern part of the Glass Mountains, on the escarpment one and one-half miles south of Gap Tank.

Kiamichi marl.	Feet
(10) Gray, finely crystalline limestone containing *Requienia*	8
(9) Buff, marly beds, with two or three thin limestone ledges. Large masses of colonial corals were noted at one level in this member	73
(8) Six-inch limestone ledges, containing chert and *Requienia*, interbedded with layers of marl	16
(7) Ledge of gray, finely crystalline, cherty limestone, containing rudistids and *Pecten*	1
(6) Marly beds	8
(5) Finely crystalline, gray cherty limestone in 2′ beds, with marl in 4′ beds between. *Requienia*	24
(4) Alternating thin and thick layers of light gray or white, dense limestone	50
(3) Limestone containing *Requienia* and *Pecten*	3
(2) Disc-fractured, white or buff marly limestone, with a few thin hard beds	21
(1) Massive, light gray crystalline limestone	5
Marly beds (Comanche Peak-Walnut?) beneath.	
Total	219

SECTION 32

In the northeastern Glass Mountains, on Pyramid Butte, 1 mile northeast of the Sibley Ranch.

Kiamichi marl.	Feet
(6) Thin ledges of limestone, interbedded with marly limestone; many of the ledges	

	Feet
are brown	32
(5) Solid ledge of massive limestone containing rudistids	11
(4) Ledges of gray limestone in 3′ beds	32
(3) Poorly exposed limestone ledges in beds from 1′ to 3′ thick	11
(2) Brown calcareous saccharoidal sandstone	3
(1) Ledges of gray limestone in beds from 1′ to 3′ thick	32
Basement sands.	
Total	121

SECTION 40

In the Western Glass Mountains, on the summit of Bissett Mountain.

	Feet
(20) Finely crystalline white limestone capping the mountain	15
(19) Buff marl, with a few harder beds, the latter containing *Requienia*	20
(18) Medium crystalline gray limestone	1
(17) Not exposed	9
(16) White marly limestone	5
(15) White, finely crystalline limestone, with some large secondary crystals. A zone of cherts occurs near the top, along with *Requienia*	12
(14) Prominent ledge of white marly limestone, full of *Requienia*, with chert near the top	6
(13) White marly limestone outcropping in several ledges; weathers to a honeycombed surface	15
(12) Irregularly crystalline gray limestone, with obscure traces of fossils	2
(11) White marly limestone	9
(10) Minutely crystalline limestone, forming a ledge	5
(9) Dense gray limestone, containing abundant chert nodules	5
(8) Not well exposed, mostly marly limestone	16
(7) Dense gray limestone, forming a ledge, somewhat marly in places	15
(6) Buff marly limestone	5
(5) Dense gray limestone, forming a ledge	15
(4) Dense gray limestone, forming a prominent ledge	11
(3) Dense gray limestone, and buff marly limestone	16
(2) Dense gray and brown limestone in a massive ledge	10
(1) Brown sandy marl	5
Bissett formation.	
Total	196

GEORGETOWN FORMATION

The beds here mapped as Georgetown have been subdivided in some detail by Adkins[66] in the Fort Stockton district. Such a subdivision was not attempted in this area because the rocks have passed into their southern limestone facies and assumed the character of the typical Georgetown. Fossils were not always as abundant as desired for the determination of each zone. However, the beds mapped as Georgetown in the extreme northeast part of the area have much the same facies as that at Fort Stockton, and will yield to detailed subdivision with further work.

The formation outcrops in residual areas on the summits of mesas of the Edwards limestone. Many of these are found north of Bissett Mountain, and others on the northeast flank of the Glass Mountains, west of Sierra Madera. Most of them preserve only the lower part of the formation. The greatest thickness of these beds is exposed in the northeast part of the Glass Mountains. A butte eight miles south of Sierra Madera and east of the Fort Stockton road is capped with a massive limestone bearing *Radiolites*-like fossils. These beds are with little doubt the Upper Cap Rock (Mainstreet) of the Fort Stockton district. About half-way down the slope to the Edwards formation is another prominent ledge of Middle Cap Rock (Denton) age. Nearly all the rest of the mesas reach only to the Middle Cap Rock. The following section is typical:

SECTION 32

Measured on Pyramid Butte, 1 mile northeast of the Sibley Ranch.

	Feet
(4) Massive gray crystalline limestone, containing small silicified fossils (Middle Cap Rock)	10
(3) Imperfect ledges of white marly limestone (Fort Worth[67])	111
(2) White nodular marly limestone. On slopes, and in float below, the following forms were noted: *Hamites*, *Inoceramus*, *Protocardia*, various ammonoids (Duck Creek)	21
(1) Marl containing *Gryphaea navia* at top (Kiamichi)	62
Brown limestone forming top of Edwards.	
Total	204

In this region the Kiamichi marl is a striking unit, outcropping in prominent white or yellow slopes with little vegetation, which may be traced for long distances with the eye. The mound-like residual hills of the Georgetown are all collared around their bases by this light band.

[66]Adkins, *op. cit.*, pp. 41-60.

[67]It should be understood that the correlations given are provisional, and may not be precise equivalents.

Farther west, near Bissett Mountain, the marls are thicker and include the Duck Creek member; they are here overlain by white marly limestone, without fossils, which probably belongs to the Fort Worth member.

HIGHEST COMANCHE

In the main area of the Glass Mountains the Mainstreet member of the Upper Georgetown is the highest stratum exposed. This is succeeded normally by the Del Rio clay and the Buda limestone. Whether these beds or their equivalents are present between the Comanche and Gulf series along the western side of the area is not known as this area was studied only in an exploratory manner. The Del Rio and Buda are known to outcrop west of the Del Norte Range, south of the latitude of Doubtful Canyon, but it is not certain whether they extend any farther toward the north.

UPPER CRETACEOUS (GULF SERIES)

The Upper Cretaceous outcrops in the west and northwest parts of the area, in a district studied in reconnaissance only. For this reason only brief mention can be given of it.

Brown platy shales and flags of Eagle Ford age outcrop in poor exposures on the plain in the synclinal area northwest of the edge of the Altuda Quadrangle about 17 miles north-northwest of Altuda. Chalk probably of Austin age is exposed beneath the lava of Cenozoic age west of Altuda Mountain and Strobel, and south of Mount Ord. In the vicinity of Mount Ord, however, the Upper Cretaceous is wanting, and the lavas rest upon the eroded surface of the Comanchean. Beds intervening between the Comanche limestones of Altuda Mountain and the Del Norte Range, and the chalk exposures to the west are concealed beneath the wash of the strike valleys of Antelope Draw and Doubtful Canyon; the Eagle Ford is probably present here.

CRETACEOUS HISTORY

The beginning of the Cretaceous record in the Marathon region is marked by a gradual overlap of the seas upon a peneplain formed during the first half of the Mesozoic. Nearly all the rocks of the Marathon Basin, even the most resistant, were worn down to a level surface. The Glass Mountains area, however, appears to have stood as a

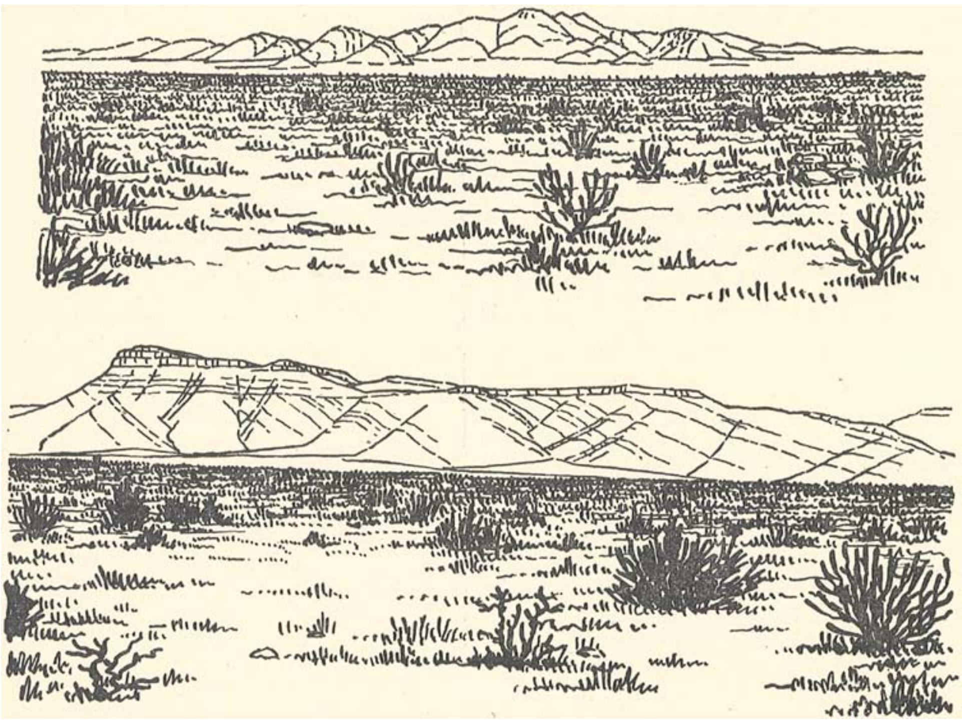

Fig. 31. *Upper.* View of Sierra Madera from a point three miles to the northwest.
Lower. The angular unconformity between the Comanche series and the Carboniferous (Tesnus formation) north of Tesnus station. The escarpment is a part of the cuesta bordering the eastern flank of the Marathon basin. Drawn from a photograph by L. V. Horton.

faint ancestral ridge several hundred feet in height. The peneplain was evidently somewhat warped during the transgression, allowing the seas to enter shallow depressions on the surface. Possibly the leveling of the surface upon which the Comanchean was deposited was perfected by marine erosion during the transgression.

At the end of Glen Rose time the ancestral Glass Mountains ridge projected westward as a peninsula into the sea, but a short time thereafter the peninsula was broken through at its eastern end, allowing the mountains to stand for a short time as an island until finally buried during Edwards time. By the time the Edwards was deposited over the higher places these had been swept clear of detritus and limestone was laid down directly upon the eroded surface of the Permian. Thereafter, deposition was continuous across the area. The shore line lay to the north, as is shown by the appearance of clays and shales in that direction, and the southward gradation of these into limestones which were probably deposited farther from shore.

CENOZOIC

VOLCANICS

West of the Del Norte Mountains, which bound the Marathon Basin on the west, are plateaus made up of lava flows and tuffs, which are a part of the Davis Mountains area. These break off to the east in prominent escarpments, one of which lies along the west side of the Del Norte Range from Strobel to Elephant Mountain. Mount Ord, 6800 feet in height, is its most imposing summit.

The volcanics rest with well-marked unconformity on the Cretaceous, but are themselves tilted to the west, away from the Marathon dome. At Mount Ord they rest on rocks of Washita age, while to the north and south various members of the Upper Cretaceous intervene.

Fossil leaves collected by Baker from the basal rhyolite tuff of the Barilla Mountains are stated by Berry to indicate an Eocene age.[68] The age of the volcanic series as a whole is, however, not known. Probably all of it is early Cenozoic.

PLEISTOCENE ROCKS

Two groups of Pleistocene deposits were mapped in the area. That which covers the greatest space is the wash, or detrital mantle of the pediment surfaces, which is of stream-laid origin. Smaller areas are occupied by landslides, caused largely by gravity.

Wash.—The extent and genesis of the wash deposits are discussed in the physiographic chapter, and they need be mentioned but briefly here. They cover the greater part of the pediments of the region, where they have been deposited by streams draining down from the mountain areas. Their thickness varies from a few feet to several hundred feet. Some of the deposits have the form of alluvial fans of the type designated as climatic alluvial fans by Blackwelder.

The deposits are largely derived from limestone areas and consist of sub-rounded to angular cobbles and pebbles, mostly of limestone and dolomite, in part cemented by caliche or secondary lime. In places, a buff marly clay, probably residual from limestone by weathering, forms a matrix for the fragments. Occasional boulders, reaching as much as four feet in diameter, occur in trains along the larger drainage channels as much as three miles from the foot of the mountains. Near the base of Iron Mountain the wash is decidedly arkosic, and derived from the weathering of the nearby igneous rocks; otherwise no material of igneous origin was seen in the wash mantle.

No fossils have been found in the detrital deposits, but there is evidence that at least some of it is of considerable antiquity. The wash deposits have been greatly dissected, in part by headward cutting of streams draining to the Rio Grande, and in part as a result of climatic changes. Some of the cutting has reached 100 feet in depth. Moreover, wash deposits on the south side of the Dimple Hills contain blocks of Comanchean limestone, though no channels drain to it which now contain outcrops of these rocks. The Comanchean outlier on the top of the hills must have been much larger at the time of the formation of the wash deposits.

Landslides.—At several places in the Glass Mountains, particularly at the base of escarpments where massive limestones cap weaker beds, landslides have taken place. This has brought about some misconceptions regarding the stratigraphy in the earlier work in the area. For this reason, and because of the fact that they cover sufficient area to necessitate separate mapping, a brief note regarding them is deemed worthy.

[68] Baker, C. L., 6, p. 123; for a detailed description of the flora, and a discussion of its correlation, see: Berry, E. W., An Eocene Flora from Trans-Pecos Texas. U. S. Geol. Surv. Prof. Paper 125-A, 1919.

At the west end of the Glass Mountains, fringing the base of the escarpment about two miles southeast of Altuda, are large confused masses of dolomite, which evidently have tumbled from the cliffs of the Capitan above. The slopes beneath the cliff are made up of outcrops of Word sandy shales, which also outcrop lower down in ravines that have cut through the entire thickness of the landslide material. Some of this displaced rock was considered to be in place by Udden (**5**, pp. 9–11), in his section 1, though he noted its irregular dip; it was placed by him in the Word formation, giving the latter a greater proportion of limestone in this region than is actually the case.

A similar landslide was seen on the south face of the mountain one and a half miles northeast of Sullivan Peak, where large mounds of confused dolomite blocks lie as much as one-fourth of a mile from the foot of the escarpment. On the escarpment itself, the underlying Word formation is mostly concealed by large and small blocks of dolomite of the Capitan, and platy siliceous shales of the Word. These have been cemented together by caliche, covered by soil, and dissected by gullies, indicating a considerable antiquity for the displacement.

Landslides of conglomeratic Hess limestone were found at the base of the escarpment one mile west from the south end of Iron Mountain, where they mask underlying soft Wolfcamp shales and Dimple limestones. This material was also considered to be in place by Udden (**5**, pp. 15–16), in his section 3, causing the basal members of his section to appear much thicker than they actually are. Similar landslides of massive Hess limestone over weaker Wolfcamp beds are found on the south and east sides of Leonard Mountain, where they greatly obscure the relations. This is unfortunate, because of the great stratigraphical importance of the relations of the Wolfcamp beds in this vicinity.

Great landslides of Edwards and Glen Rose limestones cover the slopes of mesas southeast of Gap Tank, where the underlying strongly deformed shales and sandstones belong to the Haymond fo-r mation. Some of the blocks reach 100 yards in length, and occur far out in the plain, indicating that they are dissected landslides of great antiquity.

IGNEOUS ROCKS

GENERAL CHARACTER

The igneous rocks of the Glass Mountains area consist of two main groups, a volcanic series which outcrops over the greater part of the Davis Mountains and extends into the western edge of the area mapped, and a group of intrusive masses of small areal extent but wide distribution in the Glass Mountains. Both groups of igneous rocks are of Cenozoic age. The volcanics have been shown by Baker and Berry to be at least in part of Eocene age, as revealed by plant remains occurring in interbedded tuffs in Jeff Davis County. Although the evidence is not conclusive, yet from the fact that the volcanics are tilted away from some of the intrusives in the western part of the mountains and from the fact that similar intrusive masses are known to invade the volcanics elsewhere, it would appear that the greater part of the intrusives are younger than the volcanic series. They are, however, older than the normal faults of probable Pliocene age.

The intrusive igneous rocks are probably all of the same age, as is suggested by their uniformity of composition. There is no evidence to show that any of them are older than the Tertiary, though the possibility that some of them are Mesozoic or Paleozoic is not disproved, since many of them are seen in contact only with Carboniferous and early Permian rocks.

The volcanic series was not studied in detail in the field, and it lies outside the area of chief interest in this report. A brief discussion of its more salient features has already been presented in its proper stratigraphic place under the heading of Cenozoic Rocks.

The intrusive rocks consist of several large stocks and laccolithic bodies, chiefly of syenitic composition, surrounded by groups of dikes and sills of trachyte, which undoubtedly have a genetic relationship to the larger masses. There are two main areas of these intrusive rocks. One of these is near Altuda Mountain, at the western end of the Glass Mountains, and the other is in the vicinity of Iron Mountain, at about the middle of the south side of the range.

The intrusive igneous rocks in the area were not studied in very great detail, and will no doubt yield much more information with further work.

However, no unusual features were discovered during the course of the field work, and their uniform appearance and composition, together with their small areal distribution, make them unattractive for petrographic study.

ALTUDA MOUNTAIN AREA

The largest igneous mass in the Altuda Mountain area is at the so-called Granite Mountain, or Granite Knob, one mile west of the James Ranch, and two miles south of the summit of the mountain. This locality was first noted by Udden (**3**, p. 70) in 1907, and the rock was called by him "the Altuda granite," which is not only a misnomer, but implies a formational name for the rock, when no such special term appears justified. Actually, the rock is a syenite or syenite porphyry. It outcrops on several rugged hills, covered with large exfoliating boulders, and occupies an area of about a square mile.

The form of the mass is roughly circular, and it appears to be very largely responsible for the uplifting of the rocks of the Altuda Mountain area. It is, however, not a laccolith in the strict sense of the word, for it exhibits well-marked cross-cutting relationships. Along the north side it is in contact with steeply dipping Leonard limestones and siliceous shales. One of the limestone beds is marmarized for several feet from the contact. Beyond the Leonard formation, successively higher members of the Permian appear to the north, all dipping away from the intrusion. On the west side of the uplift the igneous rock cuts across successively higher strata, until on the southwest and south sides it is in contact with the thin-bedded limestones of the Altuda member of the Capitan formation. Along the eastern side of the intrusive body, the uplift of the sedimentary rocks has been accompanied by faulting, for Leonard outcrops lie closely adjacent to the Altuda member.

Hand specimens[69] of the rock are seen to be highly kaolinized and otherwise altered. The rock is phanerocrystalline, medium-grained, and of light gray color. Flow structure is suggested by a parallel alignment of the darker constituents. Under the microscope the rock is seen to consist largely of kaolinized feldspar, probably mostly alkalic, abundant green amphibole, some titanite, and a few altered grains of what may have been nephelite. Dr. Lonsdale considers the rock to be a syenite, which is probably nephelite-bearing. It is not especially porphyritic.

Closely related to this intrusive mass are several small dikes to the north, mostly of trachytic composition, but one of which, outcropping in a valley one-quarter of a mile northeast of the central intrusion, appeared to be of more basic character. Farther north, in the ring-like outcrop of tilted strata surrounding the central intrusion, are two sills of trachyte, each about 50 feet in thickness. One of these, one mile north of the central intrusion, has a length of outcrop of about one mile, and lies near the middle of the Word formation. The other sill, to the northwest, has a length of outcrop of one and one-quarter miles and lies within the thin-bedded limestones of the Altuda member.

On the north side of Altuda Mountain, near the Bird Mine, are several other intrusive masses, which have cross-cutting relationships to the sedimentary rocks. On the south side of the first large valley north of the mountain is a circular mass about 700 feet in diameter, which invades the flat-lying beds of the Altuda member, and which rises as a prominent beehive-like knob on the slope of the mountain. This was the scene of the greatest development work on the properties of the Bird Mine, but the old underground workings were not examined during the present study. The contact rock consists of greatly brecciated material, made up of fragments of baked and partially recrystallized sedimentary rock, and of igneous fragments. The main mass of the body, however, consists of fine-grained syenite porphyry, very much like the other intrusives in the area. The brecciated character and the cylindrical form of the intrusion were suggestive of a volcanic neck, but no additional evidence which might sustain this interpretation was obtained.

One-quarter of a mile away, on the north side of the valley, another mass of syenite porphyry of similar dimensions appears also to be a plug. Toward the east are several small dikes and sills.

One of the dikes, a quarter of a mile east of the mine, is megascopically a dark gray or greenish-gray aphanitic rock, in which a few crystals of feldspar and quartz are imbedded. Some fresh surfaces show a faint violet-gray color. Under the

[69]All petrographic descriptions of hand specimens and thin sections which are given in this chapter were made for the Bureau of Economic Geology, from the writer's small collections, by Dr. John T. Lonsdale, of Texas A.&M. College. The writer wishes to express at this place his great indebtedness to Dr. Lonsdale for making this examination.

microscope the rock is seen to consist of a fine felty aphanitic ground mass, partly of glass, and partly crystalline, in which are imbedded numerous phenocrysts of albite and sanidine, all of which are much smaller than the phenocrysts seen in the hand specimen. A considerable number of fluorite grains were noted, most of which occupy vesicular openings in the rock. Dr. Lonsdale considers the rock to be a sodic trachyte, for the large blebs of quartz in the rock are too few to justify the use of the term rhyolite. The rock is suggestive of a keratophyre.

Three miles northeast of Altuda Mountain, near the Old Young Place, are other outcrops of syenitic igneous rock, evidently closely related to the Altuda Mountain intrusion. These invade quartzites, probably belonging to the Word formation, which rise as an isolated hill on the plain. These rocks are high above their normal position, and have probably been uplifted by forces accompanying the igneous intrusion.

The Bissett Mountain dome deserves mention at this place, though no igneous rock is known to outcrop on it. It lies several miles to the east of the Young Place exposures and is a broad structural dome of Permian and Cretaceous rocks which very probably had its origin from a laccolithic intrusion not yet exposed at the surface. Near the structural center of the dome, at the Bissett Mine, there has been some replacement of the Capitan dolomites by iron and copper minerals, and the surrounding rock has been dedolomitized and converted into a finely granular pink marble, much veined by calcite.

IRON MOUNTAIN AREA

The largest intrusion in this area is that of Iron Mountain, at the south foot of the Glass Mountains, and from this place stocks, dikes, and sills are found rather abundantly for a distance of seven miles to the northeast. The sedimentary rocks dip away northwest and northeast from the Iron Mountain mass and it appears also to have been genetically related to the formation of the large anticline which trends from it down Gilliland Canyon. The most notable structural effect of the intrusions, however, is that produced by the smaller mass on the Hess Ranch horst six miles northeast of Iron Mountain, where a block of Permian strata have been uplifted as a mass to at least 2000 feet above their normal positions in the surrounding area.

Iron Mountain is an oval mass of igneous rock, rising abruptly at the south base of the Glass Mountains, seven miles north of the village of Marathon. It is about one and one-half miles in length and a mile in width, with its greatest elongation toward the north-northeast. Its south and southwest face is a steep curved surface of bare rock, over which concentric sheeting is developed on a large scale. Toward the northeast the igneous rock is transected by several systems of close-set vertical joints, and in this part of the mountain the rock outcrops are less bold and more broken and irregular. On all sides of the mountain the igneous rock pitches steeply beneath an alluvial flat, and at no point was a contact with sedimentary rock observed. A similarly isolated, but smaller mass of igneous rock rises abruptly from the alluvial plain one-quarter of a mile northwest of the northeast end of Iron Mountain.

Because of its isolated character, it is not possible to state definitely the youngest formation invaded by the mass, nor the age of the intrusion. However, indirect evidence leads to the conclusion that it is certainly post-Permian, and probably post-Cretaceous. Dikes of similar composition invade the Permian rocks on Leonard Mountain to the northeast and to the northwest large calcite veins cutting Permian rocks are very numerous in the vicinity of the mountain. The Permian rocks dip northeast, north, and northwest away from the intrusion, at angles of 10° to 15°. To the south, some of the complexity of structure in the Carboniferous rocks is probably to be explained by the force of the intrusion. The Iron Mountain intrusive is probably a member of the system of Cenozoic intrusions found elsewhere in the area.

It is probable that the intrusion of Iron Mountain has the form of a stock, and it has been so interpreted on the cross-section sheets. It is likely that the present form of the mountain represents very nearly the outline of the original mass.

Specimens of the igneous rock collected from a small quarry on the south side of the mountain are holocrystalline and porphyritic, consisting of abundant phenocrysts of feldspar in a ground mass of alkali feldspar and quartz, with small amounts of accessory minerals, including biotite, augite, magnetite, zircon, and apatite. The feldspar phenocrysts reach 4 mm. in length and are oligoclase-albite. The rock apparently shows considerable variation from place to place, since Cross[70] described specimens, exact locality unknown, containing no biotite or augite, but with titanite. Dr. Lonsdale calls this rock a syenite porphyry, since this name has already been assigned to it by Cross, but calls attention to the small but distinct amount of quartz present. A chemical analysis of the specimens described by Cross, and the norm of the rock are given below.[71]

Chemical Analysis		*Norm*	
SiO_2	65.47	Q	7.50
Al_2O_3	17.93	or	30.58
Fe_2O_3	2.15	ab	52.40
FeO	0.43	an	4.73
MgO	0.06	C	0.41
CaO	1.10	hy	0.20
Na_2O	6.21	mt	0.46
K_2O	5.21	il	0.61
H_2O	0.19	hm	1.92
H_2O	0.41	ap	0.32
TiO_2	0.29		
ZrO_2	0.07		
MnO	tr.		
SrO	tr.		
BaO	0.16		
LiO	nil.		
S	tr.		
CO^2	tr.		
Rare earths	0.05		
Total	99.92		

Several dikes of trachyte are exposed at the west end of Leonard Mountain, which penetrate the Hess limestone, and which are probably offshoots of the Iron Mountain mass. Along the east base of the mountain, several dikes and small stocks are exposed which penetrate the Wolfcamp and Hess formations. Locally also the limestones have been replaced by iron minerals. Specimens collected from a dike on the east slope of the mountain are stated by Dr. Lonsdale to be a trachyte composed mostly of feldspar laths in parallel orientation.

The largest of these masses outcrops on the flat one-half mile south of the Hess Ranch and is separated from other outcrops of the bed rock by alluvial deposits. It is a fine-grained holocrystalline rock, with a trachytic texture. About 90 per cent consists of sanidine laths and prisms with a common direction of orientation. The few phenocrysts are corroded and resorbed. Quartz fills some of the interstices between the feldspars and makes up 9 per cent of the rock while the remaining part consists of decomposition products of ferromagnesian minerals and of fluorite. This rock is classed as a rhyolite with a trachytic texture by Dr. Lonsdale.

Northeast of the Hess Ranch are other masses of intrusive igneous rock. Several small plugs of trachyte are found on the low spur of Hess limestone one-half mile north of the ranch house and the wide distribution of replacement deposits of iron minerals in the limestone of this vicinity attests a wider extent of the porphyry masses beneath the surface.

Two and one-half miles northeast of the Hess Ranch is the intrusive body of the Hess Ranch horst. As noted in the structural chapter the horst is a block of Wolfcamp and Hess strata three miles in length and one and one-half miles in width, which has been uplifted as a mass nearly 2000 feet above the surrounding rocks. The igneous body lies along the southeast edge of the horst, about 700 feet from the southern marginal fault. From it, the sedimentary rocks dip away at steep angles, on the southeast at 60°, and on the northwest at 20°. The igneous mass is an elongate body, trending northeast, having a width of a few hundred feet, and a length of nearly three-quarters of a mile. Wolfcamp shales, with which it is in contact on the northwest side, are considerably baked and hardened near the intrusion. The rock is a syenite porphyry, very similar megascopically to that of Iron Mountain. To the north and northwest of the main intrusion, several small plugs and dikes are seen to invade the sedimentary rock of the horst.

OTHER AREAS OF IGNEOUS ROCK

Eight miles north of Iron Mountain, a mass of igneous rock about one-half mile in diameter rises as a sharp peak on the east side of Gilliland Canyon. This mass is isolated by many miles from the other intrusions of the area. It is seen to invade Vidrio and Gilliam dolomites, and also a small outlier of Edwards limestone on its eastern side. Its form, and its cross-cutting relationships to these rocks, suggest that it is a stock. This mass appears to have produced no structural effect on the surrounding rock, since it lies in the trough of a shallow syncline. One of the large normal faults which transect the mountains passes within a few hundred yards of its southeast end, and contains fragments of igneous rock in its breccia, indicating that the intrusion antedates the faulting. The rock

[70]Cross, W., United States Geological Survey Bulletin 591, p. 61.
[71]United States Geological Survey Professional Paper 99, p. 293.

is aphanitic, but apparently is of much the same composition as the other intrusive masses in the region. Another outcrop of igneous rock is shown on Udden's map farther north down Gilliland Canyon, but a careful search during the present study failed to locate it; it is probably very small.

East of the Hess Ranch along the base of the Glass Mountains escarpment is a sill of igneous rock about 40 feet in thickness, which lies in the thin-bedded limestones of the lower part of the Hess formation. It is probably related to the igneous masses of the Hess Ranch area, but it stands at a considerable distance from the other intrusive masses of the area. Its westernmost exposure is three miles east of the ranch, and from this point it has been traced continuously for two miles to the east, to the vicinity of Wolfcamp, beyond which it apparently dies out. The rock consists of syenite porphyry of a somewhat finer texture than that of Iron Mountain. The inclosing sedimentary rocks show no effects of heating or contact metamorphism.

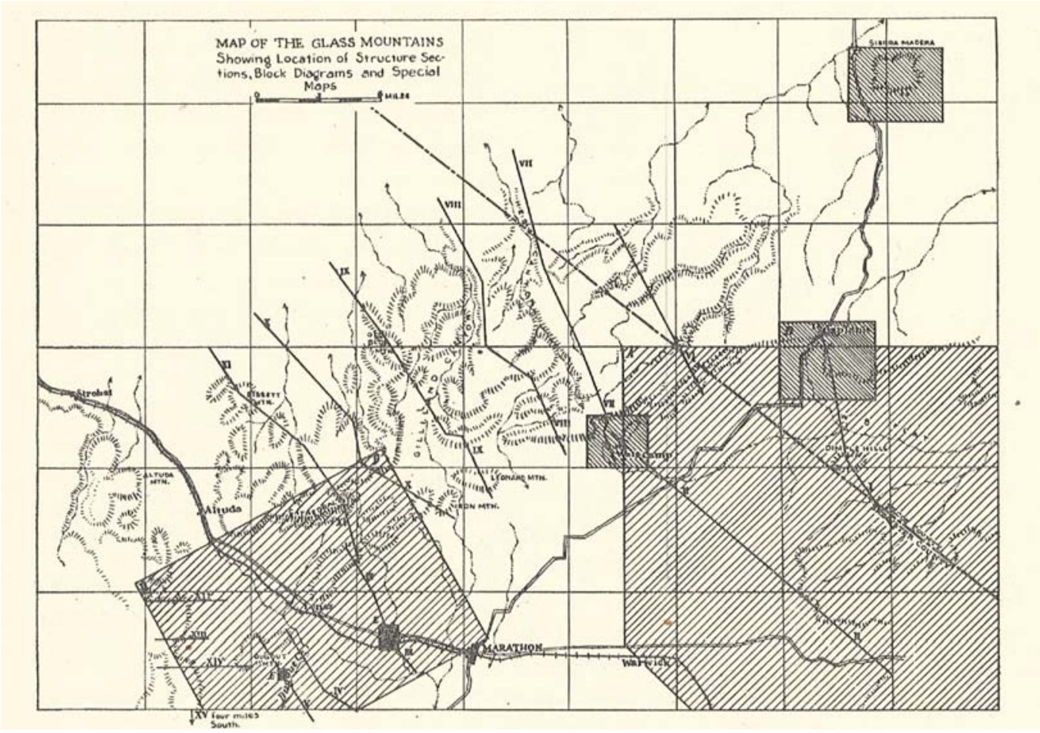

Fig. 32. Map of the Glass Mountains, showing the location of structure sections, block diagrams, and special maps. Cross-sections I to V are shown on Plate IV; cross-sections VI to XI on Plate VIII; cross-sections XII to XV on Figure 41. The shaded area A is a block diagram shown in Figure 16; B is a map shown in Figure 15; C is a map shown in Figure 19; D is a block diagram shown in Figure 37; E represents maps shown in Figure 13, D and E; F is a map shown in Figure 42.

GEOLOGIC STRUCTURE

Deformation in the Marathon region was recurrent in several geologic periods, and as a result the structure is complicated. The known periods of deformation are indicated in the accompanying Figure 33.

For purposes of description, we may divide the structural features of the area studied into three groups. The structures of the Marathon Basin, produced at the end of the Pennsylvanian, will be described first; then the structures of the Glass Mountains and adjacent areas, largely of post-Cretaceous age; and finally, an attempt will be made to separate from this group the structures possessed by the Permian before Cretaceous time.

THE MARATHON BASIN

GENERAL FEATURES

In the Marathon Basin there is exposed a system of ancient structures of Appalachian type, the Marathon folds produced by the Marathon disturbance which closed the Pennsylvanian in Trans-Pecos

Texas. They are made up of closely folded geosynclinal strata; graptolite-bearing, black, shaly limestones and bedded cherts in the lower part, and a vast succession of sandstones and shales in the Carboniferous portion above. The Marathon folds in their geosynclinal facies are also exposed in the Solitario, 35 miles to the southwest, and they also resemble the Ouachita Mountains of Oklahoma and Arkansas in structure, facies and age. In the Hueco and Diablo Mountains, to the northwest, the gently wrinkled foreland is brought to the surface.

The major features of the Marathon Basin are plainly revealed by the hogsbacks of the pre-Carboniferous Caballos novaculite and the mid-Carboniferous Dimple limestone, which rise as a skeleton of the greatly denuded mountains. (See under Physiography, pp. 12–29.) The minor features, on the other hand, are in many places complex and obscure, a fact further complicated by the extensive mantling of the lowlands by mountain waste.

The structure consists of northeast-trending folds, overturned toward the northwest. Many of these are broken by thrust faults; the faulting culminates on the northwest in the Dugout Creek overthrust, with a known displacement of over six miles. These folds are crossed in a north-northwesterly direction by cross-warps; in the western half of the basin the folds are arched up and structurally this is the highest portion of the area; in the eastern half there is a complementary depressed area whose axis extends roughly from Tesnus to Gap Tank. Two large doubly-plunging anticlinoria lie athwart the arch and expose pre-Carboniferous rocks; these are here named the Dagger Flat and Marathon anticlinoria. Only the northern, or Marathon, anticlinorium lies within the field of this report. The Dugout Creek overthrust is laid bare in its center as a result of the warping. (Fig. 34.)

Estimates of the amount of crustal shortening were made in the openly folded area between Haymond and Gap Tank, allowing faults their minimum possible throw and the folds their minimum possible height. This indicated a shortening by about one-third. If we apply this estimate to the known present width of the folded belt, about 40 miles, it indicates a crustal shortening of 20 miles.

	AGE	INTENSITY	CHARACTER		WHERE FOUND	
TERTIARY	Late Tertiary		Normal faulting and uplift (?)		Glass and Del Norte Mountains	
TERTIARY	Mid-Tertiary (Post-Eocene)		Gentle folding	Igneous Intrusions	Mt. Ord area and Davis Mtns.	Not separable in the Glass Mountains.
TERTIARY	Laramide Revolution (Close of the Cretaceous)		Folding, increasing in intensity in western Trans-Pecos Texas		Del Norte Mtns.	
MESOZOIC	Later Mesozoic		Quiesence. Peneplanation, followed by submergence			
MESOZOIC	Late Permian or Early Mesozoic		Tilting and warping		Glass Mountains	
PERMIAN	Late Permian (Post-Tessey and pre-Bissett)		Uplift		Glass Mountains	
PERMIAN	Early Permian (Post-Wolfcamp and pre-Hess)		Tilting and folding		Glass Mountains	
CARBONIFEROUS	Caballos Disturbance (Post-Gaptank and pre-Wolfcamp)		Strong folding and overthrusting		Marathon Basin	
CARBONIFEROUS	Late Pennsylvanian (Mid-Gaptank)		Beginning of folding		Marathon Basin	
CARBONIFEROUS	Earlier Carboniferous (Tesnus to Haymond time)		Strong uplift of hinterland (indicated by thick clastic deposits)		Marathon Basin	
	Mid-Paleozoic (Pre-Tesnus and post-Caballos)		Uplift and retreat of sea.		Marathon Basin	

FIG. 33. Table showing periods of crustal disturbance in the Marathon basin and Glass Mountains. For "Caballos" disturbance in the legend read "Marathon" disturbance.*

*Since this manuscript was written evidence has been obtained of an orogenic epoch in the Marathon Basin in late Haymond time, when overthrusting took place in the south part of the district.

It is not unlikely that the actual figure is much larger, in view of the extensive overthrusting.

The strata of the Marathon Basin are nearly unmetamorphosed, though the sandstones and shales are somewhat indurated, and the latter approach slates toward the southeast. The brittle novaculite and chert members of the pre-Carboniferous have responded to deformation by fracturing and gliding and are broken in many places into an imbricate structure. The lower portions of the Carboniferous are deformed into broad competent folds several miles across, without noticeable crumpling. The Gaptank at the top of the Carboniferous, being made up largely of shales and thin sandstones, has responded by incompetent folding, which is of great complexity beneath the Dugout Creek overthrust.

HAYMOND-GAP TANK AREA

The Haymond-Gap Tank area embraces the northern part of the belt of downwarping referred to above, which occupies the eastern half of the Marathon Basin. The area is bounded on the southwest by zig-zag novaculite hogbacks forming the downward plunging termini of the Dagger Flat and Marathon anticlinoria. The formations exposed in the area are of Carboniferous age, with the youngest rocks exposed at Gap Tank, which is structurally the lowest point in the Marathon Basin. (Figs. 16 and 35.)

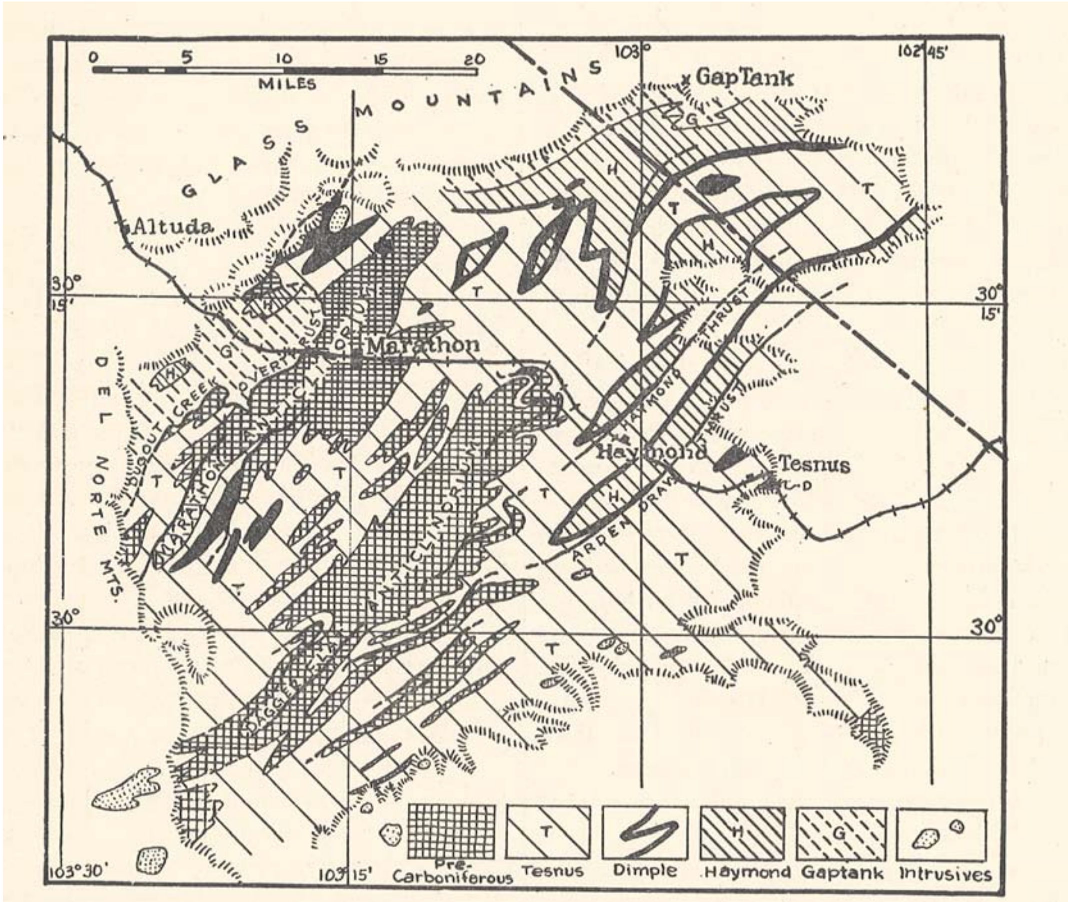

FIG. 34. Structural map of the Marathon basin to show general relationships. Note the northeast trend of the folds, and the northwest-trending cross-folding, represented by an arch crossing the Marathon and Dagger Flat anticlinoria, and by a downwarp between Tesnus and Gap Tank. The Dugout Creek overthrust is brought to the surface by the cross-folding. That portion of the map south of the area of the main geologic map (below 30°10′) is generalized from reconnaissance surveys of the writer for the United States Geological Survey in 1929.

Interpretation of the structure of the region is made difficult by the extensive Pleistocene cover of the lowlands and the considerable areas still covered by outliers of the Comanche. Fortunately, however, the structure is relatively simple, with broad, open folds and few faults. The Dimple limestone, which serves as a key horizon for the interpretation of the structure, is well exposed in sharp hogbacks, though erosion has breached them along master superimposed streams.

Three synclinoria cross the downwarped area in a general northeasterly direction, and are separated by two anticlinorial areas. The anticlines are steeply dipping or even overturned on their northwest flanks, whereas on the southeast flank dips are more gentle, ranging from 30 to 60 degrees. There is a noticeable lack of local crumpling and drag folding, so that dips are regular and the structural axes may be traced with some ease. The only exception is to be noted in those parts of the Dimple formation where considerable shale is intercalated between the limestones; these portions have many small drag folds, with confusing dips, particularly near the axes of major folds.

The axis of downwarping crosses the folds in a north-northwest direction and lies approximately along a line between Tesnus and Gap Tank, passing through the Dimple Hills. In the western part of the area the folds consistently plunge northeastward toward this axis. The axis of the minor syncline which crosses the Sanderson highway 15 miles east of Marathon, has an observed pitch of 25° NE on the Tesnus formation. The eastern flank of the downwarp is largely concealed beneath the Comanchean overlap, though a westward pitch of the axis of the central of the three synclinoria is shown by the abrupt turning about of the Dimple hogbacks five miles east of the Dimple Hills.

Three major and one lesser thrust fault break the anticlines on their northwest sides. The major thrust faults are here named, from southeast to northwest: the Arden Draw, the Haymond, and the Frog Creek. These faults break the continuity of the Dimple hogbacks, and place the Tesnus sandstones and shales in contact with the Haymond rocks of similar lithology, making an interpretation of structure difficult. Baker (**6**, p. 107; **14**, p. 1114) has suggested that the Haymond formation of this region may in reality be Tesnus formation thrust over Dimple, and then infolded, but this seems hardly possible in view of the wide extent of the formation, its gradational relations with the Dimple, and the absence of fracturing, brecciation, or other thrust features at the base.

The Frog Creek thrust is exposed in several ravines which notch the Dimple hogback eight miles S 75° E of Wolf Camp (Fig. 36). Its plane here dips 20° E, with Dimple thrust over Haymond. There is very little fracturing or brecciation at the contact. Five miles to the south, where Tesnus is thrust in contact with Dimple, it must be steeper, for the Dimple of the downthrown block slopes up from the fault at an angle of over 40 degrees. No exposures of the Haymond and Arden Draw thrusts were seen, and their trace is nearly everywhere occupied by a fault-subsequent valley. The minor thrust between the Haymond and Frog Creek thrusts is exposed one and a half miles north of the Sanderson road 16 miles east of Marathon, and has a dip of 45° where Dimple is thrust over Haymond.

The Dimple Hills, which rise as a dome-shaped group of hills on the south side of W B Flat, are a basin of moderately folded Dimple limestone produced by downwarping of the crest of an anticlinorium. Though dips in the hills range from 20° to 45°, those on the flanks of the anticlinorium are much steeper, and are even overturned on the north. The hills lie on the axis of the major cross fold of the area, which is continued northward into the Gap Tank area, where the Gaptank formation, at the top of the Carboniferous, is exposed.

The Gaptank formation of this area is folded into several broad anticlines and synclines with dips, averaging 20 degrees, though becoming much greater along local minor folds which are common in this generally incompetent formation. At several places about a mile south of the tank, limestones of the middle Gaptank stand vertically. On the north flank of the northernmost anticline, whose axis is one and a half miles south of the tank, the dips gradually flatten, and the formation passes beneath the Permian to the north with equal dip and strike, that is, about 20° N. Whether the Gaptank formation at this place was folded at the same time as the rest of the Pennsylvanian to the south is a problem still in dispute. Baker (**6**, pp. 107–112; **14**, pp. 1111–1114) has argued that it is younger than the folding of the older rocks, whereas the writer (**12**, p. 117) as well as Schuchert (**11**, pp. 388–390) and Keyte, Blanchard, and Baldwin (**9**, p. 117) have concluded that they were all deformed at the same time. Evidence is presented elsewhere in this paper, however, which shows that folding had begun to the south of

Gap Tank as early as lower Gaptank time. Conclusive evidence regarding the problem is difficult to obtain here because of the extensive Pleistocene cover. To the west, the upper Gaptank is seen beneath the Wolfcamp of the basal Permian in scattered exposures as far west as Wolf Camp, always maintaining an apparent conformity. To the east the base of the Permian is again exposed near the Allison and Gilbert Ranch, three miles east of the tank, at this place and to the east it rests on the Haymond formation. Such a relationship is hard to explain on any other basis than a structural unconformity whereby the Gaptank was removed by erosion. The folds of the Gap Tank area plunge from both east and west toward the axis of the downwarp, which lies to the east of the tank. The anticline one and a half miles south of Gap Tank, in the Gaptank formation, plunges east and that three miles southeast of the tank, in the Haymond formation, plunges west. (See Fig. 35 and Fig. 15, showing detailed map of Gap Tank area.)

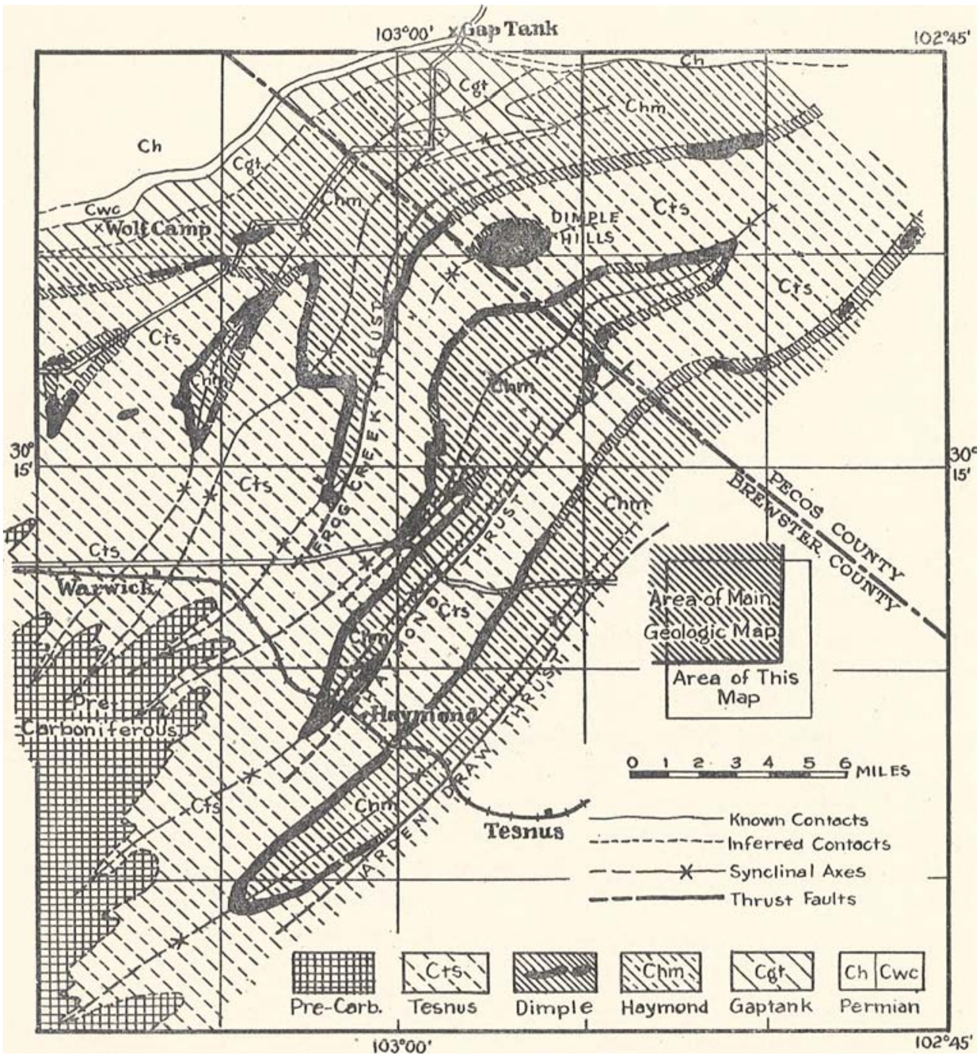

FIG. 35. Areal geologic map of the Paleozoic rocks of the northeast part of the Marathon basin, in which the Comanchean and Pleistocene cover is disregarded. There is considerable interpretation in certain parts of the area in which there are only scattered exposures. Known outcrops of the Dimple formation, which serves as a key horizon in the interpretation of the structure, are shown in black. The data south of the area of the main geologic map are obtained from reconnaissance work by the writer in the summer of 1929. The Carboniferous pre-Carboniferous contact, which is actually broken by many thrust faults, is generalized.

MARATHON-DUGOUT CREEK AREA

This area embraces the northwest part of the Marathon Basin, and lies across the belt of upwarping; it includes the northern part of the Marathon anticlinorium. In the northwestern part of the area, the Dugout Creek overthrust, which brings pre-Carboniferous rocks above the Gaptank formation, is exposed, evidently as a result of the warping. For purposes of description we may conveniently divide the structures of the area into those of the overridden, and those of the overriding block.

the surface, and is not known to be exposed in this direction again. Farther to the east, the outcrop of the fault is masked by wash deposits, except for a small exposure on the Hargus Ranch. (Fig. 37.)

North of the railroad, however, on the Decie Ranch, small klippen, or outliers of the overthrust sheet, mostly of novaculite, are found resting on the Gaptank formation. North of the ranch, at

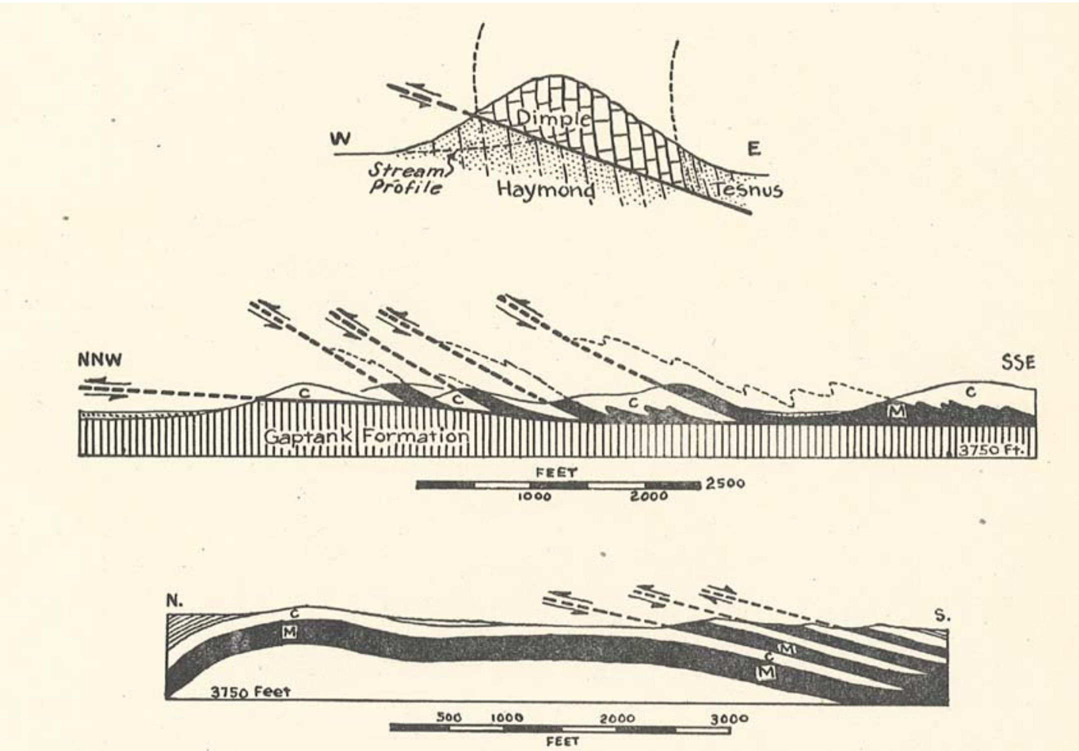

FIG. 36. *Upper.* Sketch showing the outcrop of the Frog Creek thrust fault eight miles S 75° E of Wolf Camp. The thrust is exposed in a small ravine in the Dimple hogback, whose profile is shown by a dotted line.
Middle. Section showing imbricate structure of overriding block of Dugout Creek overthrust south of Dugout Creek. C—Caballos novaculite; M—Maravillas chert; the structure of the Gaptank of the overridden block is complex, and obscured by surface deposits, and is not shown.
Lower. Section showing imbricate structure in chert and novaculite on an anticline two miles south of Leonard Mountain. M—Maravillas chert; C—Caballos novaculite.

The Dugout Creek overthrust is best exposed about seven miles west of Marathon, in the hills south of Dugout Creek, where Caballos novaculite and Maravillas chert rest upon the upper part of the Gaptank formation. The fault plane is nearly flat here, as is revealed by the position of its dissected trace. At the east end of the hills, the trace of the fault turns to the south for more than a mile around a reëntrant valley in which there are wide exposures of the upper part of the Gaptank formation. To the south, the fault pitches gently beneath the base of the Permian escarpment, is a considerable area of chert and novaculite, with exposures of Gaptank formation to the north and south. Relations are obscured by wash, but the pre-Carboniferous has probably attained its present position by overthrusting. This exposure is four miles from the present main front of the fault, and gives it a known displacement of five and one-half miles. Another exposure, possibly related to the overthrust, is that of the Gaptank underlying the Permian northwest of Iron Mountain. Not far to the south are exposures of Dimple formation, but they have not been seen in contact. The two formations have attained their present proximity either by an unconformity at the base of the Gaptank, a steep thrust fault, or an overthrust carrying the Dimple over the Gaptank formation. The latter interpretation is partially confirmed by the coincidence of this locality with the position of the trace of the overthrust as inferred from other evidence. complicated by the development of imbricate structure, resulting from the brittle nature of these formations. This was noted south of Leonard Mountain (Fig. 36C), where chert and novaculite dipping uniformly 10 to 20 degrees SE are repeated several times, evidently by thrust faulting. A similar repetition of the chert and novaculite to form an imbricate structure is seen in the hills south of Dugout Creek, immediately above the

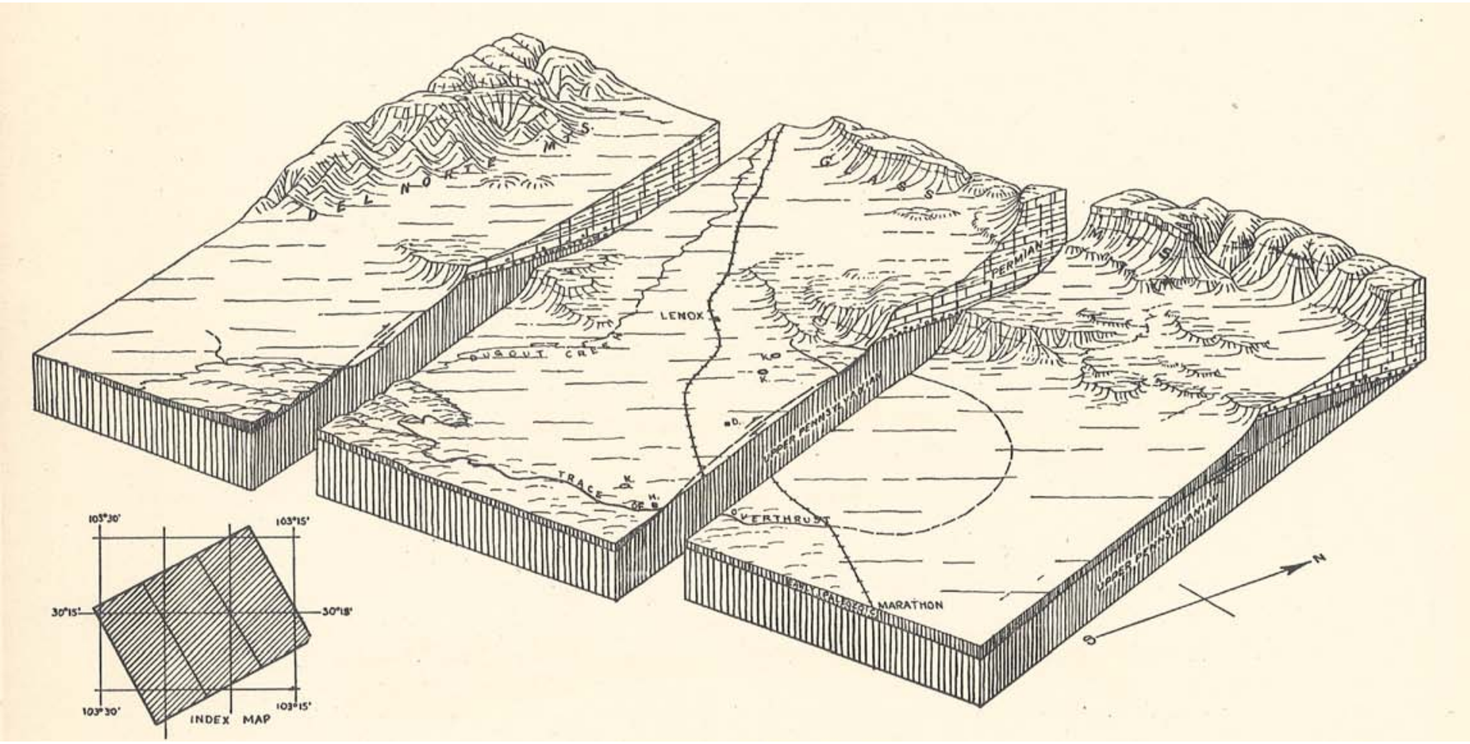

FIG. 37. Block diagram of the Dugout Creek area, showing the trace of the Dugout Creek Overthrust.

overthrust. It is evidently directly related to the overthrusting here, and results from friction developed at the base of the overriding block (Fig. 36). The cherts are considerably crumpled and fractured near the overthrust contact at this locality. Both here, and on the Hargus Ranch, there is a thin local development of angular chert breccia at the thrust plane, but no mylonite was noted.

As shown in the accompanying figures, the overthrust plane is believed to plunge eastward beneath the surface, since structures north and northeast of Marathon are continuous with that of the overriding block. (Fig. 38.)

The overriding block is a part of the Marathon anticlinorium. Hogbacks of Caballos novaculite bound it on the southeast and northeast sides, and lower Ordovician limestone is exposed in its center. The Tesnus and Dimple formations outcrop near Iron Mountain in a synclinal area northwest of the anticlinorium. Dips on the flanks of the anticlinorium are gentle, ranging from 10 to 45 degrees, though the lower Ordovician limestones have a steeply dipping, isoclinal structure. Despite the gentle dip of the Caballos novaculite and the underlying Maravillas chert, their structure is locally

The Gaptank shales and sandstones beneath the overthrust are quite generally incompetent and have been minutely deformed by small folds and thrusts (Fig. 13), but though the deformation is intense, metamorphic effects are negligible, and the shaly beds are only slightly indurated. The thin incompetent limestone beds intercalated in the series are bent about, broken, and repeated in a most complicated manner. At a locality four miles

S 15° W of Lenox (Fig. 13), a limestone layer is thus duplicated 12 times in one-third of a mile. The complexity appears to be greatest in the lower part of the series; higher up there are more numerous beds of competent limestone and limestone conglomerate, so that the folding is more open, as at Milepost 580, four miles west of Marathon (Fig. 13). The planes of the thrusts and the axial planes of the folds dip to the southeast.

The highest part of the area structurally is in the northwest, near the base of the Permian escarpment. Here beds of Haymond age are brought up in two anticlinoria, one on the Decie Ranch, the other south of Dugout Mountain. These anticlinoria have a complicated minor structure, and are bounded by a thin limestone with a basal Gaptank fauna. The north flank of the anticlinorium south of Dugout Mountain is overturned, and dips 35 degrees south. The higher Gaptank beds are exposed to the southeast, in a synclinorial area. It is likely that this major structure is the reflection of broad open folds in the competent Dimple and Tesnus formations beneath, and that the complex minor structure has been superimposed upon it in these incompetent strata as a result of the overthrusting.

The Dugout Creek overthrust was evidently a late event in the deformation of the region, since its plane is nearly flat, and since the folds above and below the thrust are cut across by it, and are unrelated to each other. On the other hand, the overthrust is older than the cross-warping, as indicated by the downward pitch of its plane to the east. The low grade of metamorphism suggests that the thrusting took place at relatively shallow depth. Although 8000 feet of Carboniferous strata would normally lie on top of the overriding block, it is not unlikely that much of this was eroded away while the block was moving forward. It is probable that the youngest Pennsylvanian preserved beneath the thrust is nearly the last to be deposited before the thrusting, and that the overthrust block rode forward on the depositional surface of the Gaptank formation.

AGE OF THE MARATHON FOLDS

It is the interpretation of the writer that the Marathon disturbance in the Marathon Basin may be subdivided into three definite, but partially overlapping epochs, which were an epoch of folding; an epoch of overthrusting, with the overthrusts cutting across the folds; and an epoch of cross-warping, which deformed both folds and thrusts. It is his conclusion that the folding epoch was initiated in early Gaptank time, and continued until near the end of the Gaptank, and that the last two epochs took place late in the Pennsylvanian, and before Permian time.

He is partially supported in his conclusions by Schuchert (**11**, pp. 388-390), and by Keyte, Blanchard, and Baldwin (**9**, p. 117). C. L. Baker (**6**, pp. 107–112) and other members of the original survey party, concluded that the folding was mid-Pennsylvanian (pre-Gaptank); and this interpretation has been stated again more recently by Baker (**14**, pp. 1111–1114). Though the writer cannot agree with Mr. Baker's views, the criticisms which he has made are pertinent. There are still many structural features in the area not easily explained, and the evidence regarding the age of the deformation appears to be partially conflicting.

Baker's arguments are three-fold, and are summarized below: (a) The cobbles and boulders in the lower part of the Gaptank at its type locality indicate vigorous erosion of the Dimple formation at a nearby locality. Baker states that in some localities south of Gap Tank these conglomerates directly overlie Tesnus or Haymond sandstones with an angular unconformity. (b) The Gaptank of the northeast part of the Marathon Basin is not as highly deformed as are closely adjacent older formations and it passes beneath the Permian to the north with equal dip and strike. (c) The beds west of Marathon assigned to the Gaptank by the writer and his brother (**12**, p. 117) are stated by Baker to be pre-Gaptank, possibly a marine equivalent of the Tesnus or other early Carboniferous formations. He proposes to call them the Dugout beds. Baker concludes that the major deformation of the Marathon Basin was pre-Gaptank, and that whatever structures the Gaptank possesses are of the same age as those of the Permian to the north, some of them having been produced during post-Wolfcamp and pre-Hess time.

It is the belief of the writer, as stated in a previous paper (**12**, pp. 122 and 143), that the conglomerates of the lower Gaptank at the type locality indicate the beginning of diastrophism in the region, rather than its culmination. The associated faunas show that these are of Canyon age. They contain boulders of many sorts, the greater number being of granular dark gray limestone of the typical aspect of the Dimple formation, which inclose abundant angular fragments of chert. There are also a few boulders of light gray, fine-grained limestone, which contain fossils of lower Gaptank age and indicate that the Chaetetes limestone and other Gaptank beds below the conglomerate group were involved in the folding (**11**, p. 385). The conglomerate beds thin out and become less coarse toward the northwest and the lowest one passes into limestone in this direction. This indicates a nearby source, and it is concluded that the Dimple Hills anticlinorium, about three miles to the south, had, at that time, risen sufficiently to expose the Dimple formation to erosion, an uplift of some 2000 feet (Fig. 39). The strata to the south of Gap Tank thus began to be folded early in Gaptank time, while the beds near the tank were not folded until the culmination of the Marathon disturbance. This helps to account for the difference in degree of folding of the two areas.

The unconformity at the base of the Gaptank formation reported by Baker south of Gap Tank, is not sustained by the writer's observations (Fig. 15, showing detailed mapping of members in the Gap Tank area). Not improbably it is the result

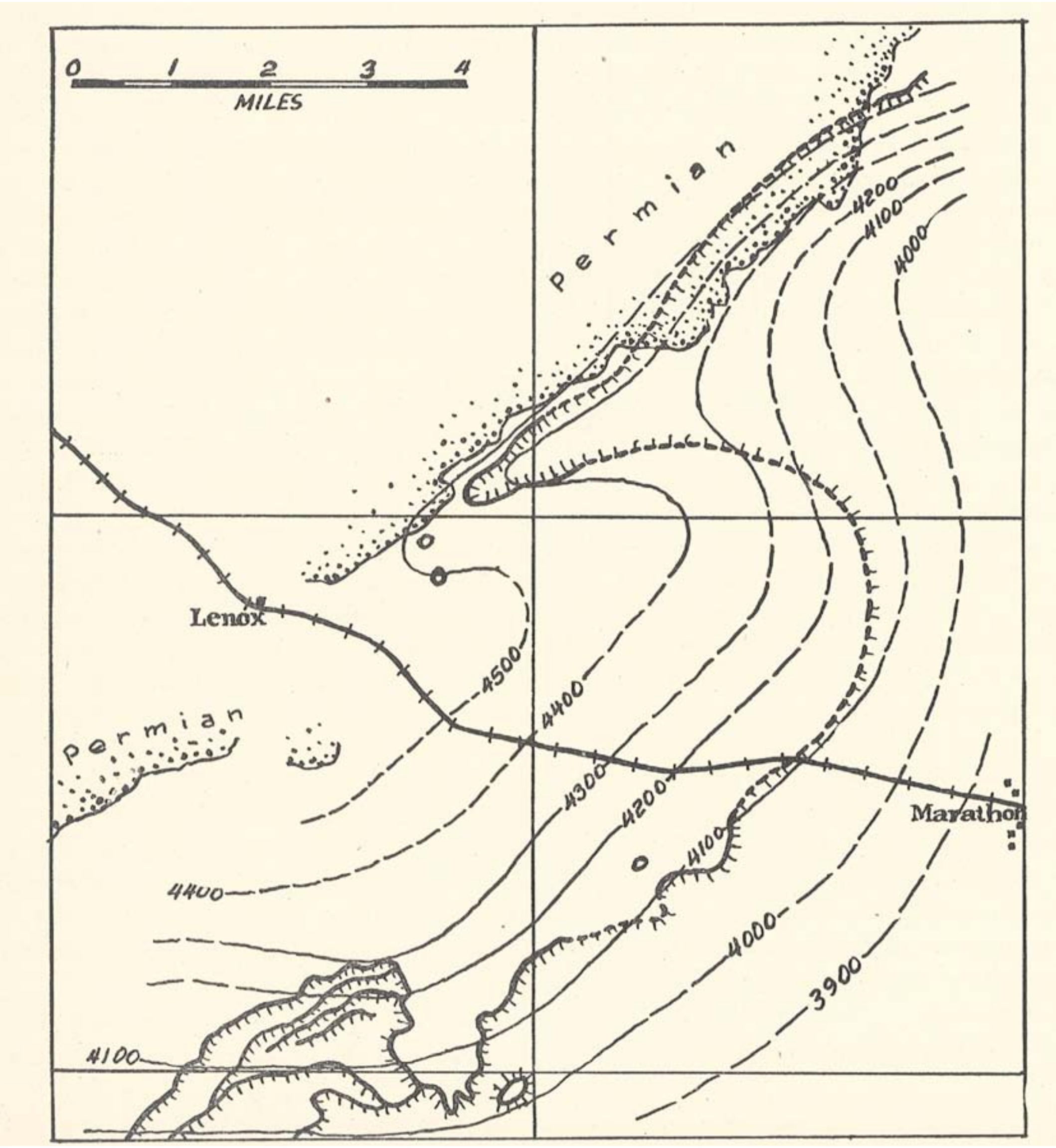

FIG. 38. Map showing structure contours on the plane of the Dugout Creek overthrust; contour interval 100 feet. Trace of the overthrust shown by heavy line, hachured on overthrust side. The contours are generalized, and do not show minor irregularities in the attitude of the plane; where hypothetical, they are broken.

of bedding slip of competent conglomerate over less competent shales and sandstones, such as has been reported by Schuchert (**11**, p. 385) at Chaetetes Hill, southwest of Gap Tank.

The correlation of Baker's "Dugout beds," west of Marathon, with the Gaptank is based on faunal evidence which is discussed in the chapter on Carboniferous stratigraphy. This evidence indicates that beds of Canyon and Cisco age are represented here. The lithologic difference between these beds and those of the typical Gaptank are to be explained by the essentially local nature of the early phases of the Caballos deformation. Conglomerates do not appear in this region until Cisco time, whereas those at Gap Tank are Canyon. The Gaptank of this region is clearly involved in the Marathon deformation, since it is overridden by pre-Carboniferous rocks along the Dugout Creek overthrust.

There is definite evidence that most of the deformation of the region was completed before Wolfcamp time, despite the well-marked unconformity at the top of the Wolfcamp, indicating a slight recurrence of movement at that time. Evidence is not so definite as to whether the deformation is older than the Uddenites member, because of the latter's restricted distribution. Keyte, Blanchard, and Baldwin (**9**, pp. 177–178) maintain that the Uddenites fauna is Pennsylvanian, and older than the deformation, but Smith's (**15**, p. 64) studies show that the fauna is clearly Permian, and that the member is therefore a part of the Wolfcamp formation. Moreover, at the east end of Leonard Mountain, the member appears to rest unconformably on the Tesnus formation, though the relations are obscured by talus.

That the Marathon deformation is older than the Wolfcamp formation as a whole is indicated by the

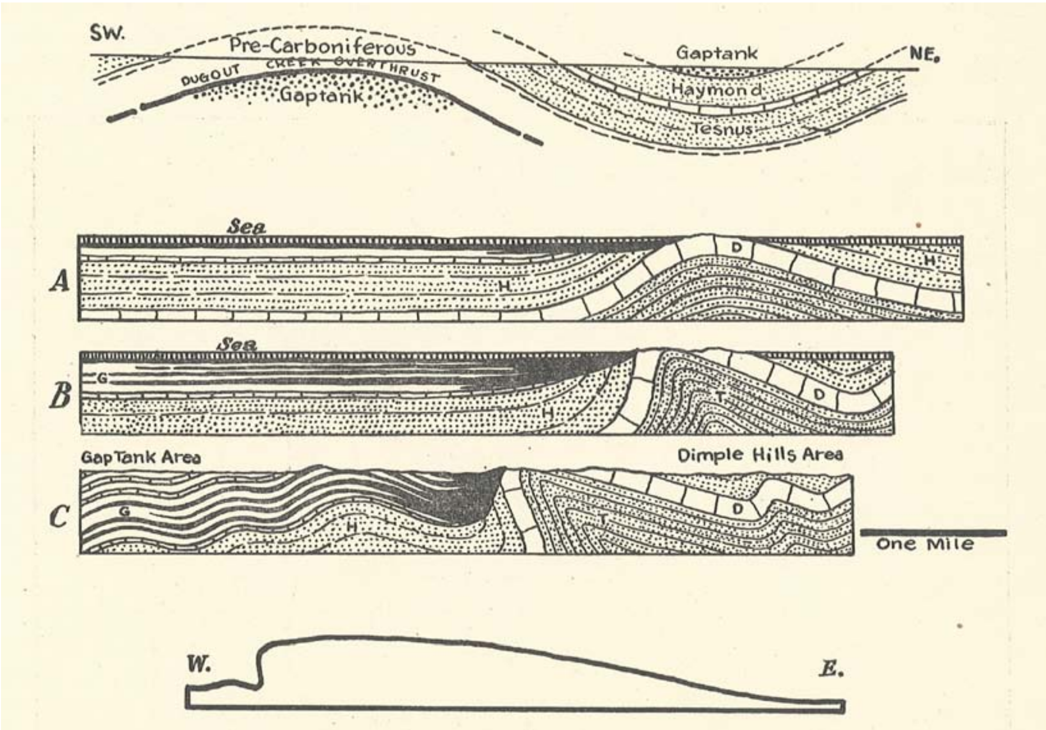

FIG. 39. *Upper*. Schematic profile along the axis of a northeast-trending fold in the Marathon basin, to show character of cross-warping.
Middle. Hypothetical sections showing the relation of the conglomerate beds of the Gaptank formation at its type locality to folding to the south. (A) is in middle Lower Gaptank time (lower Canyon); (B) is at the close of Lower Gaptank time close of Canyon); (C) is at the close of Upper Gaptank time (near end of Pennsylvanian). T—Tesnus; D—Dimple; H—Haymond; G—Gaptank. Conglomerate beds are shown in solid black. Vertical scale, same as horizontal.
Lower. Schematic profile, at about the latitude of Marathon, to show the form of the Marathon dome. Heavy line indicates base of Comanche series. Length of section about 30 miles.

fact that this formation rests unconformably over the cross-warping structure formed in the last epoch of the disturbance.

The folding indicated in the cross-section of the Gap Tank area is certainly not all to be accounted for by the relative lesser competency of the Gaptank as compared with the Permian. Moreover, to the east of Gap Tank and to the west of Wolf Camp, the Gaptank disappears, showing that it was preserved from pre-Wolfcamp erosion only because it lay in the axis of downwarping. The Permian (but not certainly the Wolfcamp) rests directly on Haymond sandstones three miles east of Gap Tank on the Allison and Gilbert Ranch, and Wolfcamp overlies the Tesnus, with basal conglomerate and angular discordance at the east end of Leonard Mountain.

Southwest of Leonard Mountain the Wolfcamp formation rests with angular discordance upon various members of the Carboniferous and pre-Carboniferous (Fig. 20), part of which form the overriding block of the Dugout Creek overthrust, and part the overridden. Three miles northeast of Lenox the Wolfcamp, with 450 feet of basal conglomerate, overlies the Captank, as well as Maravillas chert and Caballos novaculite, which are erosional remnants of the overthrust sheet. On the scarp of Dugout Mountain, two and a half miles S 40° W of Lenox, the Wolfcamp, with 300 feet of basal conglomerate, rests on Gaptank which is overturned and now dips 35° south.

The relations of the Wolfcamp formation to the Dugout Creek overthrust show that the formation was deposited over an eroded surface, so that a considerable portion of the overthrust sheet had been removed prior to Wolfcamp time.

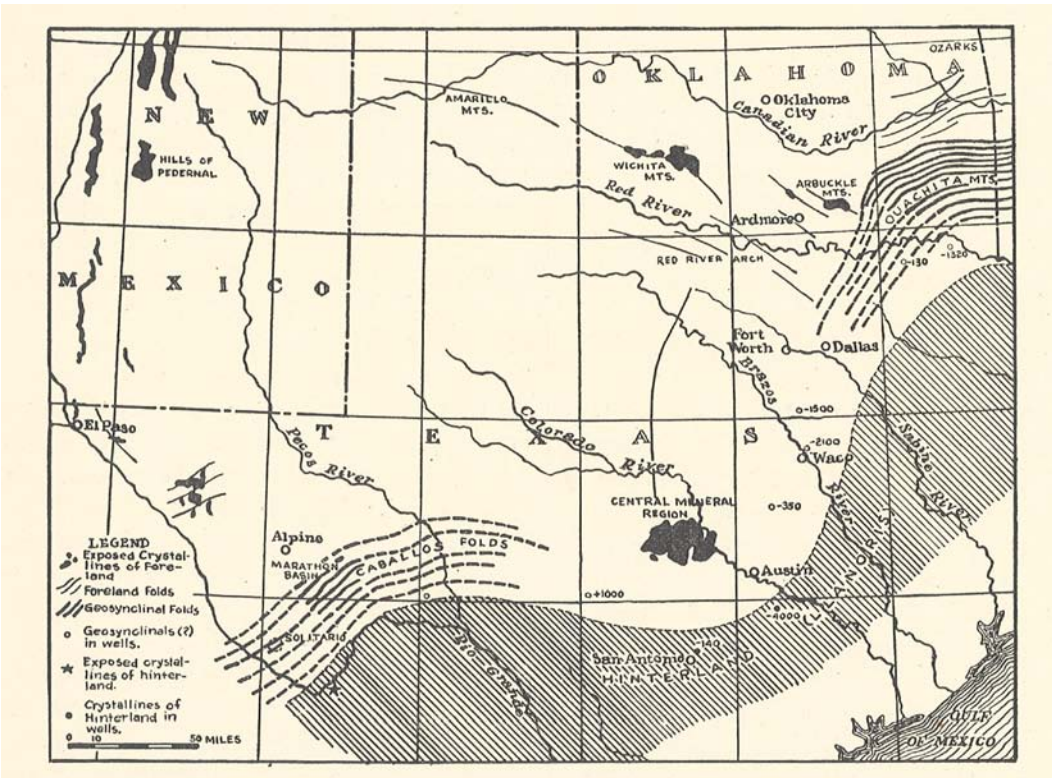

FIG. 40. Map showing regional relations of the Marathon folds. Known structures are shown in solid lines, and are differentiated from hypothetical structures which are shown in broken lines. The suggested relationship with the Ouachita folds is uncertain because of the overlap of Cretaceous rocks across the intervening area. The words "Caballos folds" in this figure should read "Marathon folds."

REGIONAL RELATIONS OF THE MARATHON FOLDS

Having described the detailed structural features of the northern Marathon Basin, we may now turn out attention to the relationships of these structures to those formed during the same Hercynian epoch in adjacent regions. After the greater part of this report was written two excellent papers, by Powers and Cheney,[72] have appeared, dealing with late Carboniferous diastrophism and sedimentation in the Southwest. The present discussion is intended to supplement these, and to set forth new data on the subject insofar as it relates to Trans-Pecos Texas.

The Marathon folds of the Marathon Basin are one of the exposed fragments of a widespread system of Hercynian structures in the Southwest. Better known portions of the system are found in Oklahoma and Arkansas in the Ouachita, Arbuckle, and Wichita mountains. Powers has used the collective term Oklahoma Mountains for these structures. The best exposures of the system are in Oklahoma, where a sequence is revealed changing from gentle folds in the north to complex, tightly compressed folds in the south. However, the record in Oklahoma is incomplete, for the roots of the range are masked by the overlap of the Cretaceous Coastal Plain deposits. In Trans-Pecos Texas our data are even more fragmentary, for the ancient folds are nearly all concealed by Permian and Cretaceous rocks. The Marathon Basin is a small window through the younger strata, revealing only a fragment of the frontal part of a mountain system which must rival the Ouachitas in complexity of structure and magnitude of forces involved.

The window of the Marathon Basin reveals a folded series of geosynclinal strata, with a northeast strike, which were overturned and overthrust toward the northwest. The same facies is also exposed in the smaller window of the Solitario, 35 miles to the southwest, where an abrupt post-Cretaceous dome brings the old folded rocks to the surface. The geosynclinal facies is characterized by a thick Cambrian and Ordovician succession of limestone, shale, and bedded chert, in which graptolites are the most abundant fossils; the Caballos novaculite and associated bedded cherts; and a thick succession of Carboniferous clastic deposits, interrupted only near the middle and top by limestone.

The source of these sediments was all from the southeast, from the old borderland of Llanoris, an area of crystalline rocks which was actively rising and shedding off sediments during the greater part of Paleozoic time. The Ordovician formations increase in thickness toward the southeast, and their shales and limestones are replaced by beds of sandstone in that direction. The Caballos formation likewise thins out from 700 feet in its southeastern exposures to less than 200 feet in the northwest. Evidence indicates that this is the result of original differences in the thickness of the deposit. In its southeastern exposures the Caballos is nearly all novaculite, and in the northwestern ones it is nearly all bedded chert, but the significance of this fact is obscure, because so little is known of the origin of these siliceous deposits.

Of the Carboniferous formations, only the Tesnus is distributed widely enough to permit us to ascertain the source of its sediments. The later Carboniferous is found only in synclinal remnants in the northern part of the basin. The Tesnus sediments were certainly derived from the southeast, for they thin out progressively to the northwest from a maximum probably in excess of 4000 feet to less than 500 feet in the extreme northwest part of the basin. Furthermore, in the southeastern corner of the basin the Tesnus is nearly all sandstone, including thick ledges of white quartzite, and other layers of arkose and graywacke. In the northern part of the Marathon Basin the formation is more than half shale, and its sandstone beds are all of fine grain. Both the Tesnus and Haymond sandstones contain minute fragments of granitic and metamorphic rocks.

The land mass of Llanoris, from which the sediments were derived, bounded the southern margin of the Marathon geosyncline, and toward the end of the Paleozoic exerted a northward thrust by which the geosyncline was folded. The extent and character of this ancient land is not known to us, for it is now mostly concealed by Cretaceous rocks. With little doubt it occupied much of what is now northeastern Mexico and eastern Texas, for many wells in this area show that the Mesozoic rests directly on metamorphic, and presumably pre-Cambrian rocks. In northern Mexico the metamorphic basement is brought to the surface in several places, one of which, at Boquillas, is only 60 miles south of the Marathon Basin.[73]

If we exclude the possibility that the schists at this place are metamorphosed Paleozoic, the out-

[72]Powers, Sidney, Age of the Folding in the Oklahoma Mountains, Bull. Geol. Soc. America, Vol. 39, pp. 1031-1072, 1928.

Cheney, M. G., History of the Carboniferous Sediments of the Mid-Continent Oil Field, Bull. Amer. Assoc. Petrol. Geol., Vol. 13, pp. 557-594, 1929.

[73]Discovered by C. L. Baker. Cited by Böse, Emil, Vestiges of an Ancient Continent in Northern Mexico, Amer. Jour. Sci. (5), Vol. 6, p. 133, 1923; also from a lecture by Baker at Austin, Texas, 1927.

crop serves to show the present southern limit of the geosynclinal belt. However, we cannot now determine by what thickness the crystallines at this place were originally covered by Paleozoic strata, if they were covered at all, and they might well be a part of an extensive overthrust sheet of pre-Cambrian covering a considerable extent of geosynclinal strata. For this reason, the original width of the geosynclinal belt is unknown in Trans-Pecos Texas.

To the northwest, the structural and stratigraphic relations are obscured by later overlaps of Permian and Cretaceous rocks, but one hundred miles or more to the northwest, in the Hueco and Franklin mountains, older rocks are again brought to the surface and here possess a foreland facies. The foreland facies is thinner than the geosynclinal facies at Marathon, and is nearly all limestone; at the base is the thin upper Cambrian Bliss sandstone, resting on crystalline rocks, followed by several thousand feet of Ordovician and Silurian limestone. A number of stages of the middle Ordovician found at Marathon are absent here, though the Silurian has no representative at Marathon. The Carboniferous is but 2000 feet in thickness, and nearly all limestone, though it is the lateral equivalent of the clastic beds at Marathon. These strata were gently folded at the end of Pennsylvanian (Cisco) time, causing the Permian to rest in various places on all the formations from Cisco to pre-Cambrian. The intra-Carboniferous movements found at Marathon have no counterpart here, and it is evident that the foreland segment was not disturbed until the culmination of the deformation of the geosyncline.[74]

The conditions described in Trans-Pecos Texas are analogous to those in Oklahoma and Arkansas. In this region the Ouachita Mountains flank Llanoris on the north, and resemble the Marathon Basin in structure and rock facies. Here again, are folds trending northeast or east, overturned generally northwestward. The lower Paleozoic is made up of cherts, black shales, and sandstones, with the Arkansas novaculite at the top; the succession is somewhat more complete than at Marathon, and attains greater thickness, but the Bigfork chert and Arkansas novaculite are probably near identities of the Maravillas chert and Caballos novaculite. These are succeeded by the great group of Carboniferous clastics, the Stanley, Jackfork, and Caney formations, which, though much thicker, invite comparison with the Tesnus. Above follow still other Carboniferous clastic formations, most of which have been eroded from the main area of the Ouachitas.

These sediments were clearly derived from the south, as shown by Miser, Honess, and Powers.[75] The Silurian Blaylock sandstone, a thick formation in the southern Ouachitas is absent from the northern folds. The Arkansas novaculite, like the Caballos, thins from 800 feet to about 200 feet toward the north. The Stanley and Jackfork formations, totaling 10,000 feet in thickness, which characterize the southern Ouachita Mountains, are absent north of the Ti Valley overthrust, so that in the northernmost overthrust sheet of the mountains, Caney shale rests on Woodford chert.[76] In the basal part of the Stanley shale in the southern Ouachitas are several beds of tuff, absent to the north, and evidently derived from volcanoes to the south. Finally, the Wapanucka and Atoka, which are a limestone and a shale north of the Ouachita Mountains, are represented where exposed in the mountains themselves by beds of sandstone.

In the Wichita and Arbuckle mountains a very different section is exposed, for here the early Paleozoic is represented largely by limestone, though of the same age as the clastics of the Ouachitas. These limestones are separated from the basement crystalline rocks of the foreland by the thin upper Cambrian Reagan sandstone. The Arbuckle section equals or exceeds that of the Ouachitas in thickness, because of the great volume of the Arbuckle limestone, which was probably deposited in a subsiding trough, far from any rising land areas. The Wichita and Arbuckle sections are analogous to those in the Hueco and Diablo Mountains, and, nearer at hand, "to those in the Ozark uplift on the northeast and those in the Llano-Burnet uplift to the southwest" (Powers, p. 1036).

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[74]The data in this paragraph were obtained by field work by the writer and R. E. King in 1928, the results of which are to appear in a later bulletin of the University of Texas.

[75]Miser, H. D., Llanoria, the Paleozoic Land Area in Louisiana and Texas. Amer. Jour. Sci. (5), Vol. 2, pp. 61-89, 1921.

Honess, C. W., Geology of the Southern Ouachita Mountains, Oklahoma Geological Survey Bull. 32, 1923.

Powers, Sidney, Age of Folding in the Oklahoma Mountains, Bull. Geol. Soc. America, Vol. 39, pp. 1037-1049, 1928.

[76]Powers, *op. cit.*, pp. 1037 1040. Miser, H. D., and Honess, C. W., Age Relations of the Carboniferous Rocks of the Ouachita Mountains of Oklahoma and Arkansas, Oklahoma Geological Survey Bull. 44, p. 11, 1927.

Though there is a superficial connection between the Ouachitas and Arbuckles by reason of the general east-west strike of both, the two are a part of unlike structural provinces, one of the geosyncline, the other of the foreland, with very different structures, faunas, and rock facies. Moreover, as the Ouachitas approach the Arbuckles, they bend strongly to the south, so that the two folded systems impinge at nearly right angles. The Ouachita folds pass southward beneath the Cretaceous and their further continuation is not certainly known. "The Arbuckles and Ouachitas are now only 15 miles apart. If the intervening mantle of Cretaceous sandstone should be removed we should probably find that the beds in the Ouachitas are overthrust on those in the Arbuckles" (Powers). Powers has also brought forth evidence to show that the Arbuckle facies underlies the overthrust sheets of the Ouachitas and was originally deposited across the foreland area north of the Ouachita geosyncline. It is known to be true that the Atoka, Wapanucka, Caney, and Woodford are present in their Arbuckle facies along the north flank of the Ouachitas north of the Ti Valley overthrust.

In summary, therefore, it may be stated that the Paleozoic of Arkansas, Oklahoma, and Texas presents two unlike structural and lithologic facies. To the southeast is the geosynclinal facies of Marathon and the Ouachitas, made up largely of clastics, but including several chert and novaculite formations. This facies was deposited along the northern margin of the old active borderland of Llanoris, away from which the geosynclinal deposits thin out. At no place has the base of the section been found. The geosynclinal facies has been crushed into folds of Appalachian type and driven forward in overthrusts as a result of a northward thrust from Llanoris during the Hercynian epoch. Perhaps a zone of deformation was produced all along the northwestern margin of Llanoris at this time. (Fig. 40.)

Northwest of the geosynclinal facies, and partially overridden by it, is a foreland facies, found in the Hueco and Diablo mountains of West Texas, the Central Mineral Region of Central Texas, and the Wichita, Arbuckle, and Ozark mountains of Oklahoma. Here, upper Cambrian sandstones rest upon the Basement Complex, and are succeeded by limestone deposits. In most places these are not as thick as the deposits of the geosyncline, though locally they exceed them in areas of unusual subsidence. The foreland area has responded to the distant thrusts from Llanoris by gentle warping, and locally, in areas of excessive thickness of sediment, such as the Arbuckles, by open folds of considerable height and extent.

Although known to be a part of the same general structural system, the actual connections between the tectonic elements of Oklahoma and West Texas are unknown, largely because of the covering of Permian and Mesozoic deposits. That the folds at Marathon and in the Ouachitas are but a part of a general belt of deformation fringing the north border of Llanoris is considered probable. Cheney, in considering the depositional history of the Mississippian and early Pennsylvanian writes, "It is conjectured that the Ouachita basin extended far southwest into Texas, possibly connecting with the Marathon Basin of southwest Texas. The southeastern origin of sediments makes such extensions seem probable, and this belief is supported by the similarities of structure as determined in Texas by well records; and similar structure under the circumstances is taken to mean similar depositional history" (p. 570). It has been suggested that this connection lay to the southeast of the Central Mineral Region and that the Balcones-Mexia fault zone represents posthumous fracturing over an old line of weakness in the Paleozoic. Such a trend is indeed suggested also in Cheney's isopach maps for Mississippian and lower Pennsylvanian, which show an alignment of the deepest depositional basins along this trend at a time which was apparently critical in the formation of the mountain structure.

Interpretation of these buried mountain structures must, however, remain hypothetical until wells have been drilled through the later overlapping deposits, which will show more clearly than now the underground extension of the folded geosynclinal facies. Probably such data can only be obtained from cores, for cores will show the dip of the strata, their metamorphism, and their significant minute deformations. Unfortunately nearly all the wells now being drilled in the critical areas use cable-tool rather than rotary equipment, so that this information will probably not be obtained for some time to come. It is recommended, however, that cable tool cuttings from critical areas, suspected of being of unusual sedimentary rocks, or of metamorphic rocks, be subjected to a thorough petrographic analysis.[77] Investigations are now being made by the Bureau of Economic Geology on pre-Cretaceous rocks of the Balcones fault region which will presently throw much light on this problem. A southward extension of the Ouachita folds into Texas is already suggested by these studies.

THE GLASS MOUNTAINS

GENERAL FEATURES

The structures of the Glass Mountains were produced by three distinct periods of movement: tilting at the close of the Permian, folding in the early Cenozoic, and normal faulting late in the Cenozoic.

The rocks of the Glass Mountains are all inclined toward the north and northwest, away from the Marathon Basin. The Permian dips more steeply than the Comanchean because of the unconformity between them; its inclination locally exceeds 20°, but averages 10°, whereas the Comanche series rarely dips more steeply than 5°. There is a general decrease in steepness of dip away from the mountains, so that in the flanking Edwards Plateau, the Comanche series is nearly flat lying, and less complete evidence suggests that the Permian also decreases in dip.

Superimposed on this major structure are minor domes, low anticlines, and terraces, developed at the same time as the larger features. The range is also transected by a series of northwest-trending normal faults. Several igneous plugs, the most notable of which are Iron Mountain and that south of Altuda Mountain, have an important influence on the structure.

EXPLANATION OF ILLUSTRATIVE MAPS

In depicting the structure of the Glass Mountains, three contour maps have been prepared (Pl. X, XI, XII). The first (Pl. X) is contoured on the base of the Edwards, the second (Pl. XI) on the top of the Word, and the third (Pl. XVII) shows the thickness of beds between the Edwards and Word. The first map shows the structures produced by post-Cretaceous folding and faulting, whereas the second shows the combined effects of all three movements. The last map shows the structure produced only by the oldest movement, which has been separated from the later structures superimposed upon it. The maps are contoured on an interval of 100 feet. Elevations were obtained from the topographic sheets whose interval is 50 feet. For this reason they are somewhat inaccurate in detail, though the broader features are made out with certainty. A greater degree of refinement seems hardly necessary, because certain difficulties enumerated below make the limit of error far greater than any error to be derived from the elevations themselves.

Certain difficulties are encountered in the making of all three maps. There are wide areas in which the bedrock is covered with valley fill, exposures scattered, and the relationships obscure. Moreover, the region is intersected by a great number of faults so that the work of contouring would be difficult with even the best of data. The faulting, with the tilting probably attendant on it, obscures and confuses the two earlier groups of folds.

On the Comanchean map, the chief difficulty lies in the scattered nature of the Comanchean outcrops. The data from these outcrops were supplemented by elevations on the resurrected pre-Comanchean peneplain, in other words, upon the elevations of the ridge crests of Permian rocks where the Comanche series has been removed by erosion. Such data may appear on first thought to be hardly

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[77]In the summer of 1929 a well drilled by the Shell Petroleum Corporation on University land, in section 23, Block 26, about 13 miles northeast of Fort Stockton, Pecos County, was completed, which furnishes us with still further information regarding the regional relations of the Marathon structures. This well was abandoned at 5124 feet in what is probably a biotite schist, the cuttings being composed chiefly of biotite, with quartz, orthoclase, and augite as accessory minerals. There is very little doubt that this rock is of pre-Cambrian age, since near its top the cuttings show clear evidence of weathering, and since it is overlain by beds identified as Cisco in age by Bruce Harlton.

Through the courtesy of Mr. Sidney Powers the following abstract of the log of the well is reproduced, along with Mr. Harlton's interpretation of its correlation

0–170	Comanchean
170–885	Rustler-Castile
885–2000	Capitan
2000–2650	Delaware Mountain
2650–4230	Leonard-Hess
4230–4632	Wolfcamp
4632–4668	Porous arkose (Gaptank or Cisco)
4668–4745	Maroon shale, with dense pink or white limestone
4745–4770	Dark gray fossiliferous limestone with arkosic sand, containing *Calcitornella*, a typical Cisco form.
4770–4850	Light gray, angular arkosic sand
4850–4900	Probably igneous or metamorphic, including weathered rock
4900–5124	Granite (schist?)

There are two likely interpretations of the crystalline rock encountered in this boring: It may represent an old monadnock on the northern side of the Marathon geosyncline, which was not buried until nearly the close of Pennsylvanian time, or it may represent an uplift of Canyon or early Cisco age, by which the earlier Paleozoic was removed by erosion. The latter interpretation appears to be more likely and in that case the uplift probably resembles the late Cisco uplifts in the Hueco and Diablo mountains farther west in the state, where the Permian rests unconformably on all the earlier formations down to the pre-Cambrian Carrizo schist. It is very probable that the uplift northeast of Fort Stockton represents this foreland type of folding, rather than the closer folding of the Marathon geosyncline farther south.

Jones and Conkling (Bull. Amer. Assoc. Pet. Geol., 14, p. 316) regard this basement rock as probably a metamorphosed sandstone cut by veins and stringers of pegmatite or aplite.

worth considering, but as shown in the physiographic chapter, the topographic surface of the Glass Mountains very perfectly reflects the post-Comanchean deformation. Such data have two inherent possibilities of error (a) that on the softer Permian formations the ridge crests have been lowered below the original surface and (b) that the harder rocks may have stood up as faint monadnocks, resulting in local overlaps of Comanche strata. An effort was made to correct for these difficulties. Fortunately, throughout most of the critical area, the Permian rocks are hard resistant dolomites, which would very perfectly retain the form of the stripped peneplain. The second possibility is discounted by a study of the Comanchean residuals, for over great areas, the basal beds are at nearly the same stratigraphic level. As shown in the chapter on the Cretaceous stratigraphy, the Glass Mountains area did rise to a height of 100 to 200 feet above their surroundings when the Comanchean seas advanced, but it is certain that there was no sharp dissection, causing valleys and abrupt ridges. At one or two localities small abrupt irregularities in the overlap were noted, but they were so small and local that they could scarcely affect the determination of the structure.

The second map has several serious possibilities of error: (a) there are great variations in the thickness of the Permian formations; (b) in some of the formations the rocks are so homogeneous and in places so obscured by wash that subdivisions cannot be distinguished over many square miles, and the local thickness of the units cannot be determined with certainty.

To minimize the first type of error the key bed was taken at the top of the Word formation, lying near the middle of the group. It also lies above the most variable of the formations and at the base of those formations which outcrop most widely in the Glass Mountains. Correction for variation in thickness was made by plotting the determined thickness of each formation and working out theoretically the manner of variation away from the outcrop. Correction for the second source of error proved less easy, particularly in the intervals between the formations above the Altuda member in the northwest part of the Altuda Quadrangle; the structure contours in this region are therefore more subject to inaccuracy than in other parts of the area.

The third map is the least accurate of the three. It shows the differences in structure between the first and second maps by the variations in thickness between the base of the Edwards and the top of the Word. For this reason it shares the sources of error contained in both the first two. Several means were employed to obtain the necessary data. The most accurate information was obtained where the Comanche strata were found resting across the contact between two Permian formations. This was supplemented by data obtained from profiles in which Comanchean and Permian dips were projected from known exposures, and from a comparison between the first and second contour maps. Because of the inherent inaccuracy of the data and the methods no great detail was attempted and only the more general features are shown.

FAULTS

The strata of the Glass Mountains are cut by a system of parallel normal faults of which about 40 have been observed, with six of major importance. These have a prevailing trend of about N 30° W, which is nearly at right angles to the strike of the rocks, though they are not affected by local strike variations. Some run straight for long distances, though local irregularities and branchings occur on others. A few have a northeast trend, such as a strike fault three miles northwest of Iron Mountain, several on Altuda Mountain, and two located five miles southwest of Sierra Madera. The two latter faults trend N 30° E. Considered as a whole the fault system forms a belt which follows the general trend of the mountains in a direction about N 60° E. Although there are certain superficial resemblances to belts of *en echelon* faulting observed elsewhere, there are well-marked differences, and it is probable that they are of different origin.

Most of the faults in the mountains have a length of only a few miles, but several exceed 10 miles in length. The longest is that which is followed by Hess Canyon for a part of its course which is 14 miles in length. Many of the faults are lost when traced into homogeneous dolomite formations, or when they pass beneath the detrital mantle of the valleys, but most of those that are traceable are seen to die out rapidly.

The major faults are all downthrown to the northeast, but the minor faults exhibit no such regularity. Many adjacent faults form grabens, some of which are only a fraction of a mile in width and many miles in length. A notable example of this type is the graben of the upper part of Hess Canyon, a quarter of a mile in width and three miles in length, whose central wedge has dropped 500 feet relative to the blocks on either side. A more complex graben is formed by a system of three or more parallel faults east of Sullivan Peak in the western part of the mountains. In both of these localities Comanchean strata are preserved on the downthrown blocks.

In some places, as at Bissett Mountain and Old Blue Mountain, the faults serve to accentuate earlier folds and suggest the recurrence of positive elements through two orogenic epochs of different types.

The throw of the faults varies from 50 feet to 500 feet or more. The largest faults are all in the western part of the mountains, and the throw is generally less in the eastern part.

The faults are classified as normal faults[78] though many exposures of the fault planes are nearly vertical and all apparently have dips of more than 70°. Fault breccia, made up of angular fragments of the country rock, has been noted, but it is generally of small amount, forming crush zones with a maximum width of 20 feet. At the intrusive plug on the east side of Gilliland Canyon a fault contains fragments of the igneous rock. There is little or no fracturing of the country rock adjacent to the fault planes.

There is some evidence of tilting and warping of the faulted blocks. In many of the grabens the central part is warped downward lower than the ends. The steep westward dip from Old Blue Mountain is quite possibly the result of tilting of the Old Blue Mountain block during faulting. Some of the streams which are consequent upon post-Cretaceous structure have a course somewhat at variance with the present dip of the Comanchean as though these rocks had been tilted after the streams took their position.

The cause of the localization of the faults in the northeast-trending belt, so nearly coinciding with the present trend of the range, is *not* certain. In the western part of the mountains, where they are nearly confined to the massive dolomites at the top of the section and die out southeastward into shaly and sandy beds, the explanation suggests itself that they represent fracturing of competent strata over incompetent beds which responded plastically to deformation. However, the sandy and shaly beds (Leonard and Word) show no evidence of the extensive flowage which would be necessary, and contain many members which are readily traceable over considerable distances. Moreover, these faults differ in no wise from those farther east in an area where the strata are of uniform competence. It is here suggested that they may represent fracturing over some line of weakness in the rocks beneath the Permian, such as the line of dying out of strong Pennsylvanian folds to the northwest. This boundary between folded and non-folded basement rocks would probably separate areas behaving differently under diastrophic forces, and might be represented above by a zone of fractures.

The faults are certainly younger than the post-Cretaceous folds in the Glass Mountains. As may be seen from the structure map, the folds are commonly cut across and displaced by the faults in a manner not possible if they were contemporaneous or older. This is confirmed by the physiographic evidence (Fig. 11) which shows that the majority of the streams are consequent on post-Cretaceous structures, whiche were more or less modified by later faulting. As shown by the occasional presnce of igneous rock in their breccias, the faults are likewise younger than the intrusions of the area.

In the Davis Mountains, not far to the west, lavas and tuffs of probable Eocene age are folded, showing that a part of the folding movement was post-Eocene. The faulting epoch is therefore placed tentatively in the late Cenozoic.

FOLDS

The folds of the Glass Mountains are best illustrated by the cross-sections (Pl. XIII) and contour maps (Pls. X, XI, and XII), and it will only be necessary to call attention to their more significant features.

The most prominent fold in the Glass Mountains is the Gilliland Canyon anticline, a northwest-plunging fold extending northwest from Iron Mountain down Gilliland Canyon. At a point five miles north of the mountain it leaves the canyon, runs directly across the crest of the range along the summit of Old Blue Mountain, and passes out into the plains, extending beyond the limits of the

[78]In a previous paper by the writer (The Geologic Structure of a Portion of the Glass Mountains of West Texas, Bull. Amer. Assoc. Petrol. Geol., Vol. 10, p. 879, 1926) the faults were stated to be reverse faults, but later observations tend to contradict this conclusion. A later examination of the locality cited, at which a fault plane was thought to hade toward the upthrow, showed this observation to be in error.

area mapped. In the mountains it is entirely in Permian strata, but north of the Stroud Ranch it passes into the Comanche series and crosses the K. C. M. and O. Railway at Leoncita section house, where Fredericksburg, Washita and Eagle Ford strata are involved. The average plunge of the fold is nearly the same as the regional dip of the strata in the mountains, but there are several local flattenings along the axis. One is located near the head of Jail Canyon, five miles north of Iron Mountain, where there is a small closure to the south in the Permian; the other is on the Stroud Ranch in Comanchean. The steep west dip off the anticline in the region of Gilliland Canyon may have resulted from later tilting of the Old Blue Mountain block during the normal faulting epoch.

The other folds in the Glass Mountains are less definite. West of the Gilliland Canyon anticline the most striking feature is the group of dome-like uplifts formed by Bissett Mountain, the Young Ranch area, and Altuda Mountain.

The Bissett Mountain dome is about four miles in breadth, with a northwestward elongation which is continued northwest and southeast in a gentle anticline. There is 200 feet of closure on the south in the Comanche series. Dips in the Permian beneath are steeper, and reach 45° at several places. The pre-Comanchean uplift has caused the Comanche series to rest directly on the upper massive member of the Capitan at the crest of the dome, though the intervening Bissett formation is exposed on the flanks. The Permian structure is seen to consist of several small irregular domes upon which the more symmetrical post-Cretaceous dome has been superimposed. At the Bissett mine, near the structural summit of the dome, the Capitan dolomites have been replaced by iron and copper minerals and veined by large masses of calcite. These data suggest the presence of an igneous body below.

Four miles west of Bissett Mountain, near the Young Ranch, an isolated hill on the plain shows igneous rock intruding sandstone of the Word formation, which is high above its normal position. To the northwest, scattered outcrops dip away from the igneous rock, indicating a greatly denuded dome of considerable magnitude in this area.

Several miles southwest of the Young Ranch is the Altuda Mountain uplift, of dome-like form, with a northwest elongation. The oldest beds, of Leonard age, are exposed around the north and northwest sides of a large plug at the south end of the uplift. The dome is delimited on the south by a large fault which brings the Leonard in contact with the Altuda member to the south. The beds dip north, northeast, and northwest away from the plug at angles of 30° to 70°, but flatten out to the north. The eastern side of the uplift is evidently delimited by faulting, since the Comanchean of Altuda Mountain is 1000 feet higher than west-dipping Comanchean exposures a few miles to the east. The western side of the uplift is marked by a strong west dip, which carries the Permian and Cretaceous beneath the Tertiary lavas.

The three uplifts described above are aligned along a northeast axis. Since two of them have exposures of igneous rock in their centers, and the third a mineralized area, it is probable that igneous intrusion was an important factor in the formation of all. The faulting which delimits the Altuda Mountain uplift on the south and east may have been produced at the time of the intrusion as a result of the uplifting force of the magmas.

The area east of the Gilliland Canyon anticline is characterized by gentle northeast-trending folds and terraces. The most prominent of these structures is seen in the Permian, extending in a northeast direction from the Word Ranch. South of the axis the Permian dips northward at angles of less than 5°, whereas to the north the dips increase to 20°. This terrace is expessed by a faint fold in the Comanchean which continues northeast toward the Sierra Madera dome. Several indistinct folds of similar trend, which have been considerably altered, or even partially obliterated by block faulting and its attendant warping are seen in both Permian and Comanchean north of the terrace. A well-marked syncline extends northeast down Gilliland Canyon from a point about six miles north of Iron Mountain.

The most prominent structure in the eastern part of the mountains is the Hess Ranch horst, a greatly uplifted block a few miles north of the Hess Ranch and about five miles northeast of Iron Mountain. This is an oval area, elongated east and west, bounded on all sides by faults; it has been uplifted at least 2000 feet above its surroundings. Along the south side is an elongate igneous body which is no doubt genetically related to the uplift. Wolfcamp limestones dip at an angle of 60° away from the intrusion on its south side and Wolfcamp and Hess beds dip 10° to 20° northward on the north side. The uplift is bordered on its south side for a length of about a mile by a narrow wedge of bituminous Leonard limestone which has dropped between Wolfcamp beds on the north and Hess beds on the south. The bounding faults of the horst are exposed only at the eastern end, and are covered elsewhere by detritus. On the east side, exposures of Hess lie adjacent to those of the Word, but the actual plane of the fault is not exposed. The forces tending to bring about the uplift must have been essentially vertical and were perhaps caused by the rise of magmas. That the rocks were under tension rather than compression is indicated by the infaulted wedge of Leonard on the south side of the uplift.

deformation is not as evident, and may be determined only by careful study of profiles and a comparison of Comanchean and Permian contour maps.

The accompanying map (Pl. XII) shows the character and position of these minor structures. The Gilliland Canyon anticline is seen to be represented by arching and by a well-marked dome on the Easterwood Ranch. The Bissett Mountain dome, the syncline of northern Gilliland Canyon, and the terrace of the Word Ranch are all more or less perfectly represented. The fold of the Del Norte Mountains, to be described later, is represented by a low anticline. A comparison of this map with

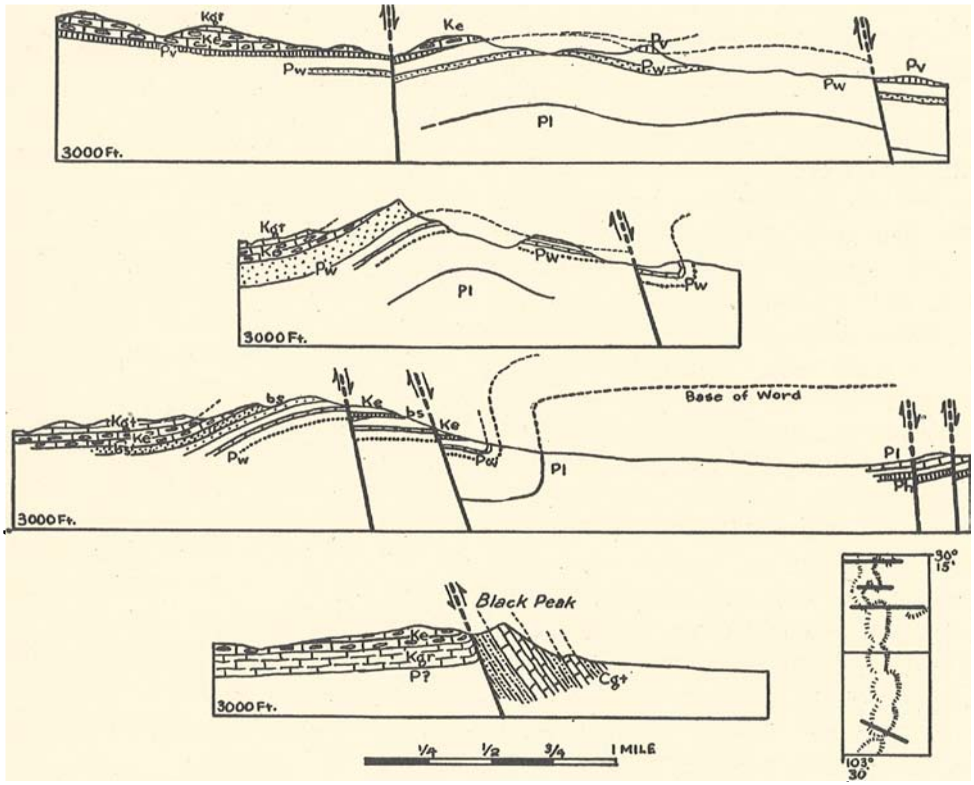

FIG. 41. Four sections showing the structure of the Del Norte Mountains. Cgt—Gaptank; Ph—Hess; Pl—Leonard; Pw—Word; Pv—Lower Massive member of Capitan; Kgr—Glen Rose; bs—Basement sands; Ke—Edwards; Kgt—Georgetown.

PRE-COMANCHEAN STRUCTURES IN THE PERMIAN

The most prominent pre-Comanchean structure in the Glass Mountains is the northwestward inclination of the Permian, which is plainly shown both in the field and upon the structure sections (Pl. XIII). Considering the mountains as a whole, slightly more than half of the present inclination of the Permian was accomplished in pre-Comanchean time. The character of the minor structures of this

the Comanchean structure map, which shows the effects of the later epochs of folding and faulting, indicates that folding has taken place several times upon the same lines of weakness, and that structures which took their form at the close of Permian time have been accentuated by later movements.[79]

[79] An opposite conclusion was arrived at in an earlier paper (Geologic Structure of a Portion of the Glass Mountains of West Texas, Bull. Amer. Assoc. Petr. Geol., Vol. 10, p. 884, 1926), but the area studied for it was too small to provide conclusive data.

THE DEL NORTE MOUNTAINS

General.—The Del Norte Mountains form an abrupt, narrow, north-south chain, bounding the Marathon Basin on the west. Through much of its course it represents the denuded roots of an overturned, west-facing monocline which forms the western flank of the Marathon Dome (Fig. 39). To the north it dies out in a low fold, but to the south it is continued with similar structure in the Santiago Range, which, south of the Marathon Basin, passes into a sharp anticline overturned and overthrust westward, as is well shown at Persimmon Gap.

Folds.—The Del Norte Mountains were studied only to the north of the latitude of Doubtful Canyon. For about five miles north from the canyon. the monocline is broken by a thrust fault, here named the Black Peak thrust, which brings the Gaptank formation on the east into contact with nearly flat-lying Word and Comanchean beds on the west. This is best shown at Black Peak, immediately to the north of Doubtful Canyon, where two thick, much sheared beds of Gaptank limestone dip 70° E, and lie against nearly flat-lying Glen Rose and Edwards limestones, which are upturned only adjacent to the fault. The fault dips 70° E and has a curved trace. Four miles to the north, fossiliferous Gaptank shales lie adjacent to the Word formation, which dips 70° W for several hundred yards from the fault, beyond which it flattens abruptly. A dike of igneous rock lies along the fault.

To the north of this point there is no evidence of faulting. The dip of the monocline is vertical or even overturned, with gently dipping beds to the east and west. In the latitude of Dugout Mountain its structural height is about 2000 feet, but this decreases rapidly to the north, by the northwest dip of the strata on the eastern side. The monocline disappears about two miles north of the latitude of Dugout Mountain.

The change in dip on the west side of the monocline is very abrupt, for flat-lying beds near the axis assume an overturned position within a few hundred yards along the outcrop. A reconstruction of the form of the monocline indicates that its axial plane dips to the east at an angle of less than 45°.

To the west of the monocline in the latitude of Dugout Mountain is a dome-like anticline elongated north-south, which is asymmetrical to the west, where its dips exceed 45°. North of the point at which the monocline dies out, near the latitude of Lenox, there are several broad, low anticlines trending north-northwest, which continue to the south edge of the Altuda Mountain uplift.

Faults.—The rocks of the Del Norte mountains are cut by normal faults with a trend parallel to that of the range. Their maximum throw is 400 feet and none are more than three miles in length. All are downthrown toward the east, and their fault-line scarps give the range much of its present height. One of these faults west of Dugout Mountain has a dip of 60°, but some of the others dip more steeply.

Relation to the Cenozoic Lavas.—The Del Norte Range and Altuda Mountain uplift are flanked on the west by an east-facing escarpment of Cenozoic lavas. These dip to the west at an angle of from 5° to 10°, but less steeply than the sedimentary rocks beneath, from which they are separated by a well-marked structural unconformity. Near Strobel and south of Mt. Ord, they rest on various members of the Upper Cretaceous, but in the vicinity of this mountain upon the Comanche series. This indicates that the structures of the Del Norte Range were formed during two epochs of post-Cretaceous deformation, though it is probable that the earlier, or pre-lava, epoch was the most important.

Pre-Comanchean Structure.—As may be seen on the map representing the pre-Comanchean structures, a low anticline had been formed in the Del Norte Mountains in Permian rocks before Comanchean time, which indicates that the area was a potential line of weakness before the formation of the present structure, which is of post-Cretaceous age.

THE EDWARDS PLATEAU

GENERAL CHARACTER

The Edwards Plateau is a broad area of gently dipping Cretaceous limestones extending from the Balcones escarpment at the inner margin of the Gulf Coastal Plain to the foot of the Cordilleras. For the most part its strata dip southeast at a rate of 5 to 10 feet per mile, and its surface is a stripped structural surface, descending from altitudes of 4000 feet near the mountains to 1000 feet or less at the rim of the Balcones scarp. In its eastern part, the minor surface structures are formless undulations of uncertain origin, but west of the Pecos, broad gentle anticlines and synclines are clearly related to the stronger folding of the mountains.

In general, dips are radial from the Marathon dome, with the beds tilted north and northeast north of the Glass Mountains, and east or southeast to the east of Marathon. This change in dip apparently takes place along a definite axis, which is a broad fold extending east-northeast from Sierra Madera as far as the Pecos River, following the divide between Sixshooter Draw on the north, and Independence and Four Mile draws on the south.

SIERRA MADERA

The most pronounced structural feature of the Edwards Plateau province near the Glass Mountains is the Sierra Madera dome, which is located eight miles northeast of the eastern end of the Glass Mountains, and 25 miles south of Fort Stockton. Sierra Madera is a dome-like group of hills about three miles in diameter, which rises about 600 feet from the encircling plains. (Fig. 31.) The hills are made up of sharply upturned Permian dolomites, ranging from Hess to Gilliam in age, and the plains are underlain by nearly flat-lying Comanchean rocks, which are exposed also on the eastern flanks of Sierra Madera.

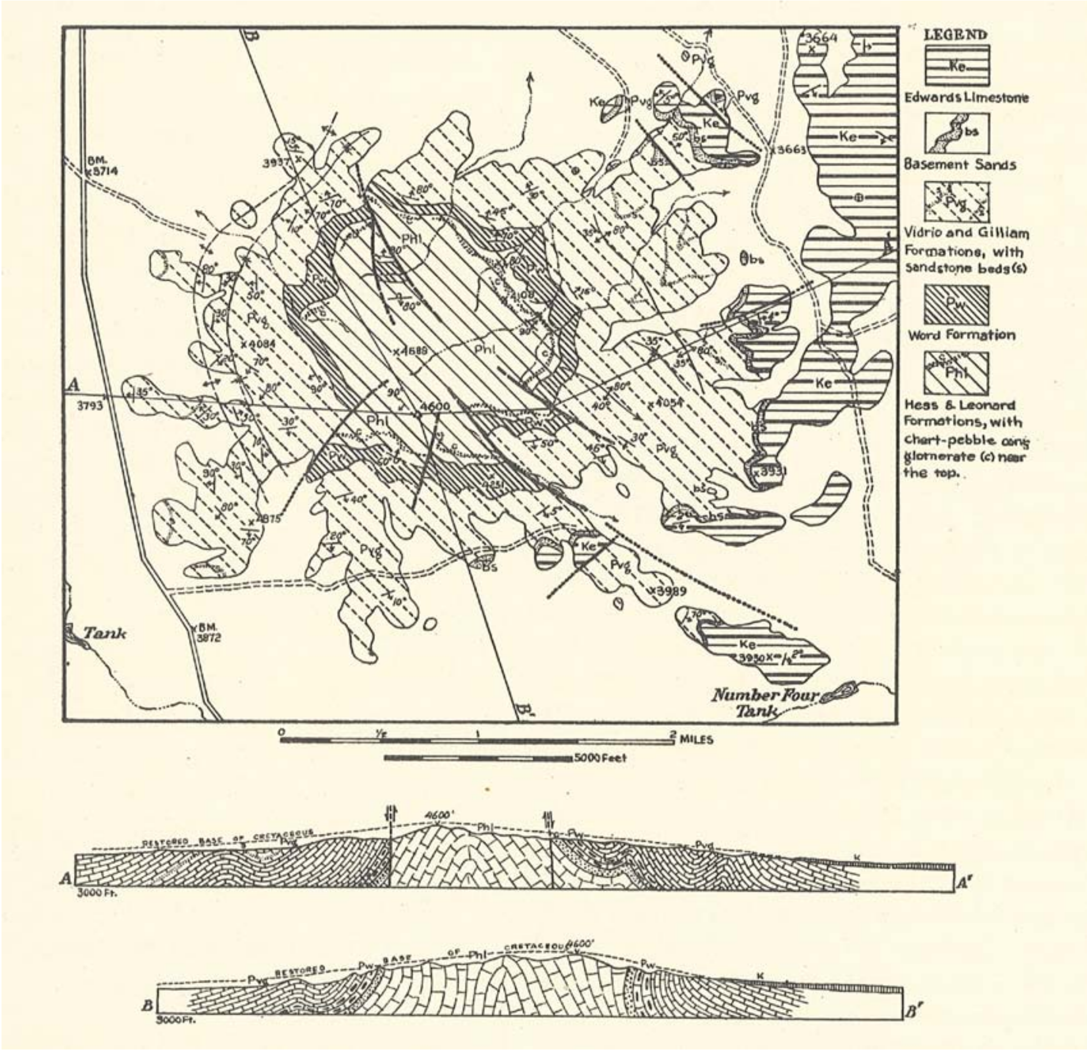

FIG. 42. Map and sections of the Sierra Madera dome.

On first view, the complexity of the Permian structure is very striking, and the strata appear to be jumbled and twisted in hopeless disorder. Over much of the uplift the beds are vertical. On study it is found, however, that dips are generally radial from the central hills. These radial dips range from 45° to 90°; but one-quarter mile south of the summit the beds are overturned and dip in reverse order into the mountain at an angle of 70°. On all sides, at about a mile from the center of the uplift, the dips flatten abruptly and the flanks are marked by small anticlines and synclines with dips of from 15° to 60°. These are best developed on the west, where a syncline of curved axis, concentric to the form of the dome, flanks the main uplift, and is succeeded to the west by an anticline of similar trend.

In studying the structure of the Sierra Madera, the most reliable key horizon was found to be a layer of quartz and chert pebbles of probable Leonard age, which is succeeded above by fossiliferous cherty dolomites, probably belonging to the Word. These horizons have a circular outcrop around the dome. In several places they are offset by as much as half a mile, apparently by radial tear faults, with a large component of horizontal movement.

The Permian rocks of Sierra Madera are hard competent dolomites, and it is a source of surprise to the observer to find them so intensely folded and crumpled. There is no metamorphism, and the rocks possess the same texture and induration as those of the same age in the Glass Mountains. There is, however, a great amount of jointing and fracturing, and good exposures show an extensive squeezing and flowage of intercalated marly layers.

To the southwest, at a distance of about two and a half miles, extensive exposures of Permian dip at angles of less than 15° to the north. The same gentle dips are found in the Glass Mountains and show that on this side at least the disturbance dies out rapidly. The Comanche series on all sides of Sierra Madera has gentle dips to within a mile of the uplift. On the eastern side of the uplift, where the series flanks the hills in an outcropping belt, the Basement sands and Edwards limestone dip away from it at angles of 2° to 10°. The absence of Comanchean exposures on the west side of the uplift, and on the mountain itself, prevents any definite conclusions to post-Cretaceous structure on this side.

The greater dips of the Permian and the well-marked angular unconformity between Permian and Comanchean strata near the mountain indicate two periods of uplift in Sierra Madera: a sharp doming in the Permian and a more gentle reflection of the same structure in the Comanchean. The absence of Comanchean outcrops over most of the dome makes it difficult to prove this, but the hill summits and ridge crests appear to represent the stripped and subsequently folded surface of the pre-Comanchean peneplain. This interpretation is partially confirmed by the radial consequent pattern of the stream drainage and the fact that the upward projection of observed dips on the Comanche would follow the ridge crests over the summit of the mountain.

DATE OF FORMATION OF SIERRA MADERA

There are several hypotheses regarding the age of the structure in Sierra Madera:

(a) That the uplift was entirely pre-Comanchean, and that the Comanche series was deposited around the present mountain after it had attained much of its present form.

(b) That all the folding took place after Comanchean time.

(c) That the uplift took place in mid-Comanchean time, and that there were marked overlaps of the higher Comanche horizons on the lower ones.

(d) That there were two periods of movement, with intense folding before Comanchean time and recurrent doming after the Comanchean.

The last interpretation is favored by the writer because of the evidence produced in the foregoing discussion.

The entire uplift is not pre-Comanchean because the Comanche series has been found tilted on its flanks. Moreover, if the dome had stood high in the Comanchean sea, there would have been extensive overlaps, and large marginal deposits of conglomerate within the series, neither of which is true. Furthermore, if the dome had been a buried monadnock, the post-Cretaceous consequent streams would have been superimposed upon it, whereas they have a radial consequent pattern.

The folding is not all post-Comanchean because the Comanche series in no place possesses the steep dips of the underlying Permian, and the angular unconformity between them is well shown in several places. Evidence indicates that the surface of the ridge crests of Sierra Madera is very nearly the surface on which the Comanche series was deposited, and that the surface was afterwards warped, stripped, and dissected. This warped surface passes downward to the lowest Permian rocks in the center of the dome, from the highest ones on the sides.

That the uplift did not take place in mid-Comanchean time is indicated by the regularity of the sequence of the horizons of the Comanche series near the mountain, and the absence of intra-serial conglomerates within the Comanchean. The overlaps of high Comanche upon low Comanche which have been reported from time to time by various geologists are not supported by the writer's observations.

MODE OF FORMATION OF SIERRA MADERA

The post-Cretaceous structure of the Sierra Madera dome is not unlike that of the other domes in the Glass Mountains region in form and magnitude, though it is more isolated, occurring far out in a region of gentle deformation. We have already seen that vertical uplift and igneous intrusions were important factors in the formation of these domes, and it is probable that similar forces operated here. No igneous rocks are exposed in Sierra Madera, but the dome lies on a line of folding extending from the intrusions of Iron Mountain and the Hess Ranch horst northeast beyond the Word Ranch.

The manner of formation of the pre-Comanchean structure is less easy to explain, because of its intensity. Rocks within the compass of but a few miles have been uplifted thousands of feet and exhibit evidences of great compressional deformation, though in the encircling area, the beds are nearly flat-lying.

The forces producing the deformation were either quaquaversal or centripetal, that is, either directed outward in all directions from a center, or inward toward a single point in a diaphragm-like movement. Evidences of radial pressure are seen in the symmetrical form of the dome, the concentric folds which flank it, and the radiating tear faults.

The pre-Comanchean dome of Sierra Madera invites comparison with the Vredefort dome of South Africa, described by Hall and Molengraaf.[80] It differs from the Vredefort dome in that the latter is many times larger, both in area and in vertical uplift, and exposes a central core of old crystalline rocks which are thought to have moved upward like a gigantic punch. Nevertheless, both domes have a symmetrical plan, show steep to overturned strata on their flanks, and are surrounded by nearly undisturbed beds. Radial tear faults are found in both. Hall and Molengraaff consider the Vredefort dome to have been produced by centripetal pressure which was relieved at this point, to the accompaniment of the intrusion of magmas which were directly responsible for the updoming and outward thrusting.

It is possible that similar forces acted to produce Sierra Madera, and that igneous intrusions played a part in the updoming. No other force is known which could produce the radial thrusting displayed in the strata, and in no other way could the space evacuated by the uplifted strata be filled. However, no pre-Comanchean igneous rocks are known to outcrop in any part of the Marathon region, or the area surrounding it.

Sierra Madera offers a remarkable example of recurrent folding in two distinct periods. In both epochs, the structure occupied nearly the same area, had the same symmetrical plan, and had nearly the same center.

REGIONAL RELATIONS OF POST-CARBONIFEROUS STRUCTURES

The Permian folding of the Glass Mountains is a part of movements which were widely developed over western Texas. There is a decided structural unconformity between the Comanchean and the Permian rocks of the Diablo Plateau, northwest of the Glass Mountains, where the Comanche series rests on all formations from Delaware Mountain to Hess, and possibly Wolfcamp. Similar unconformable relationships were also noted in the Finlay Mountains, and at Shafter. A little farther west, in the Malone Mountains, the Leonard formation is overlain by the upper Jurassic. From the evidence available, it appears that the plane of unconformity and erosion passes beneath, rather than above the Jurassic strata, for the latter continue without interruption into the lowest Cretaceous.

East of the Glass Mountains conditions are more complex, for though a folded series of Permian rocks lies beneath almost undeformed Comanchean strata, they are usually separated by the Dockum group, of upper Triassic age, which is less folded than the Permian below and more folded than the Comanche above. In the Glass Mountains the greatest period of movement is younger than the Bissett formation, and the dating of the disturbance hinges very largely on the age of that formation, which has so far yielded very little definite evidence.

[80]Hall, A. L., and Molengraaff, G. A. A., The Vredefort Mountain Land in Southern Transvaal and Northern Orange Free State, Hand. Kon. Akad. Wiss. Amsterdam, Z sect XXIV, pt. 3, 1925.

The opinion is expressed in earlier pages of this work that the Bissett formation may be of late Permian age, and that the major period of post-Permian and pre-Comanchean disturbance in the Marathon region may have been produced at the end of the Paleozoic. There is, however, some evidence that the movement is late Triassic but the regional relations and the nature of the various periods of erosion indicate clearly that it could have been no younger.

These post-Permian and pre-Comanchean movements are not known to have reached any great intensity in West Texas, and at no place did they produce mountain structure.

The post-Cretaceous folds of the Marathon region are gentle structures lying in front of a more intensely deformed region which occupies the whole of northern Mexico and extends into the southwest part of Trans-Pecos Texas, where large overthrusts have been reported by Baker.[81] These structures were all formed during the general Laramide epoch.

The normal faulting is probably of the same age as a part of the block faulting of Basin Range type which is widely developed farther west in Trans-Pecos Texas. Evidence indicates that a part of this faulting is relatively recent, but a great deal of it is of considerable antiquity, to judge by the profound denudation of some of the fault blocks. The faulting in the Marathon region evidently took place at the same time as the earlier faults farther west. No faulting of any consequence belonging to this period is known east of the mountains of Trans-Pecos Texas, unless the Balcones faults of Central Texas are of this age.

STRUCTURAL HISTORY

The first period of diastrophism in the Marathon region came in Tesnus time, and is indicated by the great thickness of clastic beds in this formation, and in the younger Haymond formation. This period of disturbance probably produced an uplift of the crystalline hinterland of Llanoris, which evidently stood high during much of Carboniferous time, shedding off its sediment into the geosyncline to the north. The shoreward deposits of the pre-Carboniferous periods were evidently involved in the uplift, for fragments of Caballos novaculite and Maravillas chert are found in intercalated conglomerate beds in the Tesnus, Dimple, and Haymond formations.

In Gaptank time the geosyncline itself began to be folded, and this represents the beginning of the main period of the Marathon disturbance which is a part of the Hercynian epoch of deformation. The crests of the anticlines south of Gap Tank had risen several thousand feet by mid-lower Gaptank time, and shed off boulders of Dimple limestone which were distributed by the the sea to make up the middle Gaptank conglomerates of the eastern part of the Marathon Basin. In the western part of the Marathon Basin the folds had risen sufficiently by early upper Gaptank (lower Cisco) time to allow fragments of Caballos novaculite and Maravillas chert to be deposited in the seas of that area. The source of this material may have been the rising fold which was later to become the Dugout Creek overthrust sheet. The deformation during most of the Gaptank was essentially local, as shown by the variability in character and age of the conglomerates in various parts of the basin.

The deformation culminated at the end of the Carboniferous when the folds were tightly compressed and at many places broken into thrusts. In the northwest, the pre-Carboniferous rocks were driven forward for over five miles across what was originally the depositional surface of the Gaptank formation; this was the Dugout Creek overthrust. During the climax of the Marathon disturbance the pressure was sufficiently great to throw the foreland area of the Hueco and Diablo mountains into broad open folds. The Marathon disturbance was closed by an epoch of cross-warping, which succeeded the intense folding; the axes of the warping trended north-northwest.

It is probable that after the deformation, the region was raised above the sea, because deep erosion is indicated by the relations of the earliest Permian to the subjacent strata. The readvancing Wolfcamp seas laid down their deposits at one place or another on nearly all the earlier formations.

The Permian period as a whole was a time of quiesence in the region though a slight recurrence of movement is indicated by the well-marked unconformity at the base of the Hess. It was a time of sedimentation in which the deposits were very largely limestones.

At the close of the Permian the region was again subjected to folding, the beginning of which is

[81]Baker, C. L., Exploratory Geology of Southwestern Trans-Pecos Texas, Univ. Texas Bull. 2745, pp. 44-47, 1927.

recorded by the thick conglomerates and marked overlaps of the Bissett formation. At this time the major structural units of the Glass Mountains came to be formed; the rocks were tilted to the northwest and folded into low domes and anticlines. It was at this time that the sharp updoming took place in Sierra Madera.

These folds were worn down to a peneplain during the early Mesozoic and then were buried by Cretaceous deposits. At the close of Cretaecous time, Trans-Pecos Texas was deformed during the Laramide epoch. Two phases of the folding are indicated. The first, immediately following the latest Cretaceous, produced the mountains of northern Mexico and southwestern Trans-Pecos Texas. In the Marathon region, it formed the Marathon dome. The second phase, which is post-Eocene, resulted in the moderate folding of early Tertiary lavas. These two phases are indistinguishable in the Marathon region. They were accompanied by intrusions of igneous rocks, some of which cut the lava flows, though some may be earlier.

The Laramide folding of the Marathon region resulted in the accentuation of older lines of folding. The crest of the Marathon dome follows a north-south axis along the western side of the Marathon Basin, nearly coincident with an old line of upwarping produced at the close of the Caballos disturbance. The folds of the Glass Mountains followed the trends of the post-Permian lines of folding. A recurrence of updoming took place in Sierra Madera, which, though less intense, had the same center and size as the earlier dome.

At a later date, probably near the close of the Pliocene, the Glass Mountains area was cut by a system of normal faults, which cross the folds. The earlier folds were partially obliterated by a warping of the fault blocks during faulting.

After this movement the Glass Mountains region has not been affected by crustal movements, except for possible vertical uplifts. The later faulting of the Basin Range area to the west and northwest has no counterpart here.

ECONOMIC GEOLOGY

At the present time no mineral resources are being exploited within the area of the Glass Mountains. At least one mine has, however, operated in the past, and within recent years several wells have been drilled near the mountains in search of oil.

ORE DEPOSITS

At several places near igneous intrusions the Permian limestones have been replaced by deposits of metallic minerals. Three of these mineral deposits deserve special notice.

Bird Mine.—The most important of these is that of the Bird Mine, northwest of Altuda, on the north side of Altuda Mountain. Extensive workings have been opened here in the past near two small plugs of syenite porphyry on the north and south sides

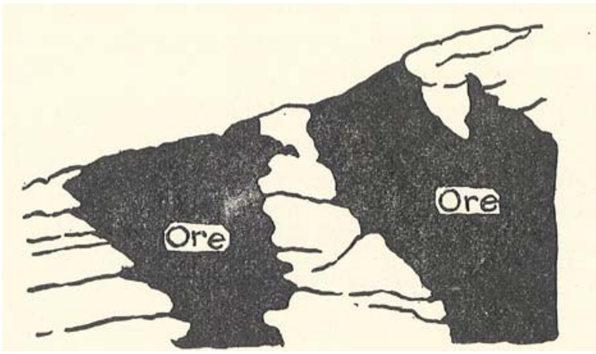

FIG. 43. Sketch of the southwest wall of the drift at the entrance to the Bissett Mine. The ore, consisting mostly of siderite, is shown in black. It invades the Capitan dolomite, indicated by white.

of a canyon draining the north side of the mountain. These had been abandoned for about 15 years at the time the area was studied. The ore appears to be a replacement of the Altuda and Upper Massive limestone members of the Capitan along their contacts with the igneous bodies. The underground workings were not examined and the writer can say little about the quality or extent of the body. Udden[82] writes that the mine "has produced some very rich silver bearing galena." It is reported that the mine was shut down because of the invasion of the workings by water. The deposit is only a few miles from the railway, so that if it is of any value its ore could be shipped out with comparatively little expense.

Bissett Mine.—Somewhat farther to the east, on the southeast slope of Bissett Mountain is the Bissett Mine, where a short drift has been driven into the hillside. The country rock is the Upper Massive dolomite member of the Capitan, which is here calcitized and converted into a finely crystalline pinkish marble, penetrated by many veins of calcite. The ore occurs in several irregular vertical

[82]Udden, J. A., Baker, C. L., and Böse, Emil, Review of the Geology of Texas, Univ. Texas Bull. 44, p. 126, 1919.

pipes which penetrate upward across the indistinct, nearly horizontal bedding across about 20 feet of exposure (Fig. 43). It consists largely of red-brown siderite, with some chryssacola along cracks and cavities.

There has not been sufficient development to reveal the underground extent of the body, though from the surface it does not appear to be great. Mining for the iron of such a small deposit would not be profitable, and the copper minerals are of too small amount to be valuable.

It should be noted that many prospect holes have also been dug in the red-bed exposures of the Bisset formation around the flanks of Bissett Mountain. These rocks are entirely unrelated to the ore deposit of the mountain, and are of no value whatsoever.

Hess Ranch Area.—In the hills north of the Hess Ranch, and on the northeast slopes of Leonard Mountain, the Hess limestones have been replaced by iron minerals over small areas near igneous bodies. The deposits consist of siderite which has weathered on the surface to dense black limonite, with some associated earthy brown limonite and red hematite. The mineralized rock weathers into large black boulders. The main areas of mineralization are vertical, subcircular pipes, but narrow areas of mineralization are found around them, along inclined joints in the limestone. The narrow areas show that the ore-bearing waters penetrated the limestone through open joints transecting the rock. Most of the deposits are near small igneous bodies, but a few are located as much as a mile from any exposure of igneous rock. All, however, were evidently derived from the porphyry masses which probably underlie the whole area. These deposits have been explored in many places by small prospect holes, but no more extensive developments have been made. The deposits are all probably of small extent, and, so far as could be determined, consisted of little else than iron minerals, so that the visible evidence would indicate that they are of little value.

BUILDING STONE

Only a few rocks of the Glass Mountains have been utilized for building stone. The only quarry known to the writer is a small one opened on the south face of Iron Mountain on Skinner's Ranch. This has been utilized by Mr. Skinner in building his ranch house at the northeast end of the mountain, and by some of the citizens of Marathon for buildings in the town. The rock is a rather fine-grained porphyry which has a blue-gray color in the quarried specimens. It is only slightly jointed and is of considerable value for local purposes.

WATER SUPPLY

No underground water has been found in the Glass Mountains. Most of the rain water which falls on the mountains probably escapes down the dip of the limestone strata, and no doubt is the chief source of the large springs and artesian wells of the Fort Stockton district to the north. A number of unsuccessful borings have been made for water in the past within the Glass Mountains, all of which have been dry. Probably the main water supply in the range will always be from surface waters impounded in cement or earth tanks, of which a considerable number have now been built. Some of these are large enough to retain water during a year or more of drought, and more of this size are certainly needed as a protection against possible dry years. During the dry summer of 1927 most of the tanks were exhausted and those ranchers who had stock in the mountains were either forced to move them out or to haul in water by truck. Mr. J. M. Montgomery, whose ranch lies across the eastern end of the range is supplying water to his stock in the mountains by means of pipe lines from water wells in the Marathon plain to the south.

On the northeast flank of the Glass Mountains, on the Elsinore Ranch, good water has been obtained from wells several hundred feet in depth. Mr. Adams, manager of the ranch, reports that the wells were drilled through limestone, and that the water was obtained from sandstone strata beneath the limestone. Since the Basement sands of the Comanche series lie at or near the surface in this region, the aquifer is probably a sandstone horizon in the Permian, possibly representing some of the sandstone members of the Gilliam outcropping a few miles to the south in the Glass Mountains, and to the east in the Sierra Madera.

On the south flank of the Glass Mountains, good water is obtained by many wells from a gravel sheet which mantles most of the north half of the Marathon Basin, or from the fractured and jointed bed rock immediately beneath the Pleistocene deposits. The flow of this underground water is southward toward the Rio Grande, and where the drainage ways cross the chert and limestone ridges in narrow water gaps the ground water rises to the surface in springs which feed short stretches of permanently flowing streams. These remain above ground for the length of the gap, and sink again beneath the surface a few miles farther down. In the northern Marathon Basin flowing water is found under these conditions in San Francisco Creek, where it crosses the Dimple limestone hogbacks near Haymond, and in Pena Colorada Creek near Old Fort Pena, where that stream crosses the Caballos novaculite hogback.

OIL AND GAS

About fifteen wells have been drilled in the immediate vicinity of the Glass Mountains in search of oil or gas, though none has so far been encountered in commercial quantities. Below are listed all wells on which information could be gained, though the list is not complete. Two other wells are known to have been drilled on the Skinner Ranch near the Old Alexander Syndicate boring, and there may be others that have escaped the writer's attention.

PECOS COUNTY

Alexander Syndicate, Montgomery No. 1
Section 6, Block I, G., C. & S. F. R.R., about two miles southwest of Gap Tank.
Total depth, 1670 feet; drilled in 1921.
Surface formation: Haymond.

Moore, et al., Arnold No. 1
Located ½ mile west of Arnold's lower ranch (old Purington Ranch), and east of the area of the map accompanying this report.
Drilling in 1929.
Surface formation: Tesnus.

Vacuum Oil Company, Elsinore No. 1
Section 60, Block B, G., C. & S. F. R. R.
Total depth 4465 feet; drilled in 1928.
Surface formation: Comanche series.

Whonlick, et al., Arnold No. 1
Section 25, Block I, G., C. & S. F. R R., about 3 miles south of Gap Tank.
Total depth 1550 feet; drilled in 1928.
Surface formation: Haymond.

BREWSTER COUNTY

Alexander Syndicate, Hargus No. 1
Four miles west of Marathon, on the south side of the old road to Alpine.
Total depth, 3560 feet plus; drilled before 1920.
Surface formation: Gaptank.

Alexander Syndicate, Skinner No. 1
Section 65, Block 2, G., C. & S. F. R. R.
Total depth, 1000 feet plus; drilled before 1920.
Surface formation: Caballos.

Alexander Syndicate, Yarbro No. 1
Section 128, Block 22, about 12 miles (east?) from Marathon.
Total depth, 1990 feet plus; drilled prior to 1920.
Surface formation: Tesnus?

E. L. Chapman et al., Skinner No. 1
Section 100, Block 2, G., C. & S. F. R.R.
Total depth, 1550 feet; drilled in 1929.
Surface formation: Caballos?

Cole and Cowden, Jackson and Harmon No. 1
Section 1, Block 331, T. C. R.R.
Total depth, 2000 feet; drilled in 1928.
Surface formation: Bissett.

Ava Scribner, Wedin (now Decie) No. 1
Section 43, Block 4, G., C. & S. F. R.R.
Total depth, 1045 feet; drilled in 1909.
Surface formation: Gaptank.

Ava Scribner, Wedin (now Decie) No. 2
Section 44, Block 4, G., C. & S. F. R.R.
Total depth, 600 feet; drilled in 1910.
Surface formation: Gaptank.

Skinner Ranch well
Two and one-half miles southwest of Skinner Headquarters Ranch.
Total depth, 900 feet; drilled in 1925.
Surface formation: Tesnus.

Wilcox and Anderson, Gage No. 1
Section 8, Block 300, T. C. R.R., at south base of Dugout Mountain.
Total depth, 2100 feet; drilled in 1927.
Surface formation: basal Gaptank.

It is reported that a favorable showing of oil was encountered in the Hargus well. Small showings of both gas and oil are said to have occurred in the Wedin well, and some gas was found near the bottom of the Skinner Ranch boring. An old well drilled for water on the Word Ranch in Hess Canyon is said to have encountered a considerable showing of gas. Shallow water wells near the town of Marathon have for some years past been contaminated by oil which does not appear to have come from storage tanks or other surface supplies.

But little encouragement can be given to exploration for oil or gas in the Glass Mountains region, though the possibility of its accumulation in commercial quantities in the region is not denied. The most promising area for exploration is north of the Glass Mountains, and in their northern foothills. The strongly folded strata of the Marathon Basin do not appear to possess structures favorable for oil accumulation, even though the rocks themselves are petroliferous. If favorable indications of oil or gas are found in the future the region faces a considerable period of wildcat exploration during which their mode of occurrence must be determined. It is recognized, however, that rocks of the same age as those near Marathon produce oil in nearby regions. The Permian strata in the Glass Mountains are certainly of the same age, though possibly not of the same lithologic facies, as those in which oil has been found in Pecos County. It is now known that the deep production (below 8000 feet) in the Big Lake oil field in Reagan County is of Ordovician age.*

The most promising areas for exploration in the Marathon Basin are in its extreme northwest and northeast portions. In the northwest part of the basin various oil showings suggest that the Gaptank formation contains oil. Those near Marathon, where the country rock is lower Ordovician limestone, may be seepages upward from the Gaptank formation beneath the Dugout Creek overthrust. Wells drilled on surface structures in the Gaptank may, however, pass through one or more recumbent folds or overthrusts beneath the surface, so that such locations are not reliable. Wells drilled on the overthrust sheet, with the hope of striking oil in the Gaptank beneath, must proceed blindly, for the structures above and below the overthrust are known to be unrelated, since the Dugout Creek fault was developed after the greater part of the folding in the region had been completed. The overthrust transects all the earlier folds. In the northeast part of the Marathon Basin the Carboniferous structures are more open, with less faulting. The strata are here thrown into a series of open anticlines and synclines, with steeply dipping flanks, in which the accumulation of oil is possible. The Tesnus and Haymond formations in this region are particularly deserving of test, for they consist of alternations of sandstone and black shale; no actual evidence of oil is known in these formations, however. Farther south, where the Tesnus is nearly all sandstone conditions are probably unfavorable for oil accumulation.

On the north dipping monocline of the Glass Mountains only a few places are known where closed structure exists. One of these is near the head of Jail Canyon, five miles north of Iron Mountain, on the crest of the Gilliland Canyon anticline. Another is at Bissett Mountain, though at this place the doming is probably the result of the intrusion of igneous rock not exposed at the surface. Favorable structures might also exist along the terrace extending northeast from the Word Ranch. Wells drilled in this region should probably be drilled far enough down the dip of the strata to penetrate a considerable thickness of Permian rocks, since these, rather than the Carboniferous, are most deserving of test. North of the Glass Mountains, the most favorable surface structures are along the northwest extension of the Gilliland Canyon anticline; it is reported that a well is now being drilled on this fold near the Orient Railway, north of the area of this report. The steepness of this structure will probably be found to increase with depth, for studies in the Glass Mountains indicate that the folding in the Comanchean is the surface reflection of an older anticline in the Permian, which appears to have been initiated well back in Permian time and to have had an influence on the sedimentation in the Glass Mountains during that period.

For convenience of reference, the following summary of data on sands, possible petroliferous horizons, and source rocks is appended. The Tesnus consists in a large part of sandstone, as does the Haymond formation; these sandstone beds thin out to the north, where they are interbedded with shale. The Gaptank also contains thick beds of sandstone. Local sandstones occur in the Wolfcamp and Hess formations, in the former near the uplifted Caballos Mountains, and in the latter in its northeastern portions. The Leonard contains lenses of sandstone toward the west, and its limestones contain much conglomerate. In the eastern part of the Glass Mountains the Leonard is a sandy dolomite containing lenses of chert pebbles. In the eastern part of the mountains, and in the Sierra Madera uplift, this formation is the only sandy one in the section. The Word contains sandstone beds in its western facies, which increase in thickness and coarseness toward the south. These sandstone beds are absent east of Hess Canyon, and in its eastern facies the Word is a non-sandy dolomite. Sandstone beds are abundant in the eastern exposures of the Gilliam, but are generally absent from the Vidrio and Tessey.

The Dimple limestones are locally quite bituminous. There are also some thin bituminous limestones in the Wolfcamp and Leonard. The basal limestone of the Word is very bituminous, and locally exceeds 100 feet in thickness. Black shale

*Producing Horizons in the Big Lake Oil Field, by E. H. Sellards, H. P. Bybee, and H. A. Hemphill, Univ. Texas Bull. 3001, pp. 152-160, 1930.

is found in the Tesnus, Haymond, and Wolfcamp formations.

STRATIGRAPHIC SECTIONS

In the course of the field work upon which this report is based a large number of stratigraphic sections were measured. Although many of them are included in the text of the report, for the sake of clarity a greater number are omitted, and chief reliance for the exposition of the stratigraphy is placed on descriptive writing. For the benefit of those geologists who might wish to study the Glass Mountains in the field, it was thought best, however, to place all the sections of the Permian rocks in this appendix. The four sections of Carboniferous strata are included in the main body of the report, and the Comanchean sections are not thought to be of sufficient interest to warrant a detailed description. All of the latter are shown graphically on the plate of Comanchean sections, and a few representative ones are included in the text.

The Permian sections described in the text were all carefully revised from the original field notes on the basis of studies made in the laboratory of specimens collected when the sections were measured. The sections described below have been less carefully prepared, and are taken with little change other than some abridgement from the original field notes. The sections of the Permian were all measured northwesterly down the dip of the strata and are numbered consecutively from southwest to northeast. In some sections included under a single number there are considerable gaps in the sequence where measurements could not be made. Where a part of a section is included in the main body of the report, it also is omitted. In both cases the omission is duly noted at the point where it occurs in the section.

SECTION 5

Section on the Altuda Mountain uplift. The Leonard and Word were measured south of Altuda Mountain, commencing at the contact with the main syenite plug at the center of the uplift and proceeding northward down the dip of the strata. The Capitan formation was measured up the northeast angle of Altuda Mountain to the base of the Comanche limestones.

CAPITAN FORMATION

	Feet
Upper Massive member:	
(16) Massive limestone, without bedding planes	495
(15) Massive ledge of white, finely crystalline limestone	25
Altuda member:	
(14) Papery limestone of very fine-grained texture, splitting into very thin sheets. The laminae are somewhat crumpled and brecciated	5
(13) Thin-bedded, dark gray limestone, with small chert nodules	48
(12) Covered	37
(11) Brown platy siliceous shale	26
(10) Covered	80
(9) Finely crystalline gray limestone	22
(8) Thin-bedded sandy brown limestone	79
(7) Dense, dark gray fossiliferous limestone, with some chert lentils	32
(6) Covered, except for a few limestone ledges	23
(5) Dense gray limestone	6
(4) Covered; possibly limestone	10
(3) Dense, dark gray fossiliferous limestone, with some chert lenses	24
(2) Siliceous shale	56
(1) Dense, dark gray limestone, with some brown sandy limestone between	29

WORD FORMATION

(8) Soft brown, very fine-grained shaly sandstone	90
(7) Fine-grained, reddish quartzitic sandstone	122
(6) Soft sandstone	30
(5) Quartzitic sandstone, containing some sills of igneous rock (the sills are omitted from the measurement)	215
(4) Brown siliceous shale, with some beds of brown sandstone and sandy limestone	92
(3) Dense limestone, containing *Waagenoceras.* Outcrops in one-foot ledges	20
(2) Siliceous shale	60
(1) Granular fossiliferous limestone in beds 2 feet to 3 feet thick, interbedded with siliceous shale	40

LEONARD FORMATION

(20) Mostly covered, across a small valley. Toward the east in the upper part of the member are beds of quartzitic sandstone containing zones of quartz pebbles (apx.)	300
(19) Soft greenish-drab shale, with thin intercalated seams of sandstone	35
(18) Interval of uncertain thickness on the back slope of the high cuesta north of the syenite plug (apx.)	150
(17) Fine-grained quartzitic sandstone, interbedded with stony siliceous shale	87
(16) Granular gray limestone	3
(15) Siliceous stony shale, some of which is thick-bedded, and outcrops in ledges of moderate prominence	95
(14) Dense bituminous limestone	2
(13) Siliceous stony shale, outcropping in massive ledges at the top	43
(12) Dark gray, coarsely granular limestone, containing many fossil fragments, the most abundant of which are bryozoa and crinoid stems	25
(11) Siliceous shale	66
(10) Finely crystalline black limestone, containing sponge spicules and other fossil debris	20

	Feet
(9) Siliceous stony shale, with some sandy beds	20
(8) Coarsely crystalline bituminous limestone, containing abundant *Perrinites,* as well as *Orthoceras,* massive bryozoa, sponges, and small pebbles	3
(7) Siliceous stony shale, with some layers of quartzitic sandstone	10
(6) Dense bituminous limestone	4
(5) Siliceous shale, with some sandy beds	62
(4) Gray granular limestone	16
(3) Siliceous shale, with some sandy layers, and some thin layers of fossiliferous limestone near the middle	89
(2) Dark gray, granular limestone containing many angular pebbles of limestone and chert, as well as various fossils. Contains large lentils of chert	57
(1) Siliceous stony shale, and quartzitic sandstone	30

Intrusive contact below with syenite plug.

SECTION 6

Measured across the west end of Dugout Mountain, about a mile west of the summit of the mountain.

LEONARD FORMATION

Top of formation not exposed; the section ends on the south side of a large alluvium covered valley.

	Feet
(17) *Fifth limestone member:* Coarsely crystalline limestone, with many fossil fragments, and some pebbles	10
(16) Sandy siliceous shale, with some stony beds	125
(15) *Fourth limestone member:* Dark gray finely crystalline limestone, with some beds of chert	5
(14) Siliceous shale, in part sandy, with some thin limestone beds	40
(13) *Third limestone member:* Dark gray, medium crystalline limestone, containing scattered fossil fragments, in two-foot ledges. There is much chert in the limestone	88
(12) Siliceous shale, in part stony, with some thin interbedded limestone layers in the upper part. There are many sandy beds in the shale	93
(11) Medium-grained calcareous sandstone, with a few layers of sandy limestone	33
(10) *Second limestone member:* Gray, finely crystalline limestone, in part sandy, crowded with fossil fragments	15
(9) Siliceous shale, with many sandstone beds	87
(8) Limestone in 2-foot to 4-foot ledges, interbedded with stony siliceous shale. The limestone is very cherty	47
(7) *First limestone member:* Light gray coarse to medium crystalline limestone in massive ledges, containing small chert nodules, rounded pebbles of chert, and a few fossils. Near the top is a thin layer of siliceous shale	66
(6) Siliceous platy brown shale with a few sandy beds, containing five thin layers of gray, finely crystalline limestone	97
(5) Gray fragmental limestone, composed of fossil fragments, and a few chert grits	4
(4) Siliceous shale	13
(3) Gray finely crystalline limestone, containing silicified fossils and chert grits	9
(2) Siliceous platy brown shale, with a few thin limestone beds	100

HESS FORMATION

(1) Cliff of limestone. The lower two-thirds is a calcareous conglomerate containing large fragments of limestone and chert widely scattered in a matrix of brown crystalline limestone. Toward the top the fragments disappear, and the rock is a gray, finely crystalline limestone containing abundant fossils	95

Wolfcamp formation below; poorly exposed, and not measured.

SECTION 7

Measured northwest from the summit of Dugout Mountain. The Wolfcamp, Hess, and lower Leonard formations were measured on the south face of the mountain, below the summit. The upper Leonard was measured down the back slope of the cuesta to the Old Payne Ranch, and the Word was measured in the hills between the old ranch and the high spur of the Del Norte Range two miles to the northwest.

CAPITAN FORMATION

(1) *Lower Massive member:* Gray dolomitic limestone forming an isolated remnant at top of spur	30

WORD FORMATION

(25) Dense, light gray, somewhat dolomitic limestone, in thin beds, containing small rounded chert nodules	95
(24) Fine-grained shaly sandstone	53
(23) Brown platy siliceous shale, with small limestone nodules	81
(22) Fine-grained, pale pink or brown sandstone, interbedded with siliceous shale. The sandstone weathers either into flags or rounded blocks	96
(21) Coarse-grained, pale brown sandstone, weathering reddish, and outcropping in a prominent ledge. This layer was traced out on the map	40
(20) Coarse-grained sandstone, interbedded with considerable sandy shale	49
(19) Coarse-grained brown friable sandstone, weathering into rounded blocks	16
(18) Fine-grained brown sandstone, interbedded with much siliceous shale. The member contains two thin nodular bituminous limestone beds	81
(17) Platy siliceous shale, with some sandy beds, and a few thin layers of limestone	197
(16) Gray, finely crystalline limestone in 1-foot beds; contains abundant *Fusulina elongata*	10
(15) Brown platy siliceous shale	12
(14) Finely crystalline limestone, with indistinct bedding planes, containing much chert	45
(13) Poorly exposed; mostly soft, pale buff, fine-grained sandstone	42

	Feet
(12) Conglomerate of quartz and chert pebbles closely packed in a sandstone matrix, separated by thin sandstone layers. The pebbles are well rounded, some are polished and they do not exceed two inches in diameter. This horizon is very persistent, and has been traced for four miles to the south, though it thins out to the north	14
(11) Dense gray cherty limestone	4
(10) Coarse to medium-grained brown sandstone	42
(9) Platy siliceous shale, with a few thin layers of bituminous limestone in the upper part	88
(8) Coarse-grained sandstone, outcropping in a prominent ledge, which locally caps small buttes. The sandstone contains small fossil fragments	42
(7) Poorly exposed. Some exposures are seen of friable, fine-grained sandstone and interbedded siliceous shale	272
(6) Siliceous platy shale, with some large limestone nodules	117
(5) Coarsely crystalline gray limestone, crowded with fossil fragments	8
(4) Siliceous shale	38
(3) White, coarsely crystalline cherty limestone	13
(2) Siliceous shale	16
(1) Dense, dark gray, finely crystalline limestone, with some interbedded dense bituminous layers. Outcrops in 2-foot ledges. Fossils very abundant in the crystalline layers	100

LEONARD FORMATION

(20) Drab clay shale, with some thin sandy seams, and two dense brown limestone layers, weathering orange, and containing *Perrinites vidriensis*	127
(19) Fine-grained shaly sandstone, in flaggy beds a few inches in thickness	105
(18) Pink and purplish massive quartzitic sandstone, containing layers crowded with rounded pebbles of chert and quartz	40
(17) Covered across alluvium filled valley south of the old Payne Ranch	525
(16) *Fifth limestone member:* Coarsely crystalline gray limestone, full of fossil fragments	12
(15) Siliceous shale	178
(14) *Fourth limestone member:* Dark gray, finely crystalline limestone, with silicified fossils. There is some interbedded siliceous shale	12
(13) Siliceous shale, with an 8-foot bed of friable sandstone in the upper part	126
(12) Brown limestone, containing abundant quartz grits	8
(11) Siliceous shale, and thin sandstone beds, with two intercalated layers of fossiliferous limestone	242
(10) *Third limestone member:* Light gray, irregularly crystalline limestone, full of silicified fossils. There are a few pebbles of chert in the limestone	21
(9) Brown siliceous shale, with some sandy beds, and a few layers of limestone	54
(8) *Second limestone member:* Gray sandy limestone, with abundant small chert pebbles, and a few fossils	15
(7) Coarse-grained, calcareous sandstone	10
(6) Siliceous shale	26
(5) *First limestone member:* Light-gray, irregularly crystalline limestone in thick, massive ledges. Chert pebbles are rather frequent in the lower part, and near the top are abundant fossils	153
(4) Covered	21
(3) Siliceous shale, with several 2-foot ledges of finely crystalline limestone, containing chert pebbles and fossils	74
(2) Gray crystalline limestone, containing some pebbles and fossils	10
(1) Siliceous shale	13

HESS FORMATION

(2) Gray, coarsely crystalline limestone in 2-foot ledges, containing scattered pebbles, and numerous *Lyttonia*, *Fusulina*, and other fossils	47
(1) Coarse gray calcareous conglomerate, made up of boulders reaching 3 feet in diameter, of limestone and of conglomerate like the Wolfcamp conglomerates below. The matrix is a gray limestone. This bed is quite massive, and breaks along smooth vertical joints	25

WOLFCAMP FORMATION

(4) Greenish sandy shale, containing fusulinids	30
(3) Hard, coarsely crystalline, dark gray limestone, weathering brown. Contains the upper Wolfcamp ammonoid fauna, which includes *Perrinites cumminsi* and *Prothallasoceras welleri*	3
(2) Greenish sandy shale. These three upper members of the formation are cut out to the east by the unconformity at the base of the Hess formation, so that this formation rests directly on the basal conglomerate of the Wolfcamp	
(1) Massive beds of brown calcareous conglomerate, outcropping in rounded ledges. The fragments consist of pebbles, cobbles, and boulders of white limestone, gray sandy limestone, chert, and novaculite; these are closely set in a matrix of sandy limestone	330

Basal Gaptank formation below, possessing a marked angular unconformity with the beds above.

SECTION 8

Measured on a small hill rising from the alluvium covered plain about 4½ miles north-northwest of Altuda.

BISSETT FORMATION

(1) Conglomerate of small rounded pebbles in a limestone matrix. Toward the top are a few beds of pink sandstone. Exposed thickness	60

CAPITAN FORMATION

(2) *Upper Massive member:* Massive, dense, dark-gray limestone, with indistinct bedding planes.

	Feet
Toward the top the limestone is brownish or reddish	215
(1) *Altuda member:* Buff shaly limestone, passing up, at the top, into the *papery limestone.* The upper limestones contain an abundant fauna, including *Squamularia guadalupensis* and *Lyttonia*	50

SECTION 9

Measured along the western end of the Glass Mountains east of Altuda. The Word formation was measured at the southwestern angle of the high scarp of the mountains, about two miles southeast of Altuda.

CAPITAN FORMATION

This portion of the section is described on page 80.

WORD FORMATION

(8) Thick-bedded, yellowish dolomitic limestone, with some layers of brown shaly sandstone between	26
(7) Soft, brownish-gray shaly sandstone	5
(6) Blue-green sandy limestone, weathering nodular, with some partings of shale	53
(5) Similar to 6, but with a greater amount of shale and sandy shale	48
(4) Platy siliceous shale, with some sandy beds, and a few 1-foot layers of gray crystalline limestone, containing ammonoids	85
(3) Siliceous shale, with a few thin beds of dense bituminous limestone	156
(2) Brown calcareous fine-grained sandstone, weathering bouldery. Contains a few fossils	64
(1) Mostly covered by landslides of Capitan dolomite. A few exposures of siliceous shale	186
Base of the Word formation not exposed.	

SECTION 10

The measurements of the Word and Capitan were made on the main escarpment of the Glass Mountains four miles west of Sullivan Peak. The lower beds were measured on the southern cuesta of the mountains two miles northeast of Lenox.

CAPITAN FORMATION

(6) *Upper Massive member:* Massive dolomite, without bedding planes, exposed on the top of a hill a mile north of the escarpment, and 2½ miles due east of Altuda	60
Altuda Member:	
(5) Thin-bedded buff dolomite, containing some chert	131
(4) Thick-bedded gray cherty dolomite	21
(3) Gray sandy flaggy limestone, containing small chert nodules in upper part. Crinoid stems noted	80
(2) Brown sandy limestone, interbedded with flaggy calcareous sandstone	115
(1) *Lower Massive member:* Massive gray dolomite, containing chert concretions. This bed thins and thickens irregularly	166

WORD FORMATION

	Feet
(11) Gray-brown limestone and sandy limestone in moderately thick beds	18
(10) Platy siliceous shale	3
(9) Gray limestone, containing small chert nodules, with some interbedded greenish calcareous sandstone. The limestones contain ammonoids	43
(8) Greenish-gray sandstone, with some nodular calcareous layers, from which a cup coral was collected	22
(7) Platy siliceous shale and some ledge-forming sandstone. There are also a few thin beds of limestone	320
(6) Calcareous flaggy brown sandstone, outcropping in thin ledges	105
(5) Mostly covered, except for a few feet of siliceous shale at the base	480
(4) Granular gray limestone, containing fossil fragments and a few limestone pebbles	44
(3) Siliceous shale, with some sandy layers, interbedded with bituminous limestone	66
(2) Coarsely granular gray limestone, containing chert nodules, abundant fossils, and some limestone pebbles	25
(1) Siliceous shale	15
Beds below this are concealed across a wide alluvium-covered valley, beneath which the basal Word and the greater part of the Leonard are concealed. The section of the Leonard formation below represents only the lower part of the formation.	

LEONARD FORMATION

(4) *First limestone member:* Massive gray limestone, containing many pebbles in the lower part. Fossils fairly abundant near top	82
(3) Siliceous shale, with a few granular conglomeratic limestone layers containing fossils	188
(2) Mostly siliceous shale	41
(1) Three-foot ledges of conglomeratic limestone, interbedded with siliceous shale	20

HESS FORMATION

(1) Conglomeratic limestone, outcropping in a cliff. In the lower part are large cobbles of chert and limestone. In the upper part are some interbedded marly layers, and the upper limestones contain a few fossils	70

WOLFCAMP FORMATION

(2) Buff marly clay, with a few thin limestone layers	156
(1) Conglomerate, outcropping in a great cliff, in part cross-bedded on a grand scale. The fragments are rounded cobbles and boulders of limestone and chert set in a calcareous brown sandstone matrix, full of chert grits	420
The base of this section rests on Caballos novaculite, which is a remnant of the overriding block of the Dugout Creek overthrust.	

SECTION 11

The Word and Capitan of this section were measured up the face of Cathedral Mountain, about 1¼ miles west of Sullivan Peak. The lower beds were measured up the face of the southern cuesta of the Glass Mountains, 3 miles northeast of Lenox, near the hill having an elevation of 5300 feet.

CAPITAN FORMATION

Feet

Lower Massive member:

(5) Massive porous dolomite, capping Cathedral Mountain ... 70
(4) Thin-bedded dolomite ... 50
(3) Massive porous dolomite, without bedding planes, weathering to jagged surfaces ... 75
(2) Thin-bedded yellow dolomite ... 5
(1) Massive dolomite, without bedding planes ... 58

WORD FORMATION

(13) Thinly and regularly bedded, dense yellow or pink dolomitic limestone, containing small chert masses. Near the middle are some sandy layers 189
(12) Platy siliceous shale, with some sandy beds ... 225
(11) Thin-bedded, fine-grained brown sandstone, in part calcareous. Near the top are some limestone nodules. This bed forms a prominent ledge around Sullivan Peak and Cathedral Mountain 124
(10) Platy siliceous shale, with some sandy beds ... 243
(9) Dense brown sandy limestone, interbedded with siliceous shale ... 34
(8) Platy siliceous shale, with some sandstone layers and some soft shale ... 235
(7) Dark gray, granular, fossiliferous limestone, containing *Fusulina* and other fossils ... 15
(6) Platy siliceous shale, with thin beds of bituminous limestone ... 85
(5) Coarsely granular cherty limestone, with a few fossils ... 16
(4) Platy siliceous shale ... 25
(3) Dark gray, coarsely granular limestone, containing abundant fossils. Contains a few chert nodules ... 50
(2) Siliceous shale, with a few thin layers of bituminous limestone ... 50
(1) Limestone. In the lower half it is dense and bituminous, and weathers white, outcropping in thin ledges. The upper part is coarse grained and of dark gray color; this contains abundant silicified fossils, and a few limestone pebbles... 127

LEONARD FORMATION

Beneath the section just described, at the base of Cathedral Mountain, are thick beds of buff or reddish quartzitic sandstone, with some layers packed by small rounded and published pebbles of chert and quartz ... 233
The middle part of the Leonard formation was not measured in this section, because it is concealed by alluvium across the wide strike valley south of Sullivan Peak.

Feet

(17) *Fourth limestone member:* Gray limestone ... 10
(16) Siliceous shale ... 32
(15) Limestone ... 2
(14) Brown platy siliceous shale ... 55
(13) *Third limestone member:* Conglomeratic limestone, containing small, well rounded pebbles of quartz and chert ... 20
(12) Siliceous shale ... 106
(11) Massive granular limestone ... 6
(10) Platy siliceous shale, with a few thin limestone beds near the middle ... 85
(9) Dense, fine-grained, dark gray limestone in 1-foot ledges, containing some chert ... 4
(8) Siliceous shale, with some sandy beds, with three 2-foot ledges of granular cherty limestone containing some fossils ... 82
(7) *First limestone member:* Gray crystalline limestone in thick ledges, containing scattered limestone cobbles and a few fossils ... 114
(6) Siliceous shale, with three 2-foot beds of irregularly crystalline conglomeratic limestone ... 78
(5) Covered; probably mostly clay shale ... 108
(4) Granular, dark gray fossiliferous limestone, containing fusulinids ... 2
(3) Buff clay shale ... 27
(2) Limestone in six-inch ledges, with some interbedded shale ... 15
(1) Clay shale, with a few thin granular limestone beds ... 29

HESS FORMATION

(1) Massive, poorly bedded limestone forming a prominent cliff. Contains many rounded pebbles and small cobbles, as well as a few fossils ... 50

WOLFCAMP FORMATION

(2) Shaly gray sandstone and sandy shale, with a few thin sandy limestone layers ... 168
(1) Conglomerate in thick ledges. Consists of angular to sub-angular fragments of chert, with a few of limestone, packed in a matrix of calcareous ferruginous sandstone. Near the base, fragments up to a foot in diameter are found. There is some interbedded buff sandy marl ... 283
At this point the Wolfcamp formation rests on the Gaptank, which is only poorly exposed. Caballos novaculite is exposed a few rods to the south. On tracing the basal contact eastward, it is found that the great mass of basal Wolfcamp conglomerate passes out abruptly by overlap.

SECTION 12

This section was measured to the north and south of Sullivan Peak. The Leonard and older beds were measured along the eastern end of the hills and cuestas which lie immediately to the west of the road to the old Sullivan Ranch. The Word formation was measured up the south face of Sullivan Peak. The Capitan formation was measured at the east end of Cathedral Mountain (just to the west of the peak), and on the high mountain north of the Sullivan Ranch.

CAPITAN FORMATION

		Feet
(10)	*Upper Massive member:* Massive, poorly bedded dolomite, which is cross-bedded on a gigantic scale. These cross-beds dip northwest, and are 10° steeper than the true inclination of the strata	800
	Altuda member:	
(9)	Thickly but regularly bedded gray dolomite	95
(8)	Pale pink or buff dolomite in thin ledges. The lower 60 feet are not well exposed; then follow a succession of gray to pink dolomite in moderately thin beds. Some of the upper beds assume a deep brown color on weathering	420
(7)	Pale pink and buff dolomite in 3-foot ledges, containing some chert nodules	57
(6)	Thin-bedded sandy brown dolomite in thin even layers	62
	Lower Massive member:	
(5)	Massive dolomite with indistinct and irregular bedding	75
(4)	Thin-bedded dolomite, containing some chert, and some sandy layers. Bedding planes are one foot or less apart	53
(3)	Massive, poorly bedded, porous dolomite. On Sullivan Peak the bed has a thickness of 111 feet. North of the Sullivan Peak it is:	80
(2)	Thin-bedded brown dolomite with some chert	5
(1)	Massive dolomite with no bedding planes except at top and base. On Sullivan Peak this bed has a thickness of 106 feet. North of the Sullivan Ranch it is:	48

WORD and LEONARD FORMATIONS

The description of these two formations is given on pp. 66–67 and pp. 70–71.

HESS FORMATION

(1)	Conglomerate. The matrix is a gray crystalline limestone, in which are imbedded chert and limestone pebbles, as well as a few cobbles. The fragments increase in abundance toward the top. This member outcrops in a cliff	67

WOLFCAMP FORMATION

(4)	Largely covered, though there are a few exposures of shale	142
(3)	Brown sandy fossiliferous limestone	1
(2)	Mostly covered, with some buff sandy shale exposed in the middle	107
(1)	Conglomerate of limestone, novaculite, and chert in well-rounded fragments set in a sandy gray limestone matrix	7

The beds underlying the Permian are not well exposed. Not far from the basal Wolfcamp conglomerate were fossiliferous limestones, evidently belonging to the Gaptank, and a little farther away were exposures of novaculite and novaculite breccia, the latter evidently being the thrust breccia of the Dugout Creek overthrust.

SECTION 13

Section measured on the southern cuesta of the Glass Mountains about one-fourth mile east of the Sullivan Ranch road.

LEONARD FORMATION

		Feet
(6)	Poorly bedded gray limestone, with some pebbles	14
(5)	Platy siliceous shale	30
(4)	*First limestone member:* Poorly bedded gray limestone, containing pebbles and a few fossils	76
(3)	Siliceous shale, some of which is quite stony, with a few thin beds of gray limestone	94
(2)	Massive limestone, containing cobbles and pebbles	14
(1)	Siliceous shale	5

HESS FORMATION

(1)	Massive gray limestone, containing pebbles and cobbles of limestone and chert, with a few partings of calcareous shale near the middle. Contains fossils near top	227

WOLFCAMP FORMATION

(1)	Buff sandy shale interbedded with 2-foot beds of brown coarsely granular limestone	63

Base not exposed.

SECTION 14

Section about halfway between Iron Mountain and the Sullivan Ranch road. Wolfcamp and Hess measured on the southern cuesta of the Glass Mountains at the summit having an elevation of 5021 feet. The Leonard section begins 1¼ miles northeast of this point, proceeds northwest, passing a little east of the Clay Slide to the base of the Word. The Word formation was measured from the hills north of the Clay Slide northwestward up the face of the high scarp of the mountains to a summit having an elevation of 6327 feet.

CAPITAN FORMATION

	Lower Massive member:	
(5)	Massive dolomite, with some thin-bedded dolomite	100
(4)	Thin-bedded dolomite	32
(3)	Massive dolomite	138
(2)	Thin-bedded dolomite	21
(1)	Massive dolomite without bedding planes	75

WORD FORMATION

(9)	Gray to yellow sandy dolomitic limestone in 1-foot ledges. Contains small chert nodules, and is interbedded with flaggy friable sandstone	224
(8)	Brown platy siliceous shale	96
(7)	Covered by landslide deposits	313
(6)	Platy brown siliceous shale, containing nodules of limestone	325

	Feet
(5) Covered; thickness uncertain, because of the probable presence of a strike fault. An attempt was made to correct for the duplication by faulting	150
(4) Massive cherty limestone, in part bituminous	33
(3) Covered	50
(2) Dense platy limestone containing long thin lenticles of black chert. The rock is bituminous, and weathers light gray	85
(1) Gray granular limestone, with some sandy beds. Contains thick lenticles of chert	30

LEONARD FORMATION

(22) Drab clay shale and sandy shale, with thin intercalations of fine-grained brown sandstone. Some of the sandstone layers are lenticular, and appear to have filled channels or pockets; others are inclined at considerable angles to form large-scale cross-bedded structures. This is the member exposed at the "Clay Slide" ¼ mile to the west. At that place it contains pyritized *Perrinites* within 100 feet of the top. The thickness at the Clay Slide is 350 feet; here it is:	200
(21) Hard brown siliceous sandstone	5
(20) Clay shale, with some sandy beds, and a few limestone layers	88
(19) Covered across a small valley	44
(18) Finely crystalline buff nodular limestone, containing a few ammonoids and pebbles	3
(17) Drab clay shale, with a thin limestone ledge near the middle	30
(16) Finely crystalline buff limestone, containing abundant well preserved fossils which weather free from the matrix and cover the slope below. *Perrinites vidriensis* is the most abundant fossil; *Medlicottia whitneyi* and *Productus ivesi* may also be found. Bryozoa are common	4
(15) Drab clay shale, with several beds of nodular limestone	61
(14) Poorly exposed shale, with three thin beds of fragmental limestone, containing ammonoids	20
(13) Covered	33
(12) Dark gray granular limestone, crowded with fossil fragments, and with occasional pebbles. Near the middle is a two-foot bed of shale	11
(11) Soft clay shale, in part exposed in gullies, with several interbedded layers of conglomeratic granular limestone, or of dense limestone. Below this bed the shale is all hard and siliceous	38
(10) Dense limestone, weathering brown	2
(9) Brown platy siliceous shale with three interbedded layers less than a foot thick of granular limestone	140
(8) Limestone, containing a few pebbles and ammonoids, with some thin intercalated layers of shale	11
(7) Siliceous shale, with several layers of limestone two feet in thickness. One of the limestone beds is cherty, and contains ammonoids	36

	Feet
(6) Granular light gray limestone in 3-foot to 4-foot ledges, possibly with some shales between. The lowest bed contains abundant *Perrinites vidriensis*, and all the beds are marked by numerous crinoid stems and fragments of brachiopod shells	27
(5) Brown platy siliceous shale, with some sandy layers, with three intercalated layers of granular fossiliferous limestone, part of which is cherty	122
(4) Massive gray limestone in indistinct ledges, containing many irregular cherty masses, and silicified fossils	27
(3) Flinty siliceous shale in beds several inches thick, with knobby bedding surfaces. There are a few intercalated sandy beds	162
(2) Finely crystalline limestone, containing irregular siliceous masses and silicified fossils	2
(1) Flinty siliceous shale, with some sandy beds, and several intercalated layers of limestone	62

HESS FORMATION

(3) Gray granular limestone, containing a few small chert pebbles, outcropping in 3-foot ledges which stand out in a prominent cliff. In the upper part some of the beds are crowded with crinoid stems	172
(2) Covered by talus; probably conglomerate	78
(1) Conglomerate in a sandy limestone matrix. The pebbles average 2 inches in diameter and consist of limestone and chert. There are some scattered crinoid stems in the matrix. Contact between Hess and Wolfcamp not certainly established in this section because of the heavy talus deposits	7

WOLFCAMP FORMATION

(4) Covered	7
(3) Conglomerate of chert and limestone pebbles in a matrix of sandy marl; not well exposed	2
(2) Covered	15
(1) Conglomerate of chert and limestone pebbles and cobbles, some of which are of the Dimple facies. The fragments are quite well rounded and lie in a matrix of buff sandy limestone. The bed weathers brown	59

Dimple formation at base of section; not well exposed at this point, but possessing a well-marked angular unconformity with the overlying beds at nearby localities.

SECTION 15

Section measured north-northwest from Iron Mountain. Section begins at the south end of limestone ridge at a point 1 mile west of the mountain, continues north to the summit, whose elevation is 5280. The overlying Leonard beds were measured northwest from this point. The Word and Capitan were measured on the high scarp of the Glass Mountains below the summit whose elevation is 5939.

CAPITAN FORMATION

(1) *Lower Massive member:* Massive porous dolomite, containing large secondary calcite crystals	100

WORD FORMATION

	Feet
(8) Pink and purple dolomitic limestone containing small chert masses, and outcropping in thin regular beds	75
(7) Dense sandy dolomitic yellow or brown limestone in flaggy layers. The limestone contains small chert nodules. There are some platy sandstone beds between	213
(6) Platy siliceous shale, with some sandy beds between. In the upper part are some nodular layers of fossiliferous limestone	136
(5) Dense, somewhat bituminous limestone in 1-foot ledges, interbedded with siliceous shale. The limestone contains some nodules of white chert	14
(4) Platy siliceous shale, with some sandy layers	68
(3) Massive ledge of gray crystalline limestone, containing some silicified fossils and some limestone pebbles in the lower part	7
(2) Siliceous shales, with some sandy beds	150
(1) Medium crystalline light gray limestone, with some bituminous layers. In the upper part are long thin limestone lenticles at intervals of 6 or 8 inches. Ammonoids (*Waagenoceras*?) noted	84

LEONARD FORMATION

	Feet
(18) Brown siliceous shale with thin ledges of dense bituminous limestone	76
(17) Quartzitic brown sandstone, with some nodular limestone layers, containing fossils	17
(16) Brown platy siliceous shale, with some thin layers of dense limestone	139
(15) Covered across valley	300
(14) Massive finely crystalline limestone, containing silicified fossils	4
(13) Greenish sandy shale	25
(12) Thin-bedded limestone with limestone pebbles in the upper part	3
(11) Fine-grained greenish sandstone, with some shale in the lower part	43
(10) Dark gray sandy limestone, containing a great abundance of *Perrinites vidriensis*	3
(9) Platy or flinty siliceous brown shale, containing numerous ledges of fine-grained gray fossiliferous limestone	56
(8) Massive limestone containing abundant small pebbles of chert, limestone, and quartz. Fossils noted	4
(7) Brown siliceous shale, with many quartzitic sandstone layers in lower part	46
(6) Coarse-grained gray limestone, containing small, well-rounded quartz, chert, and limestone pebbles, averaging one-fourth inch in diameter. There are many fragmented silicified fossils	4
(5) Brown platy siliceous shale, containing two thin limestone layers	42
(4) Coarsely crystalline gray limestone, containing many silicified shell fragments, including *Perrinites*	25
(3) Brown siliceous shale, in part of flinty or stony texture. There is a thin limestone layer in the lower part	92
(2) Gray, finely crystalline limestone, containing abundant silicified fossils, and considerable secondary silica in irregular masses	6
(1) Brown platy siliceous shale, containing numerous layers of sandstone, cemented into quartzites. There are several thin layers of fossiliferous limestone	119

HESS FORMATION

	Feet
(5) Massive light gray finely crystalline limestone, with a few conglomerate lenses. In upper part are abundant silicified fossils, of which corals are most common. This layer caps the cuesta west of Iron Mountain	70
(4) Massive light gray limestone, containing numerous limestone cobbles, and a few large boulders	62
(3) Thin-bedded finely crystalline light gray limestone, containing no conglomerate	60
(2) Light gray crystalline limestone, outcropping in thick ledges. The limestone contains scattered cobbles, and a few lenses of conglomerate. A few fossils were noted, including large crinoid stems	85
(1) Calcareous conglomerate. The fragments are rounded cobbles and pebbles, with some large boulders, consisting of limestone and chert. The matrix is a sandy marl, or a hard limestone, and is in places impregnated with limonite	110

WOLFCAMP FORMATION

	Feet
(8) Drab clay shale, with some layers of sandy shale	99
(7) Sandy brown limestone, containing numerous chert pebbles, as well as wood fragments, crinoid stems, and *Schwagerina*	2
(6) Drab clay shale, with some thin intercalated sandy layers	17
(5) Conglomerate of chert and limestone pebbles	1
(4) Soft sandy clay shale	10
(3) Calcareous sandstone, weathering brown	1
(2) Buff sandy clay shale	31
(1) Conglomerate composed of closely packed rounded pebbles of limestone, of chert in various colors, and of quartz. The matrix is a brown calcareous sandstone	5

Dimple formation at base of section having a well marked angular unconformity with the beds above. The Wolfcamp at the contact dips 15° west-northwest, and the Dimple limestones 30° north-northeast.

SECTION 16

Under this number are included a number of disconnected sections along Gilliland Canyon. The Capitan was measured up the south end of Old Blue Mountain. The Word was measured 3 miles to the south, on the east face of the mountain whose summit has an altitude of 6523 feet. The Leonard was not measured. The Hess formation was measured on the westernmost spur of Leonard Mountain.

CAPITAN FORMATION

This portion of the section is described on pages 79–80

WORD FORMATION

		Feet
(9)	Buff or yellow, finely crystalline limestone in 6-inch to 2-foot ledges. These contain small geode-like pockets	90
(8)	Ledges similar to above, less well exposed; small chert nodules noted	61
(7)	Covered	48
(6)	Soft, fine-grained, brown shaly sandstone, weathering into nodular ledges	40
(5)	Buff, finely crystalline nodular limestone, containing small chert concretions	6
(4)	Mostly covered; probably all siliceous brown shale, which is exposed in several places	120
(3)	Pink, fine-grained quartzitic sandstone in one-foot ledges with some intercalated siliceous shale	40
(2)	Covered by talus of Capitan dolomite, but with a few obscure outcrops of siliceous shale in the upper 80 feet	274
(1)	Finely crystalline light gray limestone in 2-foot to 3-foot ledges, with some chert concretions and a few fossils. This overlies Leonard siliceous shale	88

LEONARD FORMATION

The Leonard formation is obscured beneath the wash of Gilliland Canyon, and was not measured in this section.

HESS FORMATION

(11)	Coarsely crystalline gray limestone in thick beds, containing fine fossil fragments	40
(10)	Poorly exposed limestone ledges	80
(9)	Thin-bedded gray limestone, with chert seams and some intercalated beds of shale	12
(8)	Covered	28
(7)	Limestone in 3-foot to 20-foot ledges, with some intercalated marl and siliceous shale	110
(6)	Mostly covered, with a few thin ledges of cherty limestone, and some exposure of shaly marl	53
(5)	Thin-bedded gray limestone, without chert	45
(4)	Covered	26
(3)	Massive limestone, with considerable chert and a few large crinoid stems	10
(2)	Covered	64
(1)	Finely crystalline dark gray limestone, with fine fossil fragments and some chert	13

Probably near base of formation; brown Wolfcamp limestones, containing *Schwagerina*, outcrop several hundred yards to the south, but these were not exposed continuously enough to be measured.

SECTION 17

Section measured northward from Leonard Mountain. The Wolfcamp and Hess formations were measured up the southeast angle of the mountain. The Leonard was measured across the saddle between Leonard Mountain and the mountain to the north, on the western side of the divide between Gilliland and Hess Canyons. The Word measurement is continued northward from this, and ends near the junction of Road and Gilliland canyons. The entire thickness of the Capitan was not measured, though an estimate of the thickness of the Upper Massive member was made near Jail Canyon and Spring Canyon (western tributaries of Gilliland Canyon), and of the Tessey member between the mouth of Gilliland Canyon and Tessey Buttes. A nearly complete section of the Gilliam member was measured 1½ miles southwest of the mouth of Gilliland Canyon. The Bissett formation was measured along the western edge of the Tessey Buttes, near the gap which is traversed by the road from Alpine to the Warren Ranch.

BISSETT FORMATION

This portion of the section is presented on page 86.

CAPITAN FORMATION

That portion of the Capitan which was measured is described on pp. 128–129 of the main report.

WORD FORMATION

		Feet
(8)	Yellow limestone, somewhat sandy and dolomitic; somewhat similar to limestones at the top of the Word farther west. In the upper part are several beds crowded with brachiopods	120
(7)	*Third limestone member:* Divided into the following members:	
	(f) Gray limestone	12
	(e) Gray saccharoidal sandstone	12
	(d) Siliceous shale	7
	(c) White oolitic limestone; richthofenia noted	30
	(b) Siliceous shale	2
	(a) Light gray or white oolitic limestone, with a thin bed of yellow dolomitic limestone at the base. This and succeeding beds contain *Waagenoceras* ammonoid fauna in great abundance	51
(6)	Brown platy siliceous shale, with four beds of limestone, some of which are bituminous, and some of which are light gray and abundantly fossiliferous	340
(5)	Fossiliferous gray limestone in 3-foot ledges, with some siliceous shale between	25
(4)	Platy brown siliceous shale, with a few thin beds of fossiliferous gray limestone	38
(3)	Irregularly crystalline gray limestone, crowded with fossils, which are silicified on the surface. Bryozoa and fusulinids are most abundant	10
(2)	Platy brown siliceous shale	10
(1)	*First limestone*: Massive, light gray oolitic limestone, containing abundant silicified fossils, including *Fusulina elongata* and *Waagenoceras*. This bed forms a prominent cliff in places	125

LEONARD FORMATION

	Feet
(16) Covered; this member is probably shale, but it is nowhere exposed	465
(15) Buff clay shale, with several thin beds of granular brown fossiliferous limestone, one of which contains a few quartz pebbles	36
(14) Richly fossiliferous granular brown limestone, containing a few quartz pebbles. The fossils weather free from the crumbling matrix and lie on the slopes below. The fauna includes many species of bryozoa, several crinoid calyces, *Productus ivesi, Richthofenia,* and a few specimens of *Perrinites vidriensis*	3
(13) Buff clay shale, with a few sandy beds, and several thin layers of granular fossiliferous limestone	143
(12) Granular, gray-brown limestone, containing fossil fragments	5
(11) Shale with thin limestone beds	41
(10) Black crystalline limestone, containing a few fossils	4
(9) Brown siliceous shale, with some thin limestone beds	30
(8) Irregularly crystalline black limestone, containing *Perrinites*	3
(7) Brown siliceous shale, with several beds of gray granular fossiliferous limestone	56
(6) Gray granular limestone, containing irregular chert masses and many silicified fossils	4
(5) Brown siliceous shale	10
(4) Granular gray limestone, with numerous rounded quartz pebbles in the lower part. In the upper part are some silicified fossils, including *Perrinites*	20
(3) Siliceous shale; poorly exposed	131
(2) Dark gray limestone of granular texture, containing broken fragments of shells	3
(1) Siliceous platy or flinty shale	5

HESS FORMATION

This portion of the section is presented on page 62

WOLFCAMP FORMATION

NOTE: The upper part of this section is not easily made out because of extensive landslides from the cliffs above. Bed (5) may represent a landslide of Hess limestone, but as nearly as the observations could be made in the field it appeared to be in place, and to be a part of the Wolfcamp formation.

	Feet
(8) Similar to the bed beneath, but not well exposed	63
(7) Massive and thin-bedded limestone	23
(6) Covered except for a few layers of sandstone near the base	42
(5) Massive gray limestone and calcareous conglomerate, containing pebbles less than an inch across	250
(4) Granular dark gray limestone, weathering yellow, containing abundant fragments of shells, including *Schwagerina* and corals	30
(3) Shale, with some interbedded brown sandstone	60
(2) Brown siliceous sandstone	10
(1) Conglomerate of limestone and chert pebbles in a matrix of brown sandy limestone. This bed has a very irregular development, being only 10 feet thick in places, but at the southeast angle of the mountain its thickness reaches:	200

The basal conglomerate rests on a worn and eroded surface of the Tesnus sandstone, with which it possesses an angular discordance of about 5°.

SECTION 18

The Hess formation in this section was measured along the northeast end of Leonard Mountain; the Leonard from a small knoll in the valley north of Leonard Mountain and 1¼ miles northwest of the Hess Ranch in a northwesterly direction up the alluvial slope to the base of the Word formation. The Word formation was measured north of this place, in the hills to the north and south of the eastern end of Road Canyon.

WORD FORMATION

This portion of the section is presented on pages 71–72.

LEONARD FORMATION

	Feet
(1) There are practically no exposures of the Leonard formation in this interval, and the surface consists of a long smooth slope of soil and wash; undoubtedly bed rock is not far beneath the surface. About half a mile to the west, and 200 feet below the base of the Word are exposed some 3-foot ledges of granular fossiliferous brown limestone, separated by platy siliceous shale. At the base of the section where measured, on the north side of the little knoll are layers of stony siliceous shale. The thickness can be considered as approximate only	800

HESS FORMATION

	Feet
(4) Massive limestone, weathering reddish in the lower part. On fresh surfaces it is light gray and crystalline, and it is of the western facies of the Hess formation	200
(3) Dirty gray, dolomitic, thin-bedded limestone of the eastern Hess facies	150
(2) Massive white crystalline limestone	100
(1) Calcareous conglomerate made up of limestone cobbles in a limestone matrix	125

This rests on the Wolfcamp formation, of which, however, there are only scattered exposures. Several hundred feet down the slope are shales with the *Uddenites* fauna.

SECTION 19

Measured at the west end of the hills of the Hess Ranch horst, about 2 miles north-northeast of the Hess Ranch.

HESS FORMATION

	Feet
(4) Thick-bedded gray limestone; top eroded, and upper limit not seen. Maximum thickness exposed	20
(3) Drab clay shale, containing numerous Hess fossils	20
(2) Thick-bedded light gray limestone, containing silicified *Meekella* and *Scacchinella* near top	100
(1) Dirty-gray, thin-bedded, dolomitic limestone of facies of eastern Hess. This layer is not always present, but appears to pass out locally by overlap on the underlying Wolfcamp	20

WOLFCAMP FORMATION

	Feet
(1) Massive limestone, in places crowded with chert and limestone cobbles, and in other places quite pure. Maximum thickness exposed is about	200

SECTION 20

Measured north of the intrusive plug on the south side of the Hess Ranch horst. The base of the section is at the intrusive contact, and the section continues northward up the face of the escarpment to the hill whose elevation is 5816 feet.

HESS FORMATION

(7) Finely crystalline light gray limestone, in massive beds 3 to 5 feet in thickness; these appear white from a distance, and resemble the cliffs on Leonard Mountain, made up of the western facies of the Hess. These layers contain a few small cherty masses	116
(6) These, and the beds below, are of the eastern facies of the Hess. Consists of moderately thick-bedded, finely crystalline limestone, weathering brown or dirty gray; some of the layers contain small fusulinids	110
(5) Finely crystalline dark gray limestone in 6-inch to 2-foot layers; some of the layers are crowded with fusulinids and fragments of crinoid stems. On weathering, the ledges break into narrow vertical plates	104
(4) Brown sandy limestone, containing numerous chert and quartz pebbles	3
(3) Finely crystalline, dark gray limestone, in 1-foot ledges, which weather to smooth buff surfaces	18
(2) Thin-bedded, finely crystalline brown limestone, containing chert pebbles	28
(1) Calcareous conglomerate, containing cobbles of chert and limestone	50
To the west this layer has an angular unconformity of 5° with the underlying beds.	

WOLFCAMP FORMATION

This part of the section is described on page 56.

SECTION 21

Measured on the low escarpment one mile northeast of the Hess Ranch house.

HESS FORMATION

	Feet
(4) The top of this layer is eroded, and was not seen. It consists of thick ledges of white crystalline limestone of the western facies of the Hess, which, about a mile to the west contain *Scacchinella* near the base. This bed is evidently the same as bed 7, section 20, and bed 2, section 19	60
(3) Two-foot to four-foot ledges of finely crystalline dolomitic limestone, weathering to dirty gray pitted surfaces. On weathering, the finely crystalline aggregate takes on a falesly sandy appearance	168
(2) Finely crystalline dolomitic gray limestone in moderately thick ledges	18
(1) Conglomerate composed of quartz, chert, and limestone pebbles, of rounded to sub-rounded form, reaching 2 inches in diameter. The matrix is a sandy ferruginous dolomite, in which the pebbles are arranged in seams	163
Base not exposed, though the base of the section is probably near the base of the formation.	

SECTION 22

Measured up the face of the Hess escarpment 2 miles east-northeast of the Hess Ranch, ending at the summit whose elevation is 5726 feet.

HESS FORMATION

(13) Thick-bedded deeply pitted gray dolomite, capping the mountain. Top of formation not exposed	5
(12) One-foot ledges of dense, light gray dolomitic limestone, weathering white or light gray. The fracture of the rock is conchoidal. Near the middle is a 6-foot ledge of massive dolomitic limestone	336
(11) Massive ledges of hackly light gray limestone	31
(10) Light gray dolomite, weathering brownish gray, in 3-foot ledges	127
(9) Thick-bedded light gray limestone forming a prominent ledge at the western end of the mountain, but merging into thinner-bedded dolomitic strata toward the east	44
(8) Thin-bedded dolomitic limestone	188
(7) Finely crystalline, somewhat dolomitic limestone in 5-foot ledges. The rock weathers gray and pitted. Obscure traces of fossils are seen on the surfaces of the rock. To the west this layer changes into a pure light gray limestone, and is traceable into bed 4 of section 21	26
(6) Thin-bedded dolomitic limestone	15
(5) Massive dolomitic limestone in 5-foot ledges. To the west this changes into white pure limestone, and to the east it merges with thin dolomitic beds	93
(4) Dense, finely crystalline dark gray limestone in 1-foot to 2-foot ledges, which weather into conchoidal chips, or split vertically into narrow plates. In part the limestones are dolomitic and	

		Feet
	in some of the beds are minute spherical bodies which may be the remains of ostracods or foraminifers	201
(3)	Dense purplish dolomitic limestone in 3-foot ledges	38
(2)	Covered	110
(1)	Conglomerate of chert and limestone pebbles in a limestone matrix; the pebbles are rounded or sub-rounded, and reach 2 inches in diameter. Some gray limestone is interbedded	29
	Base of the Hess formation is not exposed, though presumably it lies not far beneath.	

SECTION 23

This section extends along the west side of Hess Canyon; it begins in the Wolfcamp formation one mile west of Wolfcamp. The Wolfcamp and lower Hess formations were measured to the north of this point. The greater portion of the Hess formation, however, was measured a mile farther to the west, up the face of the escarpment to the summit whose elevation is 5751. Thence, the section continues north-northwest about a mile west of Hess Canyon, and parallel to it, ending on the escarpment capped by the Vidrio member of the Capitan, at summit 5543.

WORD FORMATION

This portion of the section is presented on page 72.

LEONARD FORMATION

		Feet
(4)	Siliceous brown shale, containing large nodules of limestone in the upper part	100
(3)	Light gray crystalline limestone, containing abundant silicified fossils	10
(2)	Soft brown clay shale, with several thin layers of fossiliferous limestone	60
(1)	White crystalline limestone, in part fossiliferous, containing many rounded and polished pebbles of quartz and chert	50

HESS FORMATION

		Feet
(14)	Massive limestone, which is dolomitic near the crest of the escarpment, but which is a white crystalline non-dolomitic limestone farther north	150
(13)	*Perrinites compressus horizon:* Gray limestone containing many nodules of brown chert, and abundant silicified fossils, the most abundant of which are crinoid stems and *Composita*	5
(12)	Thin layers of white dolomite alternating with sandy buff marl and marly sandstone	175
(11)	Thin-bedded dense gray or brown dolomitic limestone, with some interbedded marl. The limestone in places possesses a conchoidal fracture. At the top is a rather prominent ledge which is the same as bed 13, section 22	315
(10)	Light gray dense or crystalline limestone, in part dolomitic. Some of the ledges are quite thick and prominent, but others are thin	298
(9)	Thin-bedded dense brown limestone, in part dolomitic	58
(8)	Dense gray limestone in 6-inch to 1-foot beds	112
(7)	Dense gray-brown limestone in thin beds, weathering to an earthy nodular surface	162
(6)	Massive gray or brown finely crystalline limestone in prominent ledges	57
(5)	Gray marl, containing thin beds of marly limestone. This contains abundant poorly preserved fusulinids, gastropods, and bellerophons	10
(4)	Massive coarsely crystalline dolomitic gray limestone, with some thin-bedded limestone near the middle	71
(3)	Nodular drab shaly limestone, with some interbedded shale; not well exposed	99
	Sill of syenite porphyry, 35 feet in thickness.	
(2)	Greenish sandy shale and shaly sandstone, not well exposed	111
(1)	Calcareous conglomerate, made up of limestone cobbles and chert pebbles, in a matrix of buff sandy marl. Toward the top are some interbedded layers of sandy limestone	35

WOLFCAMP FORMATION

		Feet
(33)	Shale	4
(32)	Thinly laminated brown sandstone	9
(31)	Drab shale, with some sandy seams	54
(30)	Fine-grained, thinly laminated brown sandstone	4
(29)	Drab sandy shale	41
(28)	Covered	54
(27)	Brown calcareous sandstone containing small quartz pebbles	1
(26)	Covered, except for a few exposures of buff calcareous sandstone	26
(25)	Gray, finely granular limestone, weathering brown; contains small chert pebbles	1
(24)	Covered, probably shale	50
(23)	Coarsely granular brown limestone, containing fossil fragments and limestone pebbles several inches in diameter	8
(22)	Covered, probably shale	29
(21)	Finely granular gray limestone, with a few scattered fossils	2
(20)	Covered, probably shale	12
(19)	Coarsely granular gray limestone containing abundant fossils, including *Schwagerina*, cup corals, crinoid stems, bryozoa, and several species of brachiopods	4
(18)	Mostly covered, but with a few indistinct ledges of limestone	11
(17)	Fossiliferous limestone	3
(16)	Mostly covered, but with a few indistinct ledges of limestone	12
(15)	Fossiliferous limestone, containing sponges, cup corals, *Productus*, and *Enteletes*	2
(14)	Covered	2
(13)	Fossiliferous limestone, containing *Schwagerina* and other fossils	3
(12)	Poorly exposed marly strata, with some interbedded limestone. Large crinoid stems noted	7
(11)	Coarsely crystalline gray limestone, containing various species of bryozoa and brachiopods	4

	Feet
(10) Covered, probably shale or marl	10
(9) Coarsely crystalline gray limestone, weathering bouldery. Contains large crinoid stems	7
(8) Mostly covered, probably marl	4
(7) Thin-bedded, finely granular gray limestone	8
(6) Brownish-gray granular limestone outcropping in several ledges, which appear to be separated by marls. This layer outcrops on a low cuesta and is the same as bed 12 of section 24 (at Wolf Camp)	30
(5) Gray marl, containing crinoid stems and limestone pebbles	23
(4) Brownish-gray granular limestone in thin ledges	8
(3) Covered, probably marl	24
(2) Gray granular limestone	4
(1) Four ledges of shell breccia separated by green shale	66

Base of the Wolfcamp formation is not exposed. That portion of the formation which was measured all belongs to the upper member of the Wolfcamp formation.

SECTION 24

Section measured northwest from Wolf Camp along the east side of Hess Canyon. The Wolfcamp formation was measured at the west end of the Wolf Camp Hills, along the western side of a small canyon draining through the hills from the main scarp of the mountains. The Hess formation is continued directly from this, proceeding up the face of the escarpment to the summit whose elevation is 5821 feet, and thence across the hills to the base of the Leonard ½ mile east of Hess Canyon. The Leonard formation was measured directly above this across a branch of Hess Canyon up which the road leads to the Word Ranch. The Word formation was measured in a north-northwesterly direction from this point, ending about a mile northwest of the summit of the Comanchean outlier whose elevation is 5575 feet. The Vidrio and Gilliam members of the Capitan were measured along the east side of Hess Canyon from 2 to 6 miles northwest of the Word Ranch. The Tessey member and the Bissett formation were measured in the hills north of the Warren Ranch in a northerly direction to the north edge of the mountains.

BISSETT FORMATION

This portion of the section is presented on page 86.

CAPITAN FORMATION

This portion of the section is presented on pages 75–76.

WORD FORMATION

	Feet
(13) *Fourth limestone member:* This member is divided into the following layers:	
(c) Light gray crystalline limestone, very similar in appearance to the Edwards limestone of the Comanche. It contains abundant small brown chert nodules as well as an abundant fauna of brachiopods, fusulinids, and other fossils	260
(b) Gray and brown limestone and dolomitic limestone, containing some chert nodules and many silicified fossils, interbedded with sandy brown limestone and some siliceous shale	255
(a) Fossiliferous cherty dolomite, weathering to dirty gray deeply pitted surfaces	40
(12) Siliceous shale, with considerable interbedded brown limestone and sandy limestone	32
(11) Thin-bedded finely crystalline brown limestone, which is sparingly cherty and fossiliferous, interbedded with thin layers of siliceous shale	64
(10) Siliceous shale, often of stony or flinty texture, interbedded with a few layers of cherty dolomitic limestone	26
(9) Fossiliferous cherty dolomite, with some interbedded siliceous shale	10
(8) Siliceous shale	26
(7) *Third limestone member:* Thick-bedded dolomite	50
(6) Siliceous shale, with several layers of fossiliferous cherty dolomite	44
(5) Thin-bedded cherty dolomite, with some interbedded siliceous shale	25
(4) Siliceous shale, interbedded with dense brown limestone, and sandy shale	30
(3) *Second limestone member:* This member is subdivided into the following layers:	
(c) Dolomite	38
(b) Siliceous shale of irregular thickness; maximum thickness is in the southern exposures, where it is	12
(a) Massive dolomite in 2-foot to 4-foot ledges. The layers are very cherty, and are sparingly fossiliferous	83
(2) Brown siliceous shale, with a ledge of dolomite near the middle	14
(1) *First limestone member:* This member is subdivided into the following layers:	
(b) Gray dolomite, weathering to a dirty gray color, and a deeply pitted and jagged surface. It is crowded with fusulinids, and is quite cherty in some layers	80
(a) Thinly laminated, dense, platy bituminous limestone, weathering light gray. Contains thin seams of chert	60

LEONARD FORMATION

	Feet
(13) Siliceous shale	68
(12) Massive gray crystalline limestone, full of siliceous masses	25
(11) Siliceous shale, with a few thin limestone layers	68
(10) Massive gray crystalline limestone, containing siliceous masses and silicified fossils	6
(9) Siliceous shale	4
(8) Medium crystalline limestone, weathering brown; containing many silicified fossils	6
(7) Siliceous shale	7
(6) Limestone	1
(5) Siliceous shale	7

	Feet
(4) Finely crystalline gray fossiliferous limestone	1
(3) Soft greenish clay shale	17
(2) Gray crystalline limestone, containing fossils and a few chert pebbles	7
(1) Chert pebble conglomerate. The matrix is a sandy gray limestone, and the pebbles are rounded chert and quartz pebbles reaching 1 inch in diameter. The pebbles are closely packed in the matrix in the lower part, and are more scattered higher up. Their abundance varies greatly along the strike of the rocks	30

HESS FORMATION

This portion of the section is presented on page 61.

WOLFCAMP FORMATION

This portion of the section is presented on pages 54–55.

SECTION 25

Measured up the south facing escarpment of the Wolf Camp Hills one and one-quarter miles northeast of Wolf Camp.

WOLFCAMP FORMATION

	Feet
Gray limestone member:	
(6) Massive gray limestone	12
(5) Covered, probably thin-bedded limestone	12
(4) Massive brown limestone containing fusulinids	15
(3) Covered; at nearby exposures it is a thin-bedded limestone	23
(2) Massive brownish gray limestone full of minute fossil fragments	14
(1) *Uddenites member:* Covered at point where section was measured. A little farther to the west it is seen to be a greenish shale, in which there are thin brown limestone beds. These limestones contain *Parenteletes cooperi*, *Meekella irregularis*, and *Scacchinella*. At one place there are ledges of friable, fine-grained sandstone at the base of the member	20

GAPTANK FORMATION

	Feet
(8) Massive finely granular gray limestone	23
(7) Mostly covered; toward the top are exposures of buff marl and nodular marly limestone. These contain *Derbya benneti*, *Echinocrinus* spines and plates, and *Triticites cullomensis*	28
(6) Massive, finely crystalline gray limestone, weathering to nodular surfaces. This, and the two overlying layers, unite into a single thick bed of gray limestone toward the west	35
(5) Covered, except for occasional exposures of drab clay shale	255
(4) Brown, irregularly crystalline nodular limestone, containing abundant shell fragments	3
(3) Drab clay shale, containing an abundance of *Cladopora*, as well as other fossils	62
(2) Finely granular brown sandy limestone, containing fusulinids, brachiopods, and bryozoa	2
(1) Drab clay shale, not well exposed in the lower part	80

Base of the formation is not exposed.

SECTION 26

This section begins at the base of an outlying cuesta of the Glass Mountains, which lies two miles north-northwest of the Old Meeks Place. The Wolfcamp and basal Hess formations were measured at this place. The main body of the Hess formation was measured north of this point, up the main scarp of the mountains to their summit, thence across the uplands to the summit whose elevation is 5632, and from this point to Split Tank, a tank two miles northeast of the Word Ranch. The Leonard formation was measured about half a mile northeast of the tank, and the Word formation to the northwest of this point, ending about 1½ miles north of the tank.

CAPITAN FORMATION

The Word formation is overlain, at the north end of the section, by massive, dirty gray, pitted dolomite belonging to the Vidrio member of the Capitan formation.

WORD FORMATION

	Feet
(7) Thick-bedded dolomite in 3-foot to 5-foot ledges. The upper third of the member is very cherty and contains a few silicified fossils	300
(6) Siliceous brown shale, mostly of stony texture, with a few thin interbedded layers of brown sandy limestone	78
(5) Massive dolomite in 4-foot to 5-foot ledges. There is no chert. The surface weathers to a jagged and deeply pitted surface	53
(4) Dolomite in 1-foot ledges, which is locally quite cherty. There are a few interbedded shaly layers	30
(3) Siliceous shale, with interbedded layers of dolomite in 2-foot ledges	43
(2) Thick-bedded dolomite, in part cherty	200
(1) Dense platy bituminous limestone, weathering to white smooth surfaces	41

LEONARD FORMATION

This portion of the section is presented on page 67.

HESS FORMATION

	Feet
(19) Limestone in 2-foot to 4-foot ledges. The limestone is medium crystalline, dolomitic, and of brown or gray color	250
(18) White or light gray dolomite, containing pisolites	50
(17) Finely crystalline pockety dark gray dolomite outcropping in prominent dirty gray ledges. Some of the layers contain abundant small fusulinids	65
(16) *Upper Hess fossil horizon:* Thick ledges of white dolomitic limestone, which are quite cherty in the upper part. This upper portion contains fossils sparingly, including crinoid stems, echinoid spines, and a few brachiopods. This layer is the same as bed 19, Section 24	50

	Feet
(15) Marl and sandy marl in 10-foot layers, interbedded with layers of brown dolomite each of which is about 2 feet in thickness	256
(14) Dense gray and brown limestone, mostly dolomitic, in thin ledges. There is a small amount of interbedded sandy shale. Fusulinids are abundant in some of the limestones	197
(13) Dense brown limestone ledges in four or five ledges, separated by buff marly shale	80
(12) Thin-bedded, dense, dolomitic brown or gray limestone, breaking into conchoidal chips. There are a few thicker ledges	78
(11) *Double Ledge:* Dense light gray limestone outcropping in two prominent ledges which are traceable for several miles to the east and west	33
(10) Thin and thick-bedded light gray dolomitic limestone, with a small amount of interbedded marl	271
(9) Dense gray or buff limestone in 2-foot ledges, with interbedded layers of marl	108
(8) Marl and shale, with thin layers of limestone	26
(7) Brown dolomitic limestone	14
(6) Coarse-grained gray cross-bedded friable sandstone	20
(5) Brown, thin-bedded dolomitic limestone, with some interbedded marl	70
(4) Brick-red shale and greenish-gray shale, with a few 1-foot layers of dense dolomitic brown limestone	121
(3) White or light gray crystalline limestone in 1-foot layers	3
(2) Ashen-gray marl	10
(1) White or light gray crystalline limestone in 1-foot to 4-foot layers. Chert occurs sparingly. This layer caps the outer foothills of the Glass Mountains in this area, and appears to be the lateral equivalent of the basal Hess conglomerate elsewhere. The lower part, however, may be of Wolfcamp age, for C. O. Dunbar states that fossils collected from its base one-half mile to the east are a new species of *Triticites,* probably of Wolfcamp age	95

WOLFCAMP FORMATION

(4) Fine-grained buff sandstone in 2-foot ledges, irregularly impregnated with limonite	27
(3) Probably similar to the foregoing, but concealed by talus	132
(2) Drab clay shale	21
(1) Brown nodular limestone in 2-foot layers. Probably the upper part of the Gray Limestone member, which outcrops about a mile to the east	18

Base of formation not exposed.

SECTION 27

This section was measured northwest from the Montgomery Ranch. The Wolfcamp and basal Hess formations were measured two miles northwest of the ranch on the slopes of the hill whose elevation is 4752, and which is one of the outer foothills of the Glass Mountains. The main body of the Hess formation was measured on the main scarp of the mountains up to the summit whose elevation is 5527; thence to the hill to the north, on which there is a triangulation station with an elevation of 5473 feet. From here the section continues northwest across the hills to the base of the Leonard formation. The Leonard and Word formations were measured 4½ miles northeast of the Word Ranch, near the Pecos-Brewster County line.

WORD FORMATION

This portion of the section is presented on pages 72–73.

LEONARD FORMATION

	Feet
(8) Siliceous shale	5
(7) Gray fossiliferous crystalline limestone	3
(6) Siliceous shale, with thin limestone beds	33
(5) Nodular gray fossiliferous limestone, in places sandy	37
(4) Siliceous shale	23
(3) Gray fossiliferous cherty limestone	2
(2) Calcareous brown shale, containing nodular brown limestone layers in which are abundant *Productus ivesi*	84
(1) Coarsely crystalline gray limestone in 3-foot ledges, containing lenses of rounded chert and quartz pebbles	50

HESS FORMATION

(20) Massive, dark gray dolomite in thick ledges. Thickness partly estimated	250
(19) Light gray, thick-bedded dolomite	100
(18) Dark gray dolomite in 5-foot and 10-foot ledges, weathering to jagged and pitted surfaces	60
(17) Light gray, thin-bedded cherty dolomite. This is the same layer as the *Perrinites compressus horizon* near Wolf Camp (bed 16, Section 26; bed 19, Section 24)	48
(16) Buff marl and marly limestone, with thin interbedded layers of dirty brown dolomite	232
(15) Thin-bedded gray and brown limestone, in part dolomitic. The upper layers contain many fusulinids	497
(14) *Double ledge:* Two massive ledges of dense gray limestone, breaking into sharp-angled chips. This is the same as bed 11, Section 26	23
(13) Thin and thick-bedded dense gray dolomitic limestone, with a conchoidal or hackly fracture. In the lower part are poorly preserved gastropods and fusulinids	348
(12) Dense brown nodular limestone	15
(11) Gray clay shale and sandy shale, with two ledges one foot in thickness of dense brown dolomitic limestone	169
(10) Dense brown dolomitic limestone	3
(9) Fine-grained sandstone of gray color, shaly toward the top	145
(8) Massive gray limestone, conglomeratic in places	46
(7) Gray coarse-grained friable sandstone in thick beds	61

	Feet
(6) Soft greenish sandy shale, containing limestone nodules in the upper part, from which was collected a *Productus semi-reticulatus*	21
(5) Greenish clay shale	27
(4) Fine-grained brown sandstone	8
(3) Conglomerate of rounded limestone cobbles, with some chert pebbles in a limestone matrix	23
(2) Red marl, with interbedded conglomerate	46
(1) Thick-bedded limestone containing a few quartz pebbles	13

WOLFCAMP FORMATION

This portion of the section is presented on pages 55–56.

GAPTANK FORMATION

The uppermost limestone of this formation is exposed at this place, and is described on page 56.

SECTION 28

This section is taken very largely from measurements and observations by Dr. J. A. Udden, as given in his section 8, Bulletin 1753 (pp. 35–36). It is supplemented by observations of the writer, and the correlations are his own. According to Udden this section is located about 5 miles west of Gap Tank. "The section begins at the foot of the escarpment, where there is a small water tank, and from where a wagon road leads past some dwelling places up the face of the escarpment." This locality is 2½ miles north-northwest of the Montgomery Ranch.

HESS FORMATION

	Feet
(34) Fine-grained gray limestone	22
(33) Shale	13
(32) Gray limestone containing fusulinids	3
(31) Limestone and shale	8
(30) Limestone	2
(29) Shale	2
(28) Fine-grained limestone, containing fusulinids	38
(27) Gray shale	11
(26) Fine-grained gray sandstone	5
(25) Gray shale	40
(24) Yellow sandy limestone	1
(23) Green shale, in part calcareous, with some layers of red shale	55
(22) Gray, cross-bedded sandstone	17
(21) Gray sandstone and shale	16
(20) Gray sandstone	12
(19) Yellow limestone	1
(18) Blue shale, with some layers of red shale	17
(17) Gray cross-bedded sandstone	24
(16) Yellow limestone	2
(15) Shale, in part reddish	18
(14) Yellow limestone	1
(13) Shale	16
(12) Yellow limestone	1
(11) Shale	11
(10) Yellow limestone	3
(9) Shale	4
(8) Yellow limestone	1
(7) Reddish and yellow clay shale	14
(6) Yellow limestone	1
(5) Gray marl	6
(4) Greenish clay shale	2
(3) Red shale	6
(2) Marly limestone	11
(1) Calcareous conglomerate of rounded limestone cobbles	20

WOLFCAMP FORMATION

	Feet
Gray limestone member:	
(13) White limestone	20
(12) Thin-bedded marly limestone	30
(11) Hard white limestone	10
(10) Thin-bedded soft limestone	15
(9) White crystalline limestone	35
(8) Soft limestone	17
(7) Limestone	15
(6) Soft marl	25
(5) Hard white limestone, containing *Composita*, *Myalina*, and crinoid stems. A few limestone pebbles were noted in the upper part	30
Uddenites member:	
(4) Calcareous brown sandstone	80
(3) Shale	55
(2) Brown sandstone	8
(1) Shale	15
Base of formation not exposed.	

SECTION 29

Measured up the lower part of the Glass Mountains escarpment one-half mile west of Gap Tank, starting at the Marathon-Fort Stockton highway and proceeding north for half a mile.

HESS FORMATION

	Feet
(1) Coarse calcareous conglomerate of limestone and chert cobbles in a brown sandy limestone matrix	60

WOLFCAMP FORMATION

	Feet
(3) Mostly covered; a few exposures of sandy shale	53
(2) Dense to medium grained light gray limestone in massive beds. This is the *Gray Limestone member* of the Wolfcamp formation	35
(1) Brown sandy limestone and sandy shale, in which a *Schistoceras* was collected. This is probably the *Uddenites member*	39

GAPTANK FORMATION

	Feet
(8) *Fifth limestone member:* Dense to coarsely crystalline light gray limestone in massive beds	43
(7) Blue-gray shale, with some marl in the upper part	33
Fourth limestone member:	
(6) Gray-brown, finely crystalline limestone, containing crinoid stems	2
(5) Mostly covered; some shale exposed in places	5
(4) Gray, finely crystalline cherty limestone, weathering to brown surfaces	22

	Feet
(3) Covered	11
(2) Buff nodular marl, containing *Heterocoelia, Spirifer triplicatus, Composita subtilita,* and *Rhipidomella carbonaria*	11
(1) Finely crystalline gray limestone, weathering brown	11
Base of formation not exposed.	

SOURCES OF THE GEOLOGIC MAP

The geologic map accompanying this report is the result of three summers of field work by the writer and Robert E. King. In addition, some mapping along the southern edge of the sheet is taken from reconnaissance work by the writer in the summer of 1929 for the U.S. Geological Survey.

The topographic base for the map is taken in part from the excellent Altuda, Hess Canyon, Sierra Madera, Monument Springs, and Marathon topographic sheets of the U.S. Geological Survey. A few changes in roads, dwelling places, and names of ranches have been made on the present map to bring the topographic surveys up to date. The older, and less accurate Alpine quadrangle was used for the western part of the map. Considerable corrections and additions were made to the topography in this region, by means of plane-table traverses and compass surveys.

The areas east of the Hess Canyon and Marathon sheets, and north of the Hess Canyon and Altuda sheets have not been surveyed topographically, and for these areas the writer and his brother constructed a topographic base by plane table and compass surveys. The broader features of the topography were ascertained by stadia traverses and triangulation, and the details were filled in by compass and pacing traverses. In the area east of Marathon, they received valuable help from Mr. Leo Horton who constructed a triangulation net for part of the area. The southeastern corner of the map is taken from reconnaissance topographic surveys by N. H. Darton.

The geologic mapping within the area of the Glass Mountains themselves is detailed. A few other areas of Comanche limestone and igneous rock, as well as a few more minor faults will perhaps be revealed by further work, and perhaps some changes will be made by others where there is a possible difference of opinion on interpretation of the field relations. The mapping of the pre-Permian rocks west and northwest of Marathon, and in the vicinity of Gap Tank is likewise detailed. The remaining portion of the Marathon Basin shown on the map is somewhat less accurately mapped, because of the more rapid nature of the field work. It is believed, however, that all the important features of this area have been determined. More detailed work is contemplated here in the future as a part of a study of the whole area of the Marathon Basin.

The Comanchean outcrops along the east edge of the sheet, and those of the Comanche, Gulf, and Tertiary volcanic series on the west edge, are sketched in from exploratory work, not for their intrinsic accuracy, but to add completeness to the mapping, and to show more clearly the regional relationships of the Glass Mountains. In parts of these areas a general symbol is utilized for undifferentiated Fredericksburg and Washita strata. This is shown, for example, between the Gulf series on the western edge of the map, and the subdivided Comanche series of the Del Norte Mountains to the east. The Del Rio and Buda formations probably are present in this area, but were not differentiated during the course of the field work.

In a similar way, the members of the Capitan formation are not differentiated in the northeast part of the map. This is because of the scattered nature of the Permian exposures in this area, and because of the fact that the Vidrio, Gilliam, and Tessey members of the formation have merged into a monotonous series of rather thin-bedded dolomites whose differentiation is well-nigh impossible. It is hardly possible that further work on the surface exposures will be sufficient to solve the problem of the subdivision of the dolomites in this area.

PLACE NAMES IN THE GLASS MOUNTAINS

The following notes on place names in the Glass Mountains are given in order to prevent confusion in later field work. Some of the place names, particularly of ranches, have changed since the first work in the area by the state survey in 1917, and some of the names used on the present map are not the same as those appearing on the topographic sheets.

Allison and Gilbert Ranch.—Formerly known as Nations Ranch.

Arnold's Lower Ranch.—See Purington Ranch.

Decie Ranch.—Formerly known as Wedin Ranch. It is located about five miles west of Marathon.

Frequent reference is made to the ranch under its former name by Udden, but it is given its present name on the Monument Spring topographic sheet.

Dessie Ranch.—See Montgomery Ranch.

Gilliam Canyon.—See Gilliland Canyon.

Gilliland Canyon.—As explained on a previous page, the name Gilliland Canyon was incorrectly spelled Gilliam by Udden, this being a phonetic rendering of the actual name. It is correctly spelled on the topographic sheets.

Iron Mountain Ranch.—A name sometimes applied to Skinner's Ranch at the base of Iron Mountain.

McGonegeal Ranch.—The Old Word Ranch is now the property of Mr. McGonegeal, and this name has been used in several papers. See Word Ranch.

Montgomery Ranch.—Formerly the Decie (Dessie) Ranch, and shown as such on the topographic sheet.

Nations Ranch.—See Allison and Gilbert Ranch.

Parker Place.—See Warren Ranch.

Purington Ranch.—The old Purington Ranch, which lies several miles east of the edge of the geologic map, is now owned by Mr. Arnold, and is generally known as Arnold's lower ranch.

Payne Ranch.—Baker makes frequent reference to the "Old Payne Ranch" in describing his Dugout beds, and some of the pre-Carboniferous formations. This ranch no longer exists, and the situation is further complicated by the fact that another abandoned ranch in the northwest part of the Monument Spring quadrangle is shown as the Payne Ranch on the topographic sheet. This latter ranch lies within the area of outcrop of Permian rocks. The true situation is explained by Mr. Baker in a letter to the writer in 1929: "I think I referred to two Payne Ranch houses. The one noted in connection with the Viola fauna of the Maravillas is, I am pretty sure, the place given on the Monument Springs quadrangle as "Rock House" at the lower end of Maravillas Gap. The one mentioned in connection with the "Dugout" part of the Tesnus was about two and three-quarter miles south by a little southeast of the summit of Dugout Mountain, a short distance north-northwest along the road from the elevation point 4056 (which elevation point is at the junction of this road with the road down Dugout Creek). This would place the house between a quarter and a half mile north of latitude 30° 10′ and a little over a mile east of longitude 103° 25′. I well remember it was on a rough road down the creek valley which was quite narrow and bounded by rusty rock ledges. I collected the fossils in going up this creek toward the northwest."

Skinner Ranch.—Sometimes known as the Iron Mountain Ranch.

Ward Ranch.—See Word Ranch.

Warren Ranch.—Incorrectly named the Old Parker Place on the Hess Canyon topographic sheet. According to the inhabitants of the region the old Parker Place is farther north.

Word Ranch.—Not Ward ranch, as shown on the Hess Canyon topographic sheet. Now the property of Mr. McGonegeal, though the ranch is still generally known under its old name.

Wolf Camp.—Wolf Camp is stated by Udden to be "the site of an old dwelling place, just to the south of two buttes, and is marked by an old open well some hundred feet deep." This locality is 12 miles northeast of Marathon on the present Taylor Ranch. It is not shown on the topographic sheet, though the old well still exists. In order to perpetuate the name, the writer has suggested that the Glass Mountains foothills north of Wolf Camp be called the Wolf Camp Hills.

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PLATES I TO VI

PLATE I

A. Detrital material of the pediment mantle, exposed in an arroyo bank four miles south of Sullivan Peak at the south foot of the Glass Mountains. The fragments consist of limestone and dolomite, and lie in a matrix of buff clay.

B. Dissection of pediment slope at the base of the scarp of Word formation north of Leonard Mountain. Leonard Mountain in the background.

C. The west face of Iron Mountain, showing weathering of the igneous rock.

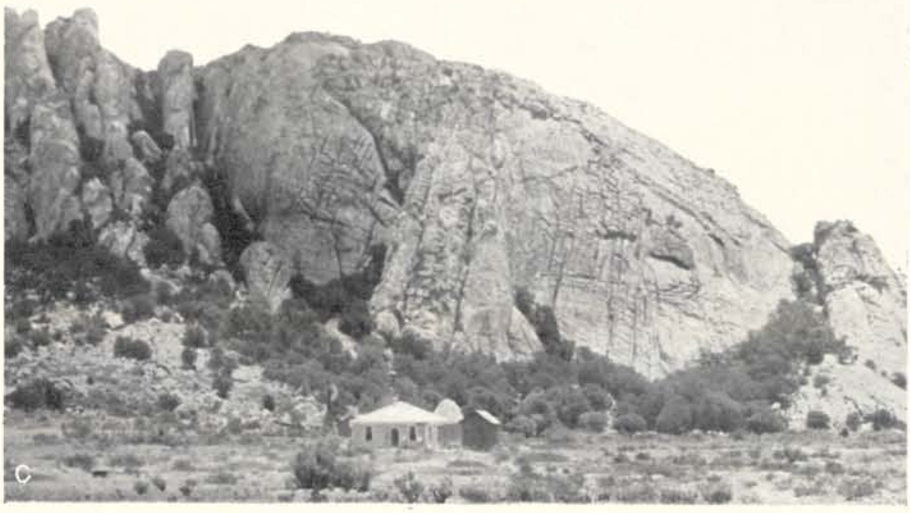

PLATE II

A. Dome-like structures outlined by chert bands, in Dimple limestone fifteen miles east of Marathon.

B. Conglomeratic limestones and interbedded shales of upper part of Gaptank formation in railway cut at milepost 580, four miles west of Marathon.

C. Leonard quartz pebble conglomerate near Split Tank, three miles northeast of the Word Ranch.

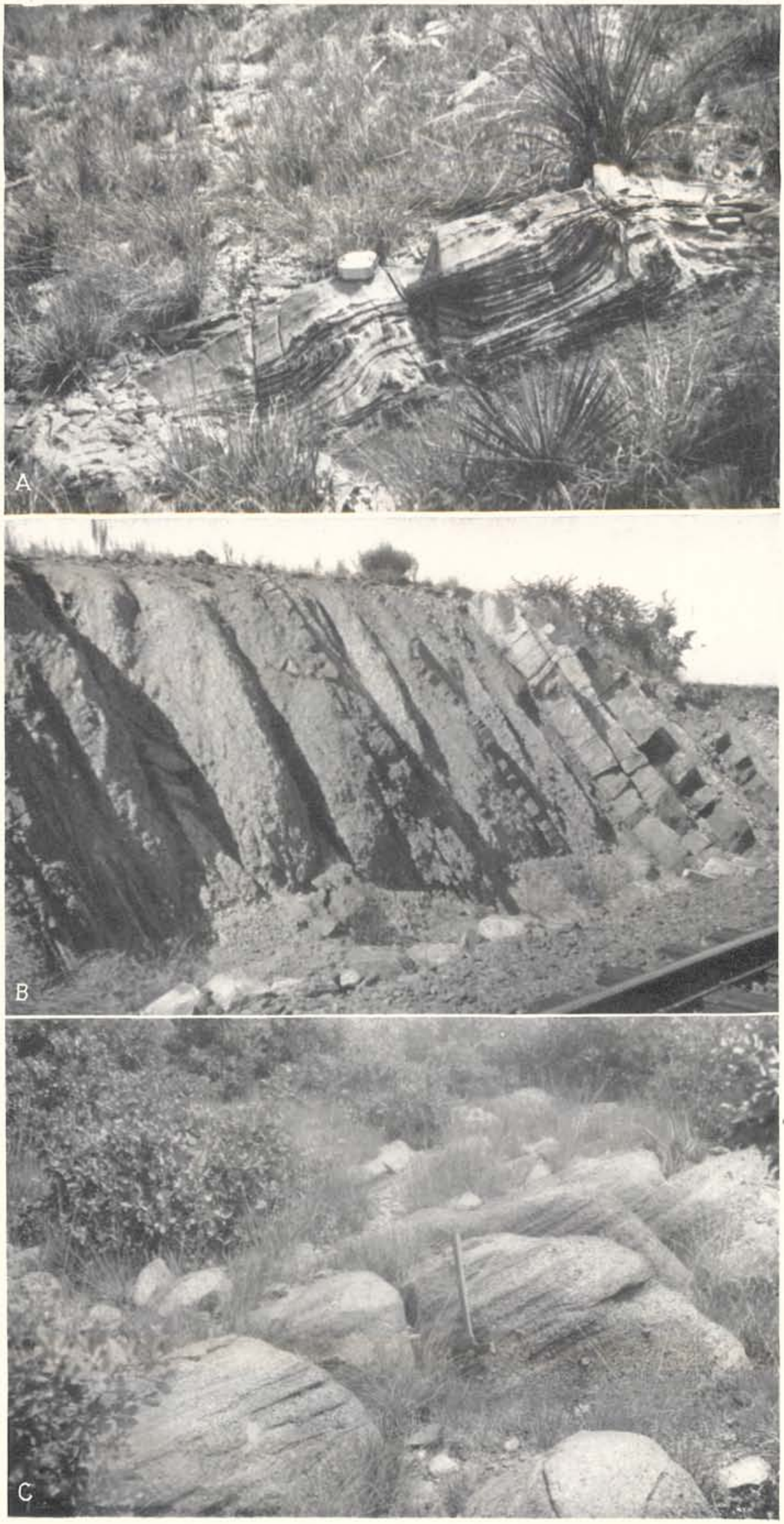
A
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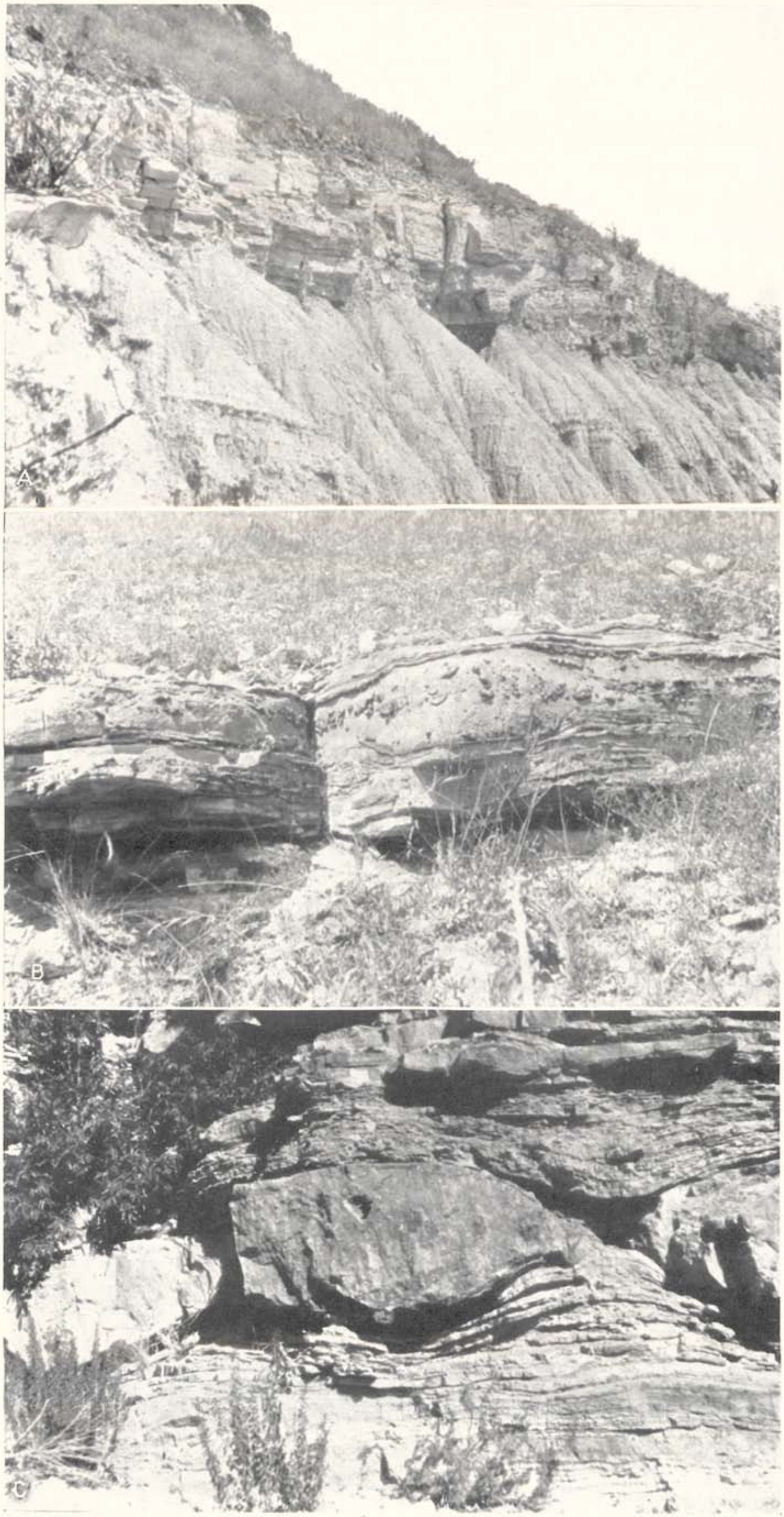
PLATE III

A. Contact between Leonard clay shales and Word bituminous limestones at top of Clay Slide two miles west of Iron Mountain.

B. Typical exposure of a thin limestone bed interbedded between siliceous shales in the lower part of the Leonard formation three miles west-southwest of Iron Mountain. Note siliceous masses, in part silicified fossils, etched into relief on the surface. The bed is about a foot thick.

C. Limestone lenses in siliceous shale (radiolarite?) of the Leonard formation on the west slope of Hess Canyon. The lens in the middle of the picture is about three feet in length.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A. Upper cherty limestone member (fourth limestone) of Word formation in Hess Canyon.

B. Cavernous, jagged weathered surface of dolomites in middle part of Word formation on Word Ranch.

C. The western slope of the high summit of the Glass Mountains, about five miles north-northwest of Iron Mountain. The beds dip toward the observer, off the Gilliland Canyon anticline, and consist of the massive dolomites of the lower massive member of the Capitan.

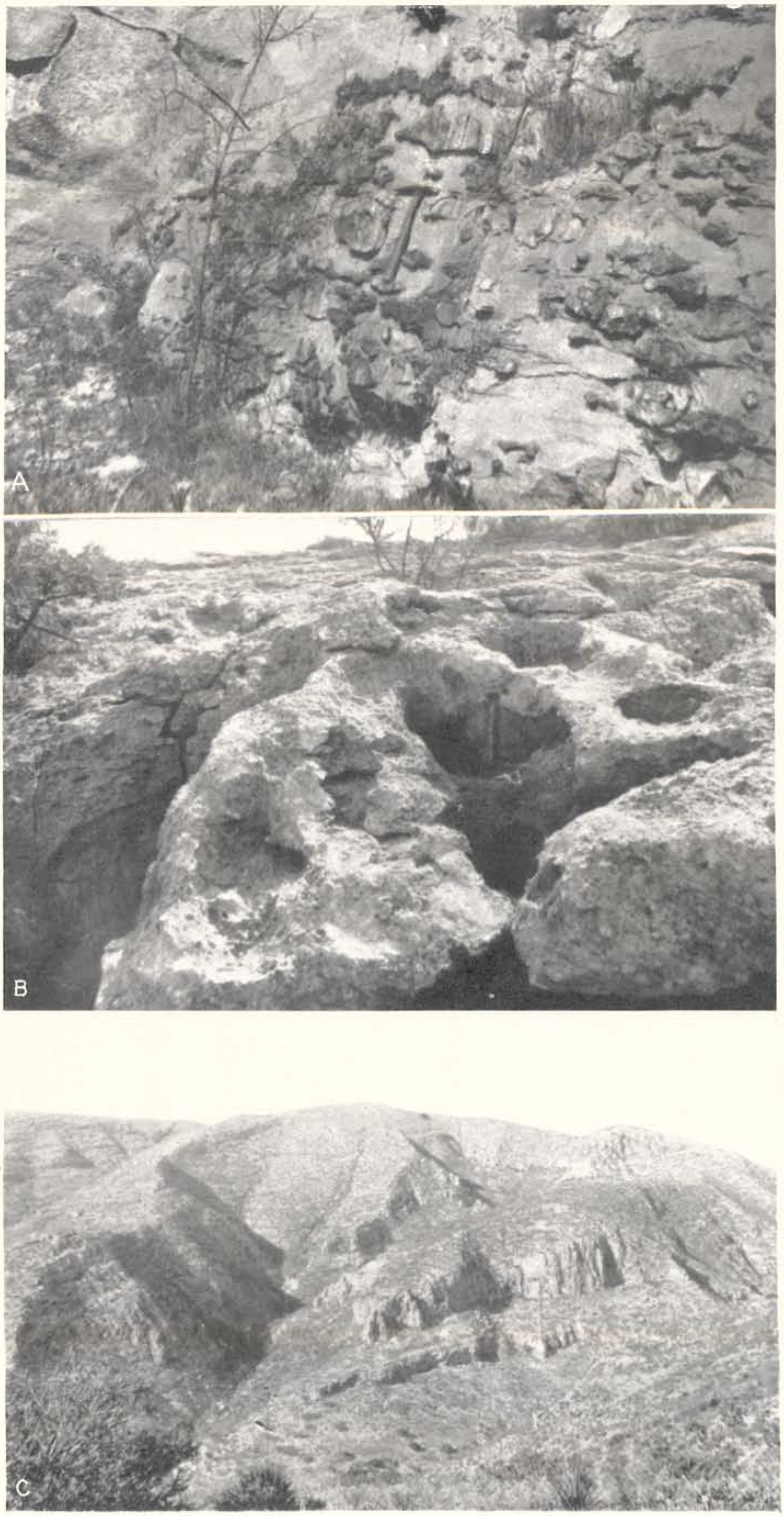
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PLATE V

A. "Papery limestone" bed at the top of the Altuda member two miles northeast of Altuda.

B. Thin-bedded dolomitic limestone near top of Altuda member of Capitan formation at the north end of Old Blue Mountain.

C. Thin-bedded dolomite of Gilliam formation at the narrows of Gilliland Canyon.

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A. Sandstone of upper part of Gilliam member of Capitan formation three miles east-southeast of the Warren Ranch.

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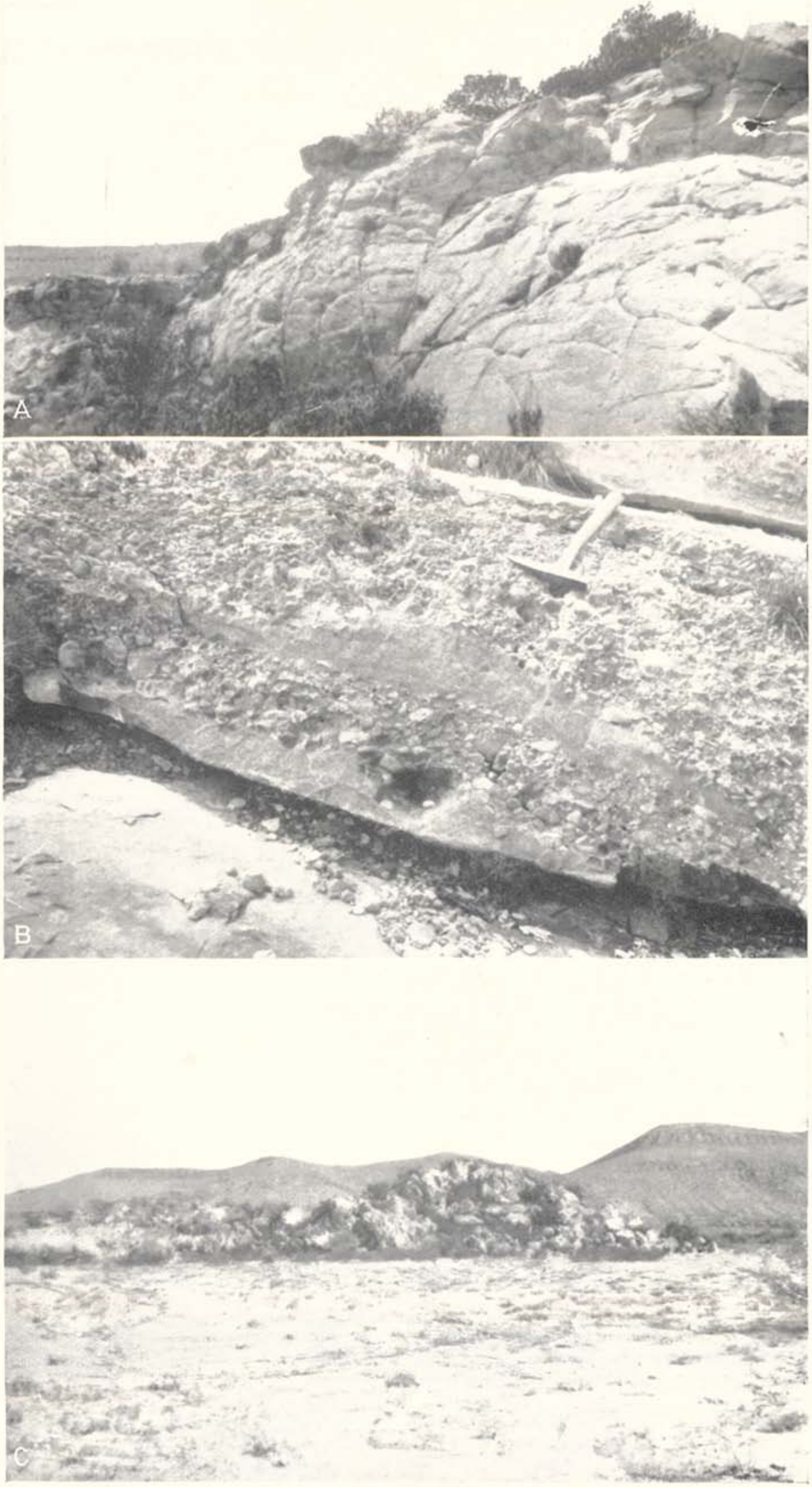
C. Small erosional remnant, or klippe, of Caballos novaculite resting with overthrust contact on Haymond sandstone two miles east of Lenox. The hills in the background are of Permian rocks, which rest unconformably on the greatly eroded surface of the overthrust strata. This locality is about four miles northwest of the main exposure of the Dugout Creek overthrust.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THE UNIVERSITY OF TEXAS BULLETIN

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THE GEOLOGY OF THE GLASS MOUNTAINS, TEXAS

PART II

FAUNAL SUMMARY AND CORRELATION OF THE PERMIAN FORMATIONS WITH DESCRIPTION OF BRACHIOPODA

By

ROBERT EVANS KING

Bureau of Economic Geology

J. A. Udden, Director E. H. Sellards, Associate Director

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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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THE GEOLOGY OF THE GLASS MOUNTAINS, TEXAS

PART II

Faunal Summary and Correlation of the Permian Formations with Description of Brachiopoda

ROBERT EVANS KING

ACKNOWLEDGMENTS

This memoir is the result of field work in Trans-Pecos Texas by the writer and his brother, Philip B. King, during the summers of 1925 to 1928, and of the laboratory study of their own and various other collections of Permian fossils from this region. The work was presented as a doctor's dissertation at Yale University in 1929, and final work on the manuscript by the author was completed in August of that year.

The investigation was largely made possible by the financial support of the writer's parents, though a material aid to field work was given through generous purchase of our fossil collections by Prof. Charles Schuchert, and by allotments for field expenses by the Texas Bureau of Economic Geology. I am also indebted to Professor Schuchert for his contagious enthusiasm for problems of the Permian, and the inspiration and assistance which he has given in that branch of the major problem on which I worked. Prof. C. O. Dunbar, of Yale University, has given invaluable criticism and counsel as the work progressed. After its completion, when I was called abroad in commercial work, he freely gave his time to editorial work on the manuscript, and by his intimate acquaintance with the fauna herein described was able to keep the work up to date by following more recent studies of paleontologists on this and related topics.

In addition to the collections made especially for this study, which are now the property of Peabody Museum, the collections which Udden, Böse, Beede, and Baker made for the Texas Bureau during the earlier investigations on the Permian were available to me for study through the courtesy of Dr. E. H. Sellards, the associate director of the Bureau. A small collection of Leonard and Word fossils, which furnished valuable supplementary material, was generously submitted for identification by Mr. D. M. Delo, now of Northwestern University, while he was with the Southwestern Crude Oil Purchasing Company in Texas. A small collection from Trans-Pecos Texas made by Mr. Ray Baker of the Texas Company was also examined. Finally, the collections made by Professor Schuchert in western Texas and Arizona were freely placed at my disposal.

The collateral study of Permian faunas outside Trans-Pecos Texas was based very largely on an extensive review of the American and foreign literature. The writer also had access to the reference sets of fossil collections at Peabody Museum, which included not only many suites from important localities and formations in the west, but also from other parts of the continent and abroad.

HISTORICAL RESUMÉ

The first fossil described from the Permian of Trans-Pecos Texas was *Composita mexicana,* which was collected by Emory's United States and Mexican Boundary Survey and described by Hall in 1857. One species from the Permian of the Delaware Mountains was described by Marcou in 1858. The first important contribution was made by the Shumards. As geologist of the expedition under Captain Pope, sent to discover artesian waters in the arid southwest, George C. Shumard collected some fossils from the Delaware, Guadalupe, and Hueco mountains, which he sent to his brother, B. F. Shumard, for study. Shumard described these collections in 1858 and 1859, and recognized the fossils from the Delaware and Guadalupe mountains as being of Permian age. The fauna of the Hueco Mountains was assigned to the Pennsylvanian. During the remainder of the nineteenth century no further paleontologic work was done in the region, and the fauna described by Shumard came generally to be regarded as Upper Carboniferous rather than Permian in age. In 1901 G. H. Girty accompanied B. F. Hill to the Delaware and Guadalupe mountains, and spent about two weeks collecting from the Permian rocks. Collections made by G. B. Richardson and R. T. Hill in other ranges in Trans-Pecos Texas were studied along

Printed August, 1931.

with Girty's own collections, and in 1908 the classic "Guadalupian Fauna" was published as United States Geological Survey Professional Paper 58. In this work, Shumard was shown to have been correct in regarding his faunas as of Permian age. The richness of the Permian faunas of this region was first made known as a result of this work. Unfortunately, circumstances prevented Dr. Girty from devoting enough time to collecting to obtain very complete material; many of his species are therefore established on only a few specimens and prove rather difficult to use. Incomplete field work also prevented any attempt at definite zonation of the faunas, and they were treated very much as a unit, to which the name "Guadalupian" was applied. The first zonation of the Trans-Pecos Permian section was made possible by the work of the late Emil Böse. Böse studied the collections he gathered and those made by Udden and his associates in the first work on the stratigraphy of the Glass Mountains, and in 1917 published detailed descriptions of the ammonoids from this area and discussed in detail their stratigraphic significance. As a result, four main ammonoid zones were made known, and were correlated with the ammonoid bearing formations in other parts of the world. In 1927 Schuchert reviewed the Glass Mountains sequence and published lists of some of the fossils. In 1929 J. P. Smith restudied the ammonoid fauna of the basal formation of the Permian, the Wolfcamp, bringing forth new facts in proof of its age.

STRATIGRAPHY AND CORRELATION

SUMMARY OF THE PERMIAN STRATIGRAPHY OF TRANS-PECOS TEXAS

THE GLASS MOUNTAINS SECTION

By accidents of structure and erosion, the most complete Permian section in Trans-Pecos Texas is in the Glass Mountains, north of the town of Marathon, where about 7000 feet of strata of this age dip northwestward away from the older rocks of the Marathon uplift. Most of the collections described in the present paper were made in this district.

The basal Permian beds rest with a considerable structural unconformity on the underlying rocks. Evidence indicates, however, that the youngest beds in the subjacent series, the upper part of the Gaptank formation, are not greatly older than the basal strata above the unconformity. West of Marathon they contain at one place the *Proudden-ites* fauna, in which A. K. Miller* has identified nine genera and 10 species of ammonoids; F. B. Plummer regards this as comparable to one of his Canyon ammonoid zones in Central Texas. Both to the east and west of Marathon the occurrence of such characteristic fusulinids as *Triticites secalicus* and *T. cullomensis* indicates the existence of strata as young as the Cisco group as well.*

The Wolfcamp formation.—The lowest Permian formation of the Glass Mountains section is the Wolfcamp, which varies from 700 feet in thickness at the type locality to only 50 feet toward the east of that locality and several hundred feet toward the west. At the type locality no angular break is apparent between it and the underlying Gaptank formation, of Pennsylvanian age, but to the west where the Gaptank beds are strongly folded there is a marked angular discordance. The section at Wolfcamp starts with the *Uddenites* zone, a shale with limestone layers, varying in thickness up to 100 feet. This unit contains a great number of ammonoids, which have been shown by Smith (**156**, pp. 63–80) to prove its lowest Permian age. The brachiopod fauna of the *Uddenites* zone comprises mostly species which occur also in the Pennsylvanian, but has in addition some notable innovations. The following is a numerical analysis of the fauna:

Number of species—34
Number also in middle and upper Wolfcamp—28
Number also in Hess—5
Number also in Leonard—3
Number also in Word—1
Number also in Pennsylvanian—22
Present in Bolivia—16
Present in Bolivia, not in Pennsylvanian—6
Present in higher Permian, not Pennsylvanian—12
Present in Pennsylvanian and higher Permian—17
Present in Pennsylvanian, not higher Permian—5
Restricted to this horizon—0

Among the lower Wolfcamp species occurring in higher beds of the Texas Permian section but not occurring in the Pennsylvanian are *Meekella irregularis texanus, Waagenoconcha montpelierensis, Avonia boulei, Scacchinella gigantea, Aulosteges wolfcampensis, Spirifer condor,* and *Martinia wolfcampensis.* All these species are definitely Permian types. An interesting element in the fauna is

*Miller, A. K., A New Ammonoid Fauna of Late Paleozoic Age from Western Texas, Jour. Pal., Vol. 4, pp. 383–412, 1930.

*For more detailed description of the Gaptank fauna see Part One of this memoir.

Paraënteleles cooperi, which occurs elsewhere in America only in the underlying Gaptank formation. Similarities may be recognized with two foreign faunas, that of the Andean "Upper Carboniferous" and that of the Trogkofel limestone of the Karnic Alps. Ten of the species in common with the Andean fauna occur also in the Pennsylvanian, but *Waagenoconcha montpelierensis, Avonia boulei, Marginifera capaci, Orthotichia kozlowskii, Spirifer condor,* and possibly *Linoproductus villiersi* do not occur below the *Uddenites* zone. This indicates that the brachiopod assemblage of the *Uddenites* zone is more closely allied to the Andean one than are those of the Pennsylvanian, which contain only 3 species in common with the Andean fauna and not occurring in the Permian of this country. The species *Meekella irregularis texanus, Scacchinella gigantea, Paraënteletes cooperi,* and *Teguliferina bösei* are very close to species in the Trogkofel limestone. In summary, it may be noted that the brachiopod fauna of the *Uddenites* zone has many identities with the Pennsylvanian, yet contains other species that are definite heralders of the Permian, and some of which are unlike American Pennsylvanian forms, but have foreign affinities.

The middle and upper parts of the Wolfcamp formation.—At the type locality, the part of the Wolfcamp formation above the *Uddenites* zone consists largely of shale, containing occasional limestone layers. Immediately above this zone *Schwagerina* makes its first appearance. This distinctive fusulinid genus is abundant there and in the succeeding beds of the Wolfcamp. Near the middle of the formation is the most prolific fossil locality (loc. 93). In the western part of the Glass Mountains the upper part of the Wolfcamp alone is fossiliferous, the lower part there consisting of conglomerate. On Dugout Mountain the upper Wolfcamp contains a rather large and well preserved fauna, including many ammonoids, among which are *Perrinites cumminsi* and *Prothalassoceras welleri.* Fossiliferous Wolfcamp is present also in the uplift northeast of the Hess Ranch, where there are a good many *Schwagerina*, associated with molluscs and echinoid spines and plates. The following is a numerical analysis of the brachiopods in the middle and upper parts of the Wolfcamp formation:

Number of species—46
Number also in Pennsylvanian—18
Number also in *Uddenites* zone—28.
Number also in Hess—12
Number also in Leonard—10
Number also in Word—5
Number also in Capitan—3
Present in Bolivia—13
Present in Bolivia, not in Pennsylvanian—4
Present in higher Permian, not lower—11
Present in lower and higher Permian—4
Present in lower and not higher Permian—24
Restricted to this horizon—6

Many interesting brachiopod types make their first appearance in this fauna, heralding the developments of succeeding faunas. Ancestors of *Prorichthofenia* and *Lyttonia* are present, and the productids show a great expansion. The following brachiopods are particularly characteristic of the fauna of the middle and upper Wolfcamp:

Orthotetella wolfcampensis	Aulosteges wolfcampensis
Derbya buchi	Teguliferina bösei
Productus gratiosus occidentalis	Parakeyserlingina fredericksi
P. semistriatus	Camarophoria thevenini
P. wolfcampensis	Spirifer condor
Avonia boulei	Martinia wolfcampensis
Marginifera capaci	

The Hess formation.—Unconformably above the Wolfcamp is the Hess formation, which varies in thickness from 2100 feet in the east to 50 feet in the west. It consists of limestone and dolomite, with a basal conglomerate. In the east the dolomite predominates, while in the west there is mostly limestone. Fossils are abundant only at certain horizons, mainly in the upper part of the formation. One fossiliferous layer on the escarpment above Wolf Camp has yielded a large proportion of the fossils which have been collected from the formation. Localities 107, 108, 212, 215, and 222 are at this horizon. Fossils are more common in the limestone facies of the west, but as the limestone is very hard, they are difficult to collect.

The great decrease in thickness from east to west in the Glass Mountains is especially remarkable because of the corresponding thinning of the younger and conformable Leonard in the reverse direction. This fact might be interpreted as due to the intergradation of lower Leonard and upper Hess. However, the evidence that could be gathered in the field and in a study of the faunas indicates that the two formations are distinct time units. The upper Hess contains the ammonoid *Perrinites compressus*, while in the lower Leonard the more specialized species *Perrinites vidriensis* is common; the two have not been found in association. *Enteletes dumblei,* a common upper Hess fossil, does not occur in the Leonard of the Glass Mountains. *Scacchinella gigantea* is abundant in the Hess at certain localities in both the western and eastern facies of the formation, in one place but a few feet below the top of the formation, yet it has not been collected from the Leonard. The primitive species of *Prorichthofenia, P. teguliferoides,* occurs in the upper Hess of both the Glass Mountains and the Sierra Diablo, but has not been found in the Leonard. While it is true that a large proportion of the characteristic Leonard brachiopods make their first appearance in the upper Hess, there are 13 species in the Hess that do not occur at a higher horizon, and several of these are present in the Hess of the Sierra Diablo and the Gym of the Hueco Mountains—a fact indicating that the Hess fauna is a separate biota. It might be argued that the reason for the differences between the Hess and Leonard faunas is that the two are of distinct faunal facies. This seems to be disproved by two facts. In the first place, different faunal facies are ordinarily to be correlated with differences in lithology, yet the lower Leonard contains limestone members which are lithologically similar to the underlying upper part of the Hess but contain Leonard types of fossils, including *Perrinites vidriensis.* In the second place, many of the species in the Hess do occur in the limestones of the Leonard, so that if there is any difference in faunal facies it is not great enough to prevent a large number of identical forms from occurring in both. A final argument is the evidence for a distinct faunal zone in the highest beds of the Hess and the lowest beds of the Leonard, characterized by the species *Enteletes plummeri.* This faunule occurs at the top of Leonard Mountain, and occupies the same stratigraphic position 5 miles to the southwest of there, though the Hess limestone underlying it has thinned from 750 feet to 250 feet.

As noted above, the ammonoid *Perrinites compressus* occurs at the upper Hess fossiliferous horizon. This form is intermediate in complexity between *P. cumminsi* of the Wolfcamp and *P. vidriensis* of the Leonard. Böse believed that the presence of the genus *Perrinites* at this horizon proved that the fauna was of Leonard age, but it has been shown that *Perrinites* is not restricted to the Leonard, making its first appearance in the Wolfcamp. The ammonoid *Prothalassoceras welleri* was collected by Baker and Böse from the conglomerate at the base of the Permian in the western Glass Mountains, at a horizon regarded by Böse as Hess. Hence the Hess was called the "zone of *Prothalassoceras*" in the "Ammonoids of the Glass Mountains." We have shown that the conglomerate from which this fossil was collected is actually part of the Wolfcamp formation, and furthermore we have collected *Prothalassoceras welleri* from the upper Wolfcamp on Dugout Mountain. (See section on Wolfcamp formation above. The genus *Prothalassoceras* has also been identified, by Miller, in the Gaptank formation.)

The following table indicates numerically the relations of the Hess brachiopod fauna:

Number of species—53
Number also in Pennsylvanian—2
Number also in *Uddenites* zone—4
Number also in Wolfcamp—9
Number also in Leonard—38
Number also in Word—20
Number also in Capitan—10
Present in Bolivia—1
Present in Bolivia, not in Pennsylvanian—1
Present in higher Permian, not lower—32
Present in lower and higher Permian—4
Present in lower and not higher Permian—8
Restricted to this horizon—10

One of the most notable features of the Hess fauna of the limestone facies is the abundance of brachiopods having high cardinal areas—especially *Scacchinella gigantea, Geyerella americana,* and *Streptorhynchus undulatus.* The former occurs in great abundance in some places. These same genera are present also in the Trogkofel formation of the Karnic Alps, and the first two in the Sosio limestone of Sicily. It is probable, however, that their presence is not of stratigraphic significance, but proves the presence of a facies, perhaps of reef nature, like the rudistid reef limestones of the Mesozoic. It is very likely that the Capitan is of the same nature, for it is, similarly, a dense hard limestone containing brachiopods having high, deformed cardinal areas. Notable innovations occur in the Hess, since here is the first appearance of *Prorichthofenia,* in a primitive species transitional from *Teguliferina.* The first specimens of *Lyttonia* occur here. Many of the species which are common in the Leonard and Word formations first appear in the Hess. It may therefore be said that the Wolfcamp fauna is transitional from the Pennsylvanian to the Permian, while that of the Hess is characteristically Permian. The following are the more important brachiopods which occur in the Hess:

Rhipidomella hessensis	Prorichthofenia teguliferoides
Enteletes dumblei	Lyttonia nobilis americanus
Streptorhynchus lamellatus	Pugnoides elegans
S.? undulatus	P. texanus
Meekella attenuata	P. transversus
Geyerella americana	Camarophoria venusta
Chonetes hessensis	Spirifer huecoensis
Productus ivesi	Squamularia guadalupensis
Striatifera pinniformis	Spiriferina angulata
Marginifera whitei	Hustedia hessensis
Scacchinella gigantea	Composita mexicana
Aulosteges medlicottianus	C. subtilita
Prorichthofenia likharewi	

At locality 223, 1.1 mile southwest of the Word Ranch, there is a very peculiar faunule in the highest beds of the Hess. *Composita mexicana* and *Pugnoides texanus* occur in great abundance, almost to the exclusion of other species of brachiopods. Several genera of ammonoids, including *Perrinites,* also are present. The abundance of the two species of brachiopods reminds one of the upper Gym, where the same forms are very common.

The Leonard formation.—This unit consists of limestone, shale, siliceous shale (radiolarite) and conglomeratic limestone, varying from 1800 feet in thickness in the western Glass Mountains to 300 feet in the east. Fossils are abundant in all the limestone and some of the shale layers. Some of the best localities are in the middle part of the formation north and northwest of Iron Mountain—localities 120 and 123. Ammonoids are abundant in places; *Perrinites vidriensis* is the most common species. The best ammonoid locality is in the middle part of the upper Leonard below the Clay Slide, northwest of Leonard Mountain.

The following table summarizes the brachiopods of the Leonard fauna:

Number of species—69
Number also in Pennsylvanian—1
Number also in *Uddenites* zone—1
Number also in middle and upper Wolfcamp—8
Number also in Hess—35
Number also in Word—39
Number also in Capitan—16
Present in higher Permian, not lower—21
Present in lower and higher Permian—21
Present in lower and not higher Permian—18
Restricted to this horizon—9

Prorichthofenia and *Lyttonia* occur abundantly in the Leonard, and there is a great diversity of productids. One of the most important species in the Leonard fauna is *Productus ivesi,* which is abundant in many places, but especially so 4.3 miles northeast of the Word Ranch, at locality 174, where the rock is a sandy limestone. *Productus leonardensis* is another of the most abundant and typical species. Affinity to the Kaibab and San Andres faunas of Arizona and New Mexico is seen in the abundance of *Productus ivesi,* as well as of two other forms which are common in the Leonard, *Marginifera manzanica* and *M. cristobalensis.*

The following are the more important species of brachiopods occurring in the Leonard:

Enteletes plummeri	Aulosteges trigonalis
Meekella difficilis	Prorichthofenia likharewi
M. globosa	P. uddeni
Chonetes subliratus	Lyttonia nobilis americanus
C. permianus	Pugnoides bidentata
Productus ivesi	Camarophoria venusta
P. leonardensis	Uncinuloides guadalupensis
P. occidentalis	Spirifer marcoui infraplica
P. schucherti	S. costella
Linoproductus waagenianus	S. mexicanus latus
Marginifera cristobalensis	S. pseudocameratus
M. manzanica	Squamularia guadalupensis
M. reticulata	Martinia rhomboidalis
M. reticulata angusta	Spiriferina hilli
M. sublaevis	Hustedia meekana
Aulosteges magnicostatus	H. mormoni papillata
A. medlicottianus	Composita mira
A. subcostatus	C. subtilita

The Word formation.—This division consists in the western Glass Mountains of three main limestone members separated by shale, sandstone, and siliceous shale (radiolarite), about 1500 feet thick. In the eastern Glass Mountains the formation consists only of about 300 feet of dolomite. Fossils are abundant in the limestones, occurring generally silicified. The following is a statistical summary of the brachiopods of the entire Word formation:

Number of species—77
Number also in Pennsylvanian—0
Number also in Wolfcamp—6
Number also in Hess—22
Number also in Leonard—40
Number also in Capitan—25
Present in higher Permian, not lower—11
Present in lower and higher Permian—14
Present in lower and not higher Permian—27
Restricted to this horizon—25

Each member of the Word formation has its characteristic fauna. The lower Word limestone, which is best developed in the western part of the

Glass Mountains, contains an abundance of silicified fossils. The best collecting localities are in the southern foothills of Cathedral Mountain. Ammonoids are rare, however, at this horizon. The more important species of brachiopods are:

Chonetes subliratus	Camarophoria venusta
Productus indicus	Hustedia meekana
Linoproductus waagenianus	Composita mira
Avonia subhorrida rugatula	

The middle limestone member, which occurs in its best development on the south side of Road and Hess canyons, and capping the mountain north of Leonard Mountain, is the most fossiliferous of the three divisions. There is a great abundance in places of ammonoids, of which the most important are *Waagenoceras dieneri, Medlicottia burckhardti, Gastrioceras roadense,* and *Stacheoceras bowmani. Prorichthofenia* and *Lyttonia* are especially abundant, as well as spinose productids. The following species of brachiopods are especially characteristic:

Enteletes dumblei	Pugnoides swallowiana
Meekella attenuata	Rhynchopora taylori
Meekella skenoides	Camarephoria venusta
Productus multistriatus	Spirifer pseudocameratus
Avonia signata	S. sulcifer
A. walcottiana	Squamularia guadalupensis
Marginifera opimus	Spiriferina laxa
M. popei	Punctospirifer billingsii
M. wordensis	Hustedia meekena
Aulosteges guadalupensis	Composita emarginata affinis
A. tuberculatus	Composita mira
Prorichthofenia permiana	Dielasma spatulatum
Lyttonia nobilis americanus	Dielasmina schucherti minor

The upper limestone member, which does not occur in its normal development to the west of Gilliland Canyon, is very profusely fossiliferous near Hess Canyon. Some species of productids are especially abundant. The fauna of this member has many identities with species of the upper dark limestone, which occupies a similar position at the top of the Delaware Mountain formation. Many of the species have Arctic affinities, and a large number occur also in the Phosphoria. The following brachiopods are especially characteristic:

Meekella attenuata	Avonia signata
Derbya crenulata	Marginifera opimus
Chonetes quadratus	Marginifera popei
Productus arcticus	M. texana
P. guadalupensis	Spirifer sulcifer
Linoproductus nasutus	Spiriferina laxa
L. phosphaticus	Punctospirifer billingsii
Waagenoconcha montpelierensis	Hustedia meekana
	Composita emarginata affinis

Permian brachiopod evolution culminates in the Word faunas, for the species of the Capitan show little further development. The Word is the highest formation in the Trans-Pecos Permian section which has a truly cosmopolitan fauna, and it is probable that thereafter the seas in this region became so restricted that there was no longer free interchanging of forms with the seas of other continents.

The Capitan formation.—This is the highest marine unit of the Glass Mountains Permian section. In the region of Hess Canyon, near the center of the Glass Mountains, it is about 3000 feet thick, but it thins greatly to the west and probably to a lesser extent to the east. It is divided into several members. In the Hess Canyon region the lower member is the Vidrio dolomite, the middle the Gilliam sandstone, red shale, dolomite, and gypsum, and the upper the Tessey dolomite. In the western part of the Glass Mountains the Altuda member of limestone and sandstone wedges into the dolomite comprising the main part of the formation. Except for *Fusulina elongata,* which is abundant throughout the Capitan, fossils are rare. No ammonoids have been found in the Capitan either here or in the Guadalupe Mountains. Some brachiopods were collected from the Altuda member, and some from the Gilliam. Where they occur, individuals are extremely abundant, but the number of species is small, the most common types being *Squamularia guadalupensis, Martinia subquadrata,* and *Composita emarginata affinis.* At one place, a great number of specimens of *Pleurophorus* were found in the Tessey. A total of 11 species of brachiopods was found in the Capitan in the Glass Mountains, all of which occur in lower formations. Two species occur also in the Wolfcamp, 4 in the Hess, 6 in the Leonard, and 10 in the Word. No species were found which occur also in the Pennsylvanian. A large part of the Capitan limestone, particularly in the more massive portions, is composed of the remains of lime-secreting algae. It is not improbable that these plants built up large reefs during Capitan time. This suggestion is more fully treated in Part One of this memoir.

The Bissett formation.—At the top of the Glass Mountains Permian section is the Bissett conglomerate and red shale, which attains a thickness of 700 feet. It contains a few layers of fossiliferous dolomite, containing ostracods, pelecypods, and gastropods, all poorly preserved, as well as a flora regarded by David White as of Upper Permian age. The conglomerate contains cobbles from the underlying Permian. This formation apparently was deposited during the late Permian period of uplift, as the final phase of Permian sedimentation.

THE DELAWARE AND GUADALUPE MOUNTAINS SECTION

The Delaware and Guadalupe mountains together form a more or less connected chain extending across northern Trans-Pecos Texas into New Mexico. They are composed entirely of Permian rocks of a similar facies to that in the Glass Mountains, with their strata tilted toward the east as a result of block faulting. The lowest beds are brought to view along their western base, but these rocks are no older than those near the middle of the section in the Glass Mountains. To the strata outcropping on the face of the mountains the name Guadalupe group has been applied, but the extended use of this title has proved unfortunate, since its indefinite lower limit depends on the accidents of structure, rather than on a stratigraphic or paleontologic definition.

The Bone Canyon member.—In general, the rocks of the Delaware and Guadalupe mountains resemble those of the Glass Mountains, but there are differences in detail. This is particularly true of the Leonard formation at the base of the section, which is here divisible into two members of limestone, of which the lower, or Bone Canyon member, consists of as much as 1000 feet of black limestone (the "basal black limestone" of Girty). It is exposed along the lower part of the Delaware and Guadalupe mountains escarpment as far south as Seven Heart Gap. Fossils are abundant in certain layers. From this horizon Girty described the ammonoids *Peritrochia erebus*, *Paraceltites elegans*, and *Agathiceras texanum*. *Perrinites* has also been identified in this horizon by other geologists working in the area. The following is a numerical analysis of the brachiopods in the Bone Canyon member:

Number of species—15
Number also in Pennsylvanian—0
Number also in Wolfcamp—1
Number also in Hess—10
Number also in Leonard—11
Number also in Word—10
Number also in Capitan—5
Present in Bone Canyon member, Sierra Diablo—5
Restricted to this member—0
Present in Leonard, not Hess—5
Present in Hess, not Leonard—2
Present in Word, not Leonard—1
Present in Leonard, not Word—4

Among the species which point clearly to a Leonard age for this unit are *Productus leonardensis*, *Marginifera cristobalensis*, *Pugnoides texanus*, *P. bidentatus*, and *Composita mexicana*. *Pugnoides texanus* and *Composita mexicana* are common also in the Hess, but the other forms are practically diagnostic of the Leonard.

The Victorio Peak member.—In the Delaware Mountains and at Guadalupe Point the Bone Canyon member is overlain without apparent break by the Delaware Mountain sandstone. On the west side of the Guadalupe Mountains, however, at Bone Canyon, there is a thick conglomerate at the base of the Delaware Mountain formation, most of its boulders consisting of white limestone. A few miles to the north the white limestone from which these boulders were derived appears beneath the Delaware Mountain sandstone and above the Bone Canyon black limestone. This limestone is known as the Victorio Peak member of the Leonard formation, the name being taken from Victorio Peak in the Sierra Diablo, to the southwest. In the Guadalupe Mountains this member is several hundred feet thick.[1] The fossils determined from the Victorio Peak member by Girty[2] do not indicate conclusively its age. *Enteletes* sp. c. Girty is *E. liumbonus* King, a species occurring in the Hess formation. It is possible that the species listed by Girty here is not conspecific with the form originally described and figured as *E.* sp. c., but *E. leonardensis*, which is somewhat similar. The original of *Enteletes* sp. d is supposed by me to be *E. wordensis*, but in any case such an identification is uncertain. *Meekella attenuata* is a long ranging species. *Productus guadalupensis* var. *comancheanus* occurs in the Word in the Glass Mountains. *Pustula subhorrida* var. *rugatula?* may be *Marginifera cristobalensis*. *Aulosteges guadalupensis* is restricted to the Word in the Glass Mountains, and *A. magnicostatus* is most common in the Leonard of the same area. The other forms listed are of very little importance or are uncertainly identified. Because of the very incomplete nature of the collections on which the descriptions in "The Guadalupian Fauna" are based, it is difficult to use that book in

[1]Darton, N. H., and Reeside, J. B.: Guadalupe Group, Bull. Geol. Soc. Amer., vol. 37, pp. 421-423, fig. 4, 1926.
[2]Idem, p. 421.

making some of the identifications, and it is probable that some of the species above mentioned have been misidentified. Probably the most reliable of the species listed is *Aulosteges magnicostatus*, for it is easily identified, and could hardly be confused with anything else. Its presence suggests a Leonard age for this horizon. However, there is little besides the lithologic similarity of this member with that on the other side of the Salt Basin (in the Sierra Diablo) to prove its age as Leonard.

The Delaware Mountain formation (in restricted sense).—This unit is about 2100 feet thick at Guadalupe Point. The lower 2000 feet consist largely of sandstone, while the upper 100 feet is the "upper dark limestone" member of Girty. To the north, along the west side of the Guadalupe Mountains, the Delaware Mountain formation thins gradually against the unconformity which is seen in Bone Canyon and northward thereof, so that it is little more than 100 feet thick at the Texas-New Mexico state line. South of Guadalupe Point it comprises the upper, main part of the escarpment of the Delaware Mountains as far south as Seven Heart Gap.

The fauna of the Delaware Mountain sandstone has been made known by Girty in "The Guadalupian Fauna." The ammonoid *Waagenoceras* is present, as well as *Paraceltites elegans*, *Gastrioceras? serratum*, and *Gastrioceras* sp. The brachiopod fauna gives still further proof of the Word age of this formation, as shown by the following statistics:

Number of species—52
Number also in Wolfcamp—0
Number also in Hess—8
Number also in Leonard—15
Number also in Word—33
Number also in Capitan—29
Restricted to this formation—7
Present in Word, not Leonard—28
Present in Leonard, not Word—3
Present in Word, not Capitan—20
Present in Capitan, not Word—10

The upper dark limestone member of the Delaware Mountain formation is a widespread unit which underlies the Capitan limestone at Guadalupe Point and the Castile gypsum farther to the east and south. In the Glass Mountains two species from this horizon, *Derbya elevata* and *Chonetes hillanus*, occur only in the upper limestone member of the Word formation and in the Capitan. *Marginifera popei*, *M. opimus*, *Spirifer sulcifer*, and *Spiriferina laxa*, which occur in the dark limestone of the Delaware Mountain, occur in both the middle and upper Word limestones but are especially characteristic of the upper Word limestone. Other species which are common in the upper Word, such as *Composita emarginata affinis*, show definite affinity to Capitan species. Another point of resemblance between the dark limestone and the upper Word limestone is that *Lyttonia* was not reported by Girty from the former, and it is very rare in the latter, though common in the middle Word limestone and the Delaware Mountain sandstone. The close similarity in faunas of the upper dark limestone of the Delaware Mountain formation with the upper limestone of the Word, along with their similar stratigraphic position, makes their equivalence fairly certain.

Until recently the upper dark limestone member at Guadalupe Point was thought to extend northeastward along the base of the Guadalupe Mountains to McKittrick Canyon, and from there to trace southward along the east slope of the Delaware Mountains between the main mass of the Delaware Mountain formation and the Castile gypsum. This eastward extension was named the Frijole limestone. In 1929, however, Lloyd* expressed the opinion that the upper dark limestone at McKittrick Canyon interfingers with steeply inclined foreset beds dipping off the upper part of the Capitan reef-mass, and that though the member was only 50 feet thick it was "the time equivalent of the upper part of the (Capitan) reef, which is 1000 feet or more thick." These seemingly inexplicable relationships are clarified by Blanchard and Davis* who have traced the Frijole limestone "to Guadalupe Canyon, of which Guadalupe Point forms the west side, and at the place where it lost its identity through transition into the massive dolomite it was above approximately 1000 feet of the dolomite of Capitan facies." The dark limestones from which Girty collected his fauna are therefore considerably lower than the Frijole, and must correlate with some horizon well down in the Delaware Mountain formation in the area to the south.

*Lloyd, E. Russel, Capitan Limestone and Associated Formations, Bull. Amer. Assoc. Petrol. Geol., Vol. 13, p. 650, 1929.

*Blanchard, W. G., and Davis, M. J., Permian Stratigraphy and Structure of Southeastern New Mexico and Southwestern Texas, Bull. Amer. Assoc. Petrol. Geol., Vol. 13, pp. 979-980, 1929.

By this interpretation the Delaware Mountain formation at its type section in the Delaware Mountains includes two stratigraphic components of identical facies, but different relationships. Below the level of the true "upper dark limestone" are strata which correlate with the Delaware Mountain sandstones at Guadalupe Point and to the north of it, as well as with the Word formation of the Glass Mountains. Between the level of the dark limestone and the Frijole limestone are beds equivalent in age to the Capitan limestone of the Guadalupe and Glass mountains, and of open sea rather than reef facies, and thus exactly comparable to the Altuda member of the Glass Mountains Capitan.

The Capitan limestone.—At the top of the Guadalupe Mountains section is the Capitan limestone, about 2000 feet thick, which forms the upper part of the mountains, terminating to the south at the bold bluff of Guadalupe Point. From it Girty has described a large fauna. A large proportion of the Capitan forms occur in the Word-Delaware Mountain, and the fauna as a whole can hardly be regarded as more than a development from the latter fauna. There is no evidence of migrants from other Permian seaways, for at this time the Permian sea in Trans-Pecos Texas probably had the form of an inclosed embayment from the south, so restricted in area that free intermigration of species was not possible. Ammonoids are not present in the formation. The following brachiopods are especially characteristic:

Streptorhynchus gregarium	Prorichthofenia permiana
Geyerella americana	Pugnoides elegans
Chonetes hillanus	Camarophoria? indentata
Productus capitanensis	C.? longaeve
P.? pileolus	Uncinuloides guadalupensis
P.? limbatus	Spirifer mexicanus
Avonia latidorsata	S. sulcifer
Linoproductus waagenianus	Squamularia guadalupensis
Marginifera popei	Martinia rhomboidalis
Striatifera pinniformis	Spiriferina laxa
Leiorhynchus bisculatus	Punctospirifer billingsii
Lyttonia nobilis americanus	Composita emarginata

Recently, various writers* have interpreted the Capitan limestone as a great reef mass built by corals and algae, a conclusion in harmony with that of the writers of this memoir for the Capitan in the Glass Mountains. As noted above, these writers show that the portion of the Delaware Mountain formation of the type area which lies above the horizon of Girty's upper dark limestone grades laterally into the Capitan reef dolomite, and is presumably its open sea facies like the Altuda member of the Glass Mountains. The Capitan reef, in its typical massive facies, extends northeast along the Guadalupe Mountains escarpment from Guadalupe Point toward Carlsbad. A few miles northwest of the reef front it merges into a complex of thinner-bedded deposits, presumably of lagoonal origin, divided into three main members. The lower, a bedded limestone, has been called the San Andres by Blanchard and Davis and the Chupadera by Crandall. Neither name is very appropriate since both of them imply equivalence to New Mexico formations whose relationship is decidedly dubious. This is succeeded by the sandstones, red beds, and gypsums of the Queen and Seven Rivers members, which thicken northward into New Mexico. The highest member of the lagoonal succession, known as the Carlsbad member, is again a well bedded limestone.

Southeast of the reef escarpment, the Frijole limestone is overlain by the Castile gypsum and Rustler limestone. At one time these were believed to be laterally equivalent to the Capitan, a relationship thought to result from rapid shoreward transition from limestone and dolomite into gypsum and red beds. The revised interpretation of the Frijole now makes it clear that these two formations are younger than the Capitan, as was originally announced by Darton and Reeside* and later by Crandall** and others. Unfortunately, the fauna of the Rustler limestone is too poor in variety and preservation to furnish much information on the life of these highest Permian deposits.

In the Apache Mountains, which lie south of Seven Heart Gap at the south end of the Delaware Mountains, massive dolomites† appear again and are considered by many geologists (as Crandall, p. 939) to be another segment of the Capitan reef.

*Ruedemann, R., quoted by King and King, **90**, p. 139, 1928.
Lloyd.*op. cit.*, pp. 645-658, 1929.
Crandall. K. H.. Permian Stratigraphy of Southeastern New Mexico and Adjacent Parts of Western Texas. Bull. Amer. Assoc. Petrol. Geol., Vol. 13. pp. 927-941, 1929.
Blanchard and Davis, *op. cit.*, pp. 957, 996, 1929.

*Darton, N. H., and Reeside, J. B., Guadalupe Group, Bull. Geol. Soc. Amer., Vol. 37, p. 420, 1926.

**Crandall, *op. cit.*, pp. 941–943, 1929.

†Sometimes called the "Apache limestone," though this name is preoccupied by the Cambrian or Algonkian Apache group of southern Arizona.

THE SIERRA DIABLO SECTION[4]

In the Sierra Diablo, which lies to the west of the Delaware Mountains on the opposite side of the Salt Basin, the lower part of the Permian section is more complete than that on the east side of the Basin. Richardson placed the entire Permian section of the Sierra Diablo, as well as the small amount of Pennsylvanian underlying it, in the Hueco formation, which he supposed to be of Pennsylvanian age. It is actually a very heterogeneous group.

The upper Wolfcamp formation.—At the base of the Permian here there is a member about 175 feet thick made up of conglomerate, red shale, sandstone, and marly limestone, which in places contains abundant upper Wolfcamp fossils. In the northern part of its exposure it rests with angular discordance on Pennsylvanian limestone, and in the south it lies upon the pre-Cambrian. In many parts of the range, especially to the south, the formation is not present, and here the Hess limestone forms the base of the Permian. The following is a numerical analysis of its brachiopod fauna:

Number of species present—7
Number also in Pennsylvanian—2
Number also in *Uddenites* zone—5
Number also in Glass Mountains Wolfcamp—5
Number also in Hess—2
Number also in Leonard—1
Number also in Gym—4
Restricted to this unit—0
Present in Wolfcamp formation, not *Uddenites* zone—1
Present in *Uddenites* zone, not higher in Wolfcamp—1

The species of brachiopods present are:

Orthotichia kozlowskii	P. wolfcampensis
Isogramma millepunctata	Linoproductus cora
Productus dartoni	Composita subtilita angusta
Productus semistriatus	

The Hess limestone.—Above the upper Wolfcamp in the northern and central parts of the Sierra Diablo, or resting on the pre-Cambrian, Cambrian, or Ordovician in the southern part of the range and in the Baylor Mountains, are 500 feet of limestone which contain an abundance of *Fusulina* and in the upper part a prolific Hess fauna. Some of the species occurring abundantly in the Hess of the Sierra Diablo are rare in the Hess of the Glass Mountains, and vice versa, but, as in the Hess of the Glass Mountains, *Lyttonia* and *Prorichthofenia teguliferoides* are common. The following is a numerical analysis:

Number of species—23
Number also in Pennsylvanian—2
Number also in *Uddenites* zone—2
Number also in middle and upper Wolfcamp—5
Number also in Hess of Glass Mountains—14
Number also in Leonard—13
Number also in Word—7
Number also in Capitan—2
Number also in Gym—7
Restricted to this unit—2
Present in Wolfcamp, not Hess—4
Present in Hess, not Wolfcamp—13
Present in Hess, not Leonard—4
Present in Leonard, not Hess—2

Among the more important brachiopods are:

Rhipidomella hessensis	Marginifera manzanica
Enteletes dumblei	Marginifera? whitei
Meekella attenuata	Prorichthofenia likharewi
Derbya nasuta	P. teguliferoides
Chonetes biplicatus	Lyttonia nobilis americanus
C. spinoliratus diabloensis	Spiriferina anculata
Productus ivesi	Hustedia hessensis
Buxtonia peruviana	

Girty's collections from the "Delaware Mountain formation, Diablo Mountains" probably came from this horizon, for the forms which Girty described in that lot are in general common in this formation.

The Bone Canyon black limestone.—On Victorio Peak and to the north of it the Hess is overlain by the Bone Canyon black limestone member of the Leonard formation, averaging about 800 feet in thickness. On the south side of Victorio Peak the black limestone grades into alternating white limestone and calcareous shale of the Glass Mountains facies. In the Baylor Mountains, which lie east of the southern Sierra Diablo, the Hess limestone is overlain by alternating white limestone and shaly limestone of the Glass Mountains facies, quite like that of the southern Sierra Diablo. The Bone Canyon member in the Sierra Diablo and the Leonard in the Baylor Mountains are very fossiliferous at some horizons. The fossils are mainly brachiopods; no ammonoids have been found here. The following table indicates the relationships of the brachiopod forms:

Number of species—28
Number also in Pennsylvanian—1
Number also in Wolfcamp—4
Number also in Hess—20

[4]This section and that of the Hueco Mountains will be discussed in detail by P. B. King and R. E. King in a forthcoming bulletin of the Texas Bureau of Economic Geology.

Number also in Leonard—26
Number also in Word—19
Number also in Capitan—8
Number also in Bone Canyon of Delaware Mts.—15
Number also in Victorio Peak limestone—12
Present in Victorio Peak, not Leonard—1
Present in Leonard, not Hess—6
Present in Hess, not Leonard—0
Present in Leonard, not Word—8
Present in Word, not Leonard—0
Restricted to this unit—1

Among the important species of brachiopods are *Productus ivesi, P. occidentalis, Marginifera manzanica, M. cristobalensis, M. sublaevis, Aulosteges magnicostatus,* and *Spirifer marcoui infraplica.*

The Victorio Peak white limestone.—From Victorio Peak northward, the Sierra Diablo is capped by the massive white Victorio Peak member of the Leonard formation, over 1000 feet in thickness. The lower part of this member replaces laterally the upper part of the Bone Canyon member. *Fusulina* is abundant throughout the Victorio Peak limestone, but other fossils are abundant only sporadically. Ammonoids have not been found. The brachiopods are the most common forms in the fauna. An analysis of them gives the following results:

Number of species—19
Number also in Pennsylvanian—0
Number also in Wolfcamp—2
Number also in Hess—10
Number also in Leonard, Glass Mountains—12
Number also in Word—10
Number also in Capitan—2
Number also in Bone Canyon member—12
Restricted to this unit—0
Present in Leonard, not Hess—8
Present in Hess, not Leonard—1
Present in Word, not Leonard—0
Present in Leonard, not Word—9

Productus ivesi, P. occidentalis, Buxtonia victorioensis, Waagenoconcha montpelierensis, Marginifera manzanica, Spirifer marcoui infraplica, and *S. pseudocameratus* are the more important species.

The Delaware Mountain formation.—In the northern part of the Sierra Diablo a northeastward dip brings the Delaware Mountain sandstone below the summit line of the range, which is determined by the stripped pre-Comanchean surface. About 500 feet of the formation are exposed. Fossils are not abundant. From a layer of sandy limestone which caps several mesas southwest of Dos Alamos a few poorly preserved forms were collected. There were 12 species of brachiopods, of which 1 occurred in the Wolfcamp, 5 in the Hess, 6 in the Leonard, 12 in the Word, and 8 in the Capitan. Seven occurred in the Word but not the Leonard, none in the Leonard but not the Word, 5 in the Word but not the Capitan, and none in the Capitan but not the Word. Among the species are *Meekella skenoides, Linoproductus waagenianus, Marginifera* o p i m u s, *Aulosteges guadalupensis,* and *Composita emarginata affinis.*

PERMIAN OF THE DIABLO PLATEAU

The Sierra Diablo is the eastern scarp of the Diablo Plateau. Except in Brackett Draw, a few miles west of the northern end of the Sierra Diablo, where the Victorio Peak member with its characteristic fossils is exposed, the plateau is underlain by a limestone and dolomite of practically homogeneous character, whose fossils are quite unlike any exposed on the escarpment. In the eastern half of the plateau the rock is largely dolomite, with a few fossils. Gypsum lenses appear toward the northeast, and in the northeasternmost part of the Plateau, on the west side of the Salt Flat (Crow Flat), opposite the Guadalupe Mountains, there is a rapid transition to the Chupadera facies of New Mexico, which is characterized by alternating beds of dolomite and gypsum. In the northeastern part of the Salt Basin quadrangle, in the hills south of a small basic igneous plug, there are alternating beds of dolomite and gypsum. The former contain abundant *Productus inca* (loc. 520), a fact which shows that these beds are faunally related to the upper part of the Gym limestone of the Hueco Mountains. The rocks here and elsewhere in the eastern part of the Diablo Plateau are apparently the northwestern facies of those exposed in Brackett Draw and on the Sierra Diablo scarp, and since there is no evidence of uplift which would bring to the surface beds of Hess age, they are probably of Leonard age. However, the faunas of the eastern Diablo Plateau are entirely unlike those of the Sierra Diablo, but closely allied to those of the Gym of the Hueco Mountains and the Chupadera of New Mexico. It therefore seems probable that there was an abrupt facies change along a northeast-southwest line passing a few miles to the northwest of the outcrops in Brackett Draw. Southeast of this line is the normal marine facies of the Sierra Diablo, while northwest of it are deposits of the Gym facies, which in turn change northward into the Chupadera facies.

In the western half of the Plateau and on its western scarp, the Hueco Mountains, the lower beds of the Permian section are again exposed. The dolomite of the eastern part of the plateau is underlain by limestone in the western part.

PERMIAN OF THE HUECO AND FRANKLIN MOUNTAINS

In the Hueco Mountains the Permian consists of massive grey limestone, which may be called the Gym formation because of its similarity faunally and lithologically to the Gym formation of the Florida Mountains, which lie about 90 miles to the west. The Gym is not as abundantly fossiliferous as many formations in the Permian of Trans-Pecos Texas, and its faunas are of a peculiar facies, unlike that of most of the formations of presumably the same age. The faunas indicate a transition to the Chupadera fauna of New Mexico. Three members are recognizable in the Gym of the Hueco Mountains. The lower one is about 500 feet thick; it is characterized by abundant *Schwagerina*. The middle Gym is a darker grey limestone containing many pelecypods and gastropods and a subordinate representation of *Schwagerina*. The upper Gym is characterized by an abundance of *Composita mexicana* and *Pugnoides texanus*.

The lower light grey limestone member of the Gym contains a great abundance of *Schwagerina*. The following is an analysis of the brachiopod fauna of this member:

Number of species—20
Number also in Glass Mountains Wolfcamp—12
Number also in *Uddenites* zone—7
Number also in Pennsylvanian—5
Number also in Hess—11
Number also in Leonard—6
Number also in Word—2
Present in Bolivia—9
Present in Bolivia, not in Pennsylvanian—4
Number occurring higher in Gym, not in Pennsylvanian—4
Number occurring in Pennsylvanian and higher Gym—2
Number in Wolfcamp and not Hess—8
Number in Hess and not Wolfcamp—7

Among the species present in the lower Gym are *Enteletes dumblei*, *Productus hessensis*, *P. huecoensis*, *P. semistriatus*, *P. wolfcampensis*, *Buxtonia peruviana*, *Avonia boulei*, *Marginifera capaci*, *Camarophoria deloi*, *Spirifer condor*, and *Spirifer huecoensis*. The Wolfcamp species appear to be dominant, though Hess elements also are well-marked. From our present knowledge it seems best to assign the lower Gym to the upper part of the Wolfcamp horizon.

The middle dark grey limestone member of the formation is about 250 feet thick. It is especially characterized by a great abundance of gastropods and pelecypods. Brachiopods are less common than in the lower Gym. Their analysis follows:

Number of species—8
Number also in Pennsylvanian—2
Number also in *Uddenites* zone—2
Number also in middle and upper Wolfcamp—3
Number also in Hess—3
Number also in Leonard—2
Number also in Word—2
Number also in Capitan—2
Present in Bolivia—4
Present in Bolivia, not in Pennsylvanian—2
Present in lower Gym—3
Present in upper Gym—3
Present in Wolfcamp, not Hess—2
Present in Hess, not Wolfcamp—3
Restricted to this unit—0

The most common species are *Meekella mexicana*, *Derbya buchi*, *Productus inca*, *Linoproductus cora*, *L. villiersi*, *Pugnoides texanus*, and *Composita mexicana*.

The upper light grey limestone member occurs along the summit of the range and in the northwestern part of the Diablo Plateau. It is about 800 feet in thickness. In its lower part there are about 150 feet of red beds, which are exposed in the vicinity of Deer Mountain. *Schwagerina* does not occur as high as this member, but the gastropod fauna of the middle member ranges up into this division. The following table expresses the relations of the brachiopod species:

Number of species—11
Number also in Pennsylvanian—0
Number also in *Uddenites* zone—2
Number also in middle and upper Wolfcamp—2
Number also in Hess—4
Number also in Leonard—4
Number also in Word—2
Number also in Capitan—0
Present in Bolivia—3
Present in lower and middle Gym—7
Present in Wolfcamp, not Hess—3
Present in Hess, not in Wolfcamp—3
Restricted to this unit—1

The most abundant and characteristic fossils of this member are *Composita mexicana* and *Pugnoides texanus*. *Derbya buchi*, *Productus inca*, and *Hustedia huecoensis* also are common. The association of *Composita mexicana* with *Pugnoides tex-*

anus appears to characterize a widespread faunal facies of this region. The two species occur together abundantly in the Gym at its typical locality in the Florida Mountains, in the Chupadera, in the Bone Canyon member of the Delaware Mountains, and in the uppermost Hess of the Glass Mountains, southwest of the Word Ranch.

On the west side of the Franklin Mountains, north of El Paso, the lower and middle members of the Gym are recognizable.

The correlation of the Gym with the Glass Mountains and Sierra Diablo sections is uncertain. Ammonoids do not occur in the Gym, and many of its brachiopods do not occur in the other faunas of Trans-Pecos Texas. The species which seem to be of significance point to the correlation of the lower Gym with the upper part of the Wolfcamp formation, and of the middle and upper members of the Gym with the Hess.

PERMIAN OF THE FINLAY MOUNTAINS

South of the central part of the Diablo Plateau is the Finlay Dome, the center of which exposes Permian rocks. At the base of the section there is a conglomeratic limestone, containing *Prorichthofenia teguliferoides*, and therefore is to be correlated with the Hess. There follows about 125 feet of shale, then dark limestone. The limestone contains ammonoids of Leonard age, and the underlying shale has abundant Leonard fossils. Six species of brachiopods were collected from this locality. Of these, one occurs in the Wolfcamp, 2 in the Hess, 3 in the Leonard, 1 in the Word, and none in the Capitan. One form was restricted to that locality. One of the species occurred in the Leonard but not in the Hess, none in the Hess or Word that did not occur in the Leonard, and 3 in the Leonard that did not occur in the Word. Among the species occurring at this place are *Chonetes subliratus, C. molengraaffi?, Productus ivesi*, and *Marginifera sublaevis.*

Permian limestone and gypsum, said to contain Leonard fossils, occur below the Jurassic of the Malone Mountains, which lie about 5 miles to the south of the Finlay Dome.[5]

PERMIAN OF THE CARIZZO AND WYLIE MOUNTAINS

In the Carrizo Mountains, near Dalberg (southwest of Van Horn), there are about 400 feet of grey Permian limestone, similar lithologically and faunally to the Gym. This limestone has the same stratigraphic position as the limestone of Hess age in the southern Sierra Diablo (which lies about 7 miles to the north), but is faunally quite different. The same facies occurs in the Wylie Mountains, about 10 miles to the east, where about 1400 feet of Permian limestone is exposed. *Productus hessensis* is the only common brachiopod.

[5]See Baker, C. L.: U. of Texas Bull. 2715, p. 11, 1927.

PERMIAN OF THE SHAFTER DISTRICT

Permian rocks are exposed in the Shafter district on the south, east, and north flanks of the Chinati Mountains. They were first studied by Udden* who measured sections along the valley of Cibolo Creek and gave to the whole the name Chinati series, which he subdivided into the Cieneguita, Alta, and Cibolo formations. The Cibolo Creek section was briefly examined by the writer in 1928. In 1929 Baker* published observations on the exposures in Upper Cibolo Basin and Pinto Canyon on the north flank of the Chinati Mountains.

According to Baker the Cieneguita clastic beds contain *Schwagerina* "from the bottom to the top" as well as other fossils which Beede informed him "belong in the base of the Permian or at least in the transition zone."' Near Ojo Bonito I measured 2400 feet of shale, sandy shale, and thin limestones, probably belonging to the Alta formation, but with the base cut off by eruptive contact and the top by the Cretaceous overlap. The intercalated limestones contain *Productus ivesi, Perrinites vidriensis* (abundant near Ojo Bonito), and other Leonard fossils. Baker does not report fossils in the Alta formation north of the Chinati Mountains, though it has a great development in both the Upper Cibolo Basin and Pinto Canyon.

I collected Word fossils in the Cibolo formation out of the "thin-bedded zone" and the "yellow limestone" between the Shafter Mine and the Chinati Mountains. North of the Chinati Mountains Baker found *Waagenoceras* and *Medlicottia* in the "lower brecciated zone" of the Cibolo, and *Agathiceras girtyi, Adrianites marathonensis,* and *Stacheoceras gilliamense* in the "thin-bedded zone," also indicating a Word age for the strata. North of Ojo Bonito the Glen Rose limestone has a basal conglomerate in which are cobbles of a white limestone, probably

*Udden, J. A., Geology of the Shafter Silver Mine District, Univ Texas Mineral Surv. Bull. 8, 1904.

*Baker, C. L., Note on the Permian Chinati Series of West Texas, Univ. Texas Bull. 2901, pp. 73-84, 1929.

a higher Permian formation no longer exposed in the vicinity.

The following are analyses of my brachiopod collections from strata assigned to the Leonard and to the Word near Shafter:

Leonard

Number of species—26
Number also in Wolfcamp—3
Number also in Hess—16
Number also in Leonard—25
Number also in Word—13
Number also in Capitan—5
Number also in Pennsylvanian—0
Present in Leonard, not Hess—14
Present in Hess, not Leonard—0
Present in Leonard, not Word—12
Restricted to this locality—1

Word

Number of species—5
Number also in Wolfcamp—1
Number also in Hess—2
Number also in Leonard—2
Number also in Word—3
Number also in Capitan—2
Present in Word, not Leonard—2
Present in Leonard, not Word—1
Present in Word, not Capitan—1
Present in Capitan, not Word—0
Restricted to this locality—1

PERMIAN NEAR LAS DELICIAS, COAHUILA, MEXICO

About 275 miles south of the Glass Mountains, in southwestern Coahuila, a thick section of Permian rocks is exposed along the foot of the Sierra del Sobaco, northwest of the hacienda of las Delicias.[8] The lowest member of the Permian is exposed at Las Puerticitas—it is a bluish limestone containing few fossils. It is followed by a considerable thickness of shale, tuff, and basic lava flows; some layers of shale contain *Perrinites vidriensis.* Near the middle of the section are layers of bluish-grey limestone containing abundant fossils. This horizon is well exposed on Cerro Caballo. It is followed by more shale, tuff, and lava. Some layers of the upper shale contain abundant ammonoids, including *Waagenoceras dieneri.* The highest bed of the section is the limestone of Cerro Pichigüia, part of the fauna of which was described by Haack.[9] The limestone of Cerro Caballo has yielded a rather large number of brachiopods, the relationships of which are as follows:

Number of species—17
Restricted to this place—2
Present also in Wolfcamp—1
Present also in Hess—7
Present also in Leonard—10
Present also in Word—15
Present also in Capitan—5

These figures point to a Word age for the horizon. The limestone of Pichagüia gives the following analysis of its brachiopods:

Number of species—6
Restricted to this place—0
Present also in Wolfcamp—0
Present also in Hess—4
Present also in Leonard—4
Present also in Word—4
Present also in Capitan—2

This analysis gives no clue in itself to a definite age for the horizon, but the fact that it overlies the *Waagenoceras* ammonoid horizon indicates that it is of Word age or perhaps younger.

CORRELATION OF THE PERMIAN SECTIONS OF TRANS-PECOS TEXAS WITH OTHER AMERICAN PERMIAN SECTIONS

PERMIAN OF THE MID-CONTINENT REGION

Permian of North-Central Texas.—In north-central Texas the Cisco, the highest group of the Pennsylvanian, is divided into six formations, of which the highest is the Putnam. The Putnam formation is 125 to 150 feet thick, and consists largely of blue-grey and dark blue carbonaceous shale in the lower part grading up into buff, pink, and red shale; the shales contain three or four lentils of buff and dirty yellow limestone and one or two layers of brown calcareous sandstone. At the top of the Putnam is the Coleman Junction limestone, 3 to 15 feet thick, which has been placed by Drake at the base of the Permian, and by Plummer and Moore at the top of the Pennsylvanian. According to Dunbar,[10] the fusulinids of the Coleman Junction limestone are like those of the Cottonwood limestone of Kansas, which is regarded as the base of the Permian there, so that the Coleman Junction limestone is most properly regarded as of Permian age.

Overlying the Putnam in the Brazos River valley is the Wichita group, the lowest division of the

[8] See Böse, E.: On the Permian of Coahuila. Am. Jour. Sci., ser. 5, vol. 1, pp. 187-191.

[9] Haack, W.: Permfauna aus Nordmexiko, Zeit. d. deutsch. Geol. Gesell. Bd. 66, pp. 482-504, 1915.

[10] Personal communication.

Permian. It is 700 to 1200 feet in thickness, and consists of a series of thick limestone layers separated by thick marine shale and marl beds containing thin limestone lentils. It is divided into three formations, named in ascending order the Admiral, Belle Plains, and Clyde. Thirty-seven kinds of invertebrates have been listed from the Admiral formation, but except for ammonoids, which are said to be of Permian aspect, there is nothing which is particularly diagnostic (**135**, pp. 183–198).

The marine shale and limestone facies of the Wichita group grades northward into red beds, with minor members of bluish and grey-white sandstone and shale and thin layers of limestone, about 800 feet thick. The red bed facies of the Wichita and Red River valleys is therefore quite different from the normal marine facies of the Brazos valley, though of the same age. In this region the base of the Permian is not easily determinable, for the Coleman Junction limestone disappears in southwestern Archer County. The equivalents of the Admiral and Belle Plains formations are dominantly red beds, but the limestones of the Clyde formation continue from the Brazos valley northward into this region.

There are two ammonoid localities* in the Wichita of this region, the faunas of which have been described by C. A. White (**186**) and Emil Böse.[11] One locality, 4 miles south of Dundee, Archer County, is at the horizon of the Belle Plains formation. It is stated by Böse to be probably lower than the other, which is at the old Military Crossing of the Big Wichita River, about 6 miles north of Maybelle, Baylor County. Böse regards the fauna of the first locality as more primitive than that of the second, but the two horizons cannot be many hundred feet apart stratigraphically. The locality south of Dundee contains, according to Böse:

Medlicottia n. sp. (aff. M. artiensis Gruenew.)
Perrinites n. sp. (aff. P. cumminsi White.)
Stacheoceras (Marathonites?) n. sp. (aff. St. romanowskyi Karp.)
Agathiceras sp. ind. (aff. A. uralicum Karp.)

The following species were described from the old Military Crossing of the Big Wichita by C. A. White:

Paralegoceras baylorense (White)
Perrinites cumminsi (White)
Stacheoceras walcotti (White)
Medlicottia copei White

The other fossils, mostly molluscs, listed from the same and adjacent localities by White, are of little value for purposes of correlation. In the Glass Mountains *Perrinites cumminsi* occurs in the upper Wolfcamp ammonoid fauna of Dugout Mountain, and probably other species of the Wichita fauna will be found to be present there when it is completely studied. The presence of *P. cumminsi* is very important, species of *Perrinites* being of great value as index fossils. There can be little doubt that the Wichita ammonoid faunas are of approximately the same age as the upper Wolfcamp fauna. Since the Wichita group starts at the base of the Permian (as defined in central Texas), it therefore seems likely that the Wichita group is approximately equivalent in age to the Wolfcamp formation.

The vertebrate faunas of the Wichita have been reviewed by Romer,[12] who says that "some of the most specialized and advanced forms of the fauna are present in Texas at the very bottom of the Permian." Seventeen genera of amphibia, cotylosauria, pelycosauria, and "protosauria" occur in the Wichita group.

Near the same locality from which the middle Wichita ammonoids were collected, 4 miles south of Dundee and 4½ miles east of Fulda, there is a fossil plant locality, from which David White[13] has listed a large number of species of clearly lower Permian age. "The material in hand from the lower and middle portions of the Wichita puts beyond question the Permian age of that formamation. . . . Besides the familiar Permian floras, including *Callipteris*, *Walchia*, *Comphostrobus* and *Dicranophyllum* and the abundant *Gigantopteris*, we find new migrants such as *Odontopteris neuropteroides*, *Odontopteris fischeri*, and *Annularia max-*

*Since this paper was completed further work has been done on the later Paleozoic ammonoids of Central Texas by F. B. Plummer and Gayle Scott. Their work will appear in a succeeding bulletin of the Bureau of Economic Geology, and brief abstracts have appeared in the Bull. Geol. Soc. Amer., vols. 40 and 41, 1929-1930 (Proceedings of the Paleontological Society). So extensive is the new information secured that no satisfactory revision of the present discussion can be attempted.

[11]Böse, E.: Permo-Carboniferous Ammonoids of the Glass Mountains, U. of Texas. Bull 1762. pp. 183-194. Böse stated that the locality south of Dundee was in the upper Wichita, and that the Military Crossing locality was in the lower Clear Fork, but in fig. 7 of U. of Texas Bull. 2801 it may be seen that the first locality is actually middle Wichita and the second upper Wichita. Dundee is not as stated by Böse, in Baylor, but in Archer County.

[12]**139**, pp. 66-108. Also see Schuchert, Charles: **150**, pp. 822-826.

[13]Proc. U. S. Nat. Mus., vol. 41, pp. 493 516, 1912.

ima. The odontopterids are Uralian plants, while the *Annularia*, like *Gigantopteris*, is Asiatic.[14]

Above the Wichita is the Clear Fork group, 1100 to 1900 feet thick, consisting of red and blue clays, sandy shales, white and red sandstones, clay-ball conglomerate, and layers of limestone, dolomite, and gypsum. There has been some controversy as to the place at which the Wichita-Clear Fork boundary should be drawn. Some workers have placed the Lueders and Arroyo formations in the Wichita and others in the Clear Fork. Plummer and Moore apparently follow Cummins in placing the Lueders in the Clear Fork group. In ascending order the Clear Fork comprises the Lueders, Arroyo, and Vale formations, the Bullwagon dolomite, and the Choza formation. The Bullwagon dolomite contains in Runnels County the following ammonoids, as identified by Böse[15]:

Perrinites n. sp.
Medlicottia n. sp. (aff. M. orbignyana Vern.)
Gastrioceras n. sp.

The other fossils from the formation are pelecypods and gastropods not specifically identified. The species of *Perrinites* is intermediate in complexity between *P. cumminsi* and *P. hilli*, but is not as complex as *P. compressus*, which occurs in the Hess formation of the Glass Mountains, and is much less highly developed than *P. vidriensis*. The most that can be said, then, concerning the ammonoid fauna of the Clear Fork group, is that it is intermediate between the Wolfcamp-Wichita and the Leonard-Double Mountain types. Because of this fact, as well as the stratigraphic position of the Clear Fork, it seems most logical to correlate the Clear Fork approximately with the Hess.

Romer lists 21 genera of amphibia, cotylosauria, pelycosauria, and "protorosauria" from the Clear Fork group, most of them from the Arroyo formation. Romer places the Lueders formation in the Wichita group, but states that its vertebrate fauna is more closely allied to that of the Clear Fork. In fact, two distinct vertebrate faunal zones are distinguishable, of which the lower, occurring in the lower and middle Wichita, and the upper Cisco, is characterized by the presence of *Cricotus*, while captirhinomorphs *(Captorhinus, Labidosaurus)*, *Seymouria*, and a number of other forms gives a criterion for the upper fauna. Small fossil plant collections have been made from the Clear Fork: they represent the lower Permian *Gigantopteris* flora.

Above the Clear Fork is the Double Mountain group, which varies in thickness from 200 feet in the vicinity of San Angelo to more than 1000 feet near the Red River. It is characterized by sandstones, thick gypsum beds, and some sandy shales and earthy limestones. At the base is the San Angelo formation, 125 to 175 feet thick, consisting of red sandstone, white sandstone, conglomerate, and shale, which rests unconformably on the underlying Choza formation of the Clear Fork. The only fossils are a few pelecypods and gastropods.

The San Angelo is followed by the Blaine formation, from 80 to 275 feet thick, which in the Colorado and Concho river valleys consists of cream-colored gypsiferous and calcareous sandstone, and farther north is composed of thick gypsum beds with some shale partings and thin dolomite. In Tom Green County it rests unconformably on the San Angelo formation. At three localities there are ammonoids in the Blaine. At the falls on Salt Crotan Creek in Kent County, *Perrinites hilli* (Smith) occurs with *Stacheoceras* sp. and *Medlicottia* sp. Smith has cited *Medlicottia copei*, the same species that occurs in the Wichita, from near San Angelo. Böse[16] lists large *Perrinites* n. sp. and large *Gastrioceras* n. sp. from Quanah, near the Red River. The only important species among those mentioned above, and the only one positively identified, is *Perrinites hilli*, which is exceedingly close to *P. vidriensis* of the Leonard formation of the Glass Mountains. Because of the absence of other significant fossils in the Double Mountain group in Texas, this species has a great deal of importance. The only similar species is *Perrinites vidriensis*, a form which does not occur above the Leonard. In the Word, *Perrinites* is unrepresented, but its descendant *Waagenoceras* is present. If the Blaine were of Word age, one would expect to find in it *Waagenoceras*, a fossil which does not occur at a lower horizon in the Glass Mountains section. Ordinarily, correlation on the basis of a single genus is not conclusive, but ammonoids of this type are very exceptionally good index fossils, and in view of the absence of other criteria for paleontologic correlation it is fortunate that such

[14]White, David, in The Permian of Western America from the Paleobotanical Stand-point. Proc. Second Pan-Pacific Congress, pp. 1060-1061, 1926.

[15]Op. cit., pp. 194-206.

[16]Op. cit., pp. 207-210.

a definite horizon marker is present. A check on the correlation of the Blaine with part of the Leonard is made possible by the subsurface tracing of the Blaine into the San Andres formation of New Mexico,[17] which in turn is very definitely correlated on stratigraphic and paleontologic evidence with the Leonard formation of the Glass Mountains. A further circumstance favoring correlation of the San Angelo and Blaine with the Leonard is the evidence of uplift at the base of the Double Mountain as shown by the unconformity at its base and the conglomerate in the San Angelo formation, which may correlate with the evidence of uplift of Llanoris in the lower part of the Leonard formation: the chert and quartz pebble conglomerate of the lower Leonard. It is highly probable that the uplift was contemporaneous in these two regions.

No vertebrate remains have been found in the Double Mountain group, and the only plants are small collections from the San Angelo formation of the *Gigantopteris* flora, of lower Permian age.

In north-central Texas the Blaine is unconformably overlain by the non-marine Triassic or by the Trinity sand.

Permian of Oklahoma and the Texas Panhandle.—In Oklahoma the Wichita group is divided[18] into the Stillwater and Wellington formations. The former, about 800 feet thick, has at its base the Cottonwood limestone, which probably is a time equivalent of the Coleman Junction limestone at the base of the Permian of north-central Texas. The typical Stillwater is a series of red and gray sandstones and red shales, but toward the north limestones appear and gradually thicken, and the red sandstone and shale grades into grey shale; this northward facies is the same as that of Kansas. Thus the northward change from non-red to red beds in the Wichita of Texas is duplicated by a change of the same kind in the opposite direction in Oklahoma. This fact is interpreted by Beede as due to the derivation of the Wichita red beds from the Wichita and Arbuckle mountains,[19] but these ranges seem to be hardly large enough to have supplied such a large amount of sediment. In southern and central Oklahoma the Wellington formation consists of red shale and sandstone and grey "mud-stone." Toward the north there is a transition to the grey and bluish shales with thin beds of "mud-stone," with a thickness of about 600 feet. This northern facies is, again, like that of Kansas. The Wichita group of Oklahoma does not contain fossils which enable correlations to be made with the Trans-Pecos sections, the fauna being largely of pelecypods and gastropods. Near Perry, Oklahoma, there are plants in the Wellington which are of definite lower Permian age. Lower Permian vertebrate remains also have been found in the Wichita.

The Clear Fork group is divided into two formations, the Garber below and the Hennessey above. The former, about 600 feet thick, consists of red clay shales, red sandy shales, and red sandstones. The latter, about 400 feet thick, is a red clay shale, without sandstone.

The Double Mountain group comprises a large number of formations.[20] At the base is the Duncan formation, consisting of two or three ledges of heavy white or buff sandstone separated by shale, varying from 100 to 300 feet in thickness. It traces southward into the San Angelo formation of Texas. Above the Duncan is the Chickasha gypsiferous red clay-shale, containing thin sandstones, varying up to 350 feet in thickness. The overlying Blaine gypsum, the ammonoid horizon of the Texas Double Mountain, is a zone of gypsum ledges with interbedded shales aggregating a thickness of about 50 feet. The next member, the Dog Creek shale, is a red clay-shale containing dolomite beds, from 30 to 400 feet thick. The Whitehorse sandstone is a friable red sandstone averaging 200 feet thick. The Day Creek dolomite is a widespread member from 1 to 5 feet thick. The Cloud Chief gypsum, containing interstratified red clay shale, varies up to 115 feet thick. The highest formation is the Quartermaster, consisting of 300 feet of soft, red sandstone, sandy clay, and shale.

The only fossils in the Double Mountain group of Oklahoma or the Texas Panhandle are in the Whitehorse sandstone, from which Beede (**5**, pp. 115–171) has described a fauna of pelecypods and gastropods, as well as a single species of brachiopod, *Dielasma schucherti* Beede. This has its

[17]Gould, C. N., and Willis, Robin: Tentative Correlation of the Permian Formations of the Southern Great Plains, Bull. Geol. Soc. Amer., vol. 38, pp. 435-438, 1927.

[18]Aurin, F. L., Officer, H. G., and Gould, Charles N.: Subdivisions of the Enid formation, Bull. Am. Assoc. Pet. Geol., vol. 10, pp. 786-799, 1926.

[19]Beede, J. W.: Origin of the Sediments and Coloring Matter of the Red Beds of Oklahoma, Science, n. s., vol. 35, pp. 348-350, 1912.

[20]Gould, C. N., and Lewis, F. E.: The Permian of Western Oklahoma and the Panhandle of Texas, Okla. Geol. Sur. Circular 13, 1926.

counterpart in the Glass Mountains faunas in *Dielasma schucherti minor* King, which differs from the Whitehorse sandstone species only in its smaller size. The presence of this form in the Word formation may indicate that the part of the Double Mountain group above the Blaine is of Word age. None of the other Whitehorse fossils is known at present to be of correlation value. The correlation made by Beede of the Whitehorse fauna with that of the Rustler limestone near Lakewood, New Mexico, is based more on similarity of facies and the presence of similar genera than on specific identities. The pelecypods of the Permian are characteristic of the limestones and sandstones intercalated with gypsum and red beds, and similar forms occur in this facies in rocks of various ages throughout the Permian. Where, on the other hand, a fossil occurring in the pelecypod facies occurs also with a normal marine fauna of brachiopods, corals, bryozoans, etc., more weight may be attached to it, for it permits the correlation of two unlike faunas. Since the classification is based on the succession of normal marine faunas, any species occurring in both it and the pelecypod facies is very important. Thus *Dielasma schucherti* is exceptionally significant because it occurs in the pelecypod facies and as a smaller variety in the normal marine facies (Word). Similarly, the ammonoids of the Blaine occur in the normal facies in the Leonard formation.

Neither plants nor vertebrates have been found in the Double Mountain of Oklahoma and the Texas Panhandle.

In conclusion, it may be pointed out that though the faunal evidence for correlating the Oklahoma section with that of Trans-Pecos Texas is meagre, fairly definite correlations are made possible indirectly by means of the equivalents of the Oklahoma formations in north-central Texas. Therefore, it is known that the Wichita is approximately equivalent to the Wolfcamp formation, the Clear Fork to the Hess, and the Double Mountain as high as the Blaine to the Leonard. The presence of related forms of *Dielasma* in the Whitehorse and the Word strongly suggests that the upper part of the Oklahoma-Texas Panhandle section is equivalent to part of the Word.[21]

Permian of Kansas.—The upper formation of the Pennsylvanian of Kansas is the Wabaunsee. The Permian types of fossils are there introduced. The total thickness of the Wabaunsee is 500 feet. Three hundred and fifty feet above the base is the Americus limestone. In the immediately succeeding lower beds of the Elmdale shale there is the first appearance of *Fusulina*, in the form of *F. longissimoidea*. This is rather a striking change, as the lower horizons are characterized by *Triticites*, while *Fusulina* is characteristically Permian. About 125 feet higher is the Neva limestone, which contains, according to Beede and Kniker (**6**, pp. 43–52), *Schwagerina kansasensis*, *Meekella mexicana* Girty, *Allorisma capax* Newberry?, and *Omphalotrochus?* sp., as well as other forms which do not occur at a lower horizon, many of them undescribed. The Eskridge shale, 30 to 40 feet thick, separates the Neva from the Cottonwood limestone, which is generally regarded as the base of the Permian, because at that horizon and above the Pennsylvanian elements drop out of the fauna, leaving a gastropod fauna of Permian aspect. *Fusulina emaciata* is common in the Cottonwood limestone, and *Triticites ventricosus* is a very characteristic species of the upper Wabaunsee and lower Permian (as the Permian is usually defined in that area).

The fusulinids in the Kansas faunas are the only fossils in that section which make possible correlations with Trans-Pecos Texas. *Schwakerina kansasensis* occurs also in the middle part of the Wolfcamp formation immediately above the *Uddenites* zone. *Triticites ventricosus* is abundant in the *Uddenites* zone. These facts would seem to indicate that the *Uddenites* zone is of the age of the beds immediately below the Neva limestone, the horizon of the Neva limestone occurring in the Glass Mountains directly above the *Uddenites* zone. If so, the base of the Permian in the entire mid-continent region has been drawn too high, and the contact should actually be placed approximately at the Americus limestone, with the first appearance of the Permian type of fusulinids.[22]

The evidence of fossil plants bears out that of the invertebrates.[23] At the level of the Neva limestone there is a plant association, embracing typical forms that can hardly be older than the Permian as recognized in western Europe. But still lower, in the Elmdale, there is a very late Odontopterid association "which would be referred to

[21]Schuchert **150**, p. 819 gives very similar correlations.

[22]Schuchert **150**, draws the line higher, at the base of the Neva limestone, in harmony with the conclusions of Drs. White and Beede.

[23]White, David: Permian of Western America from the Paleobotanical Standpoint, Proc. Second Pan-Pacific Congress, pp. 1057–1058, 1926.

the Permian by some paleobotanists, but which we regard as very latest Pennsylvanian. Also a few plants gathered by me from a level probably as low as the Americus limestone embrace fragments possibly representing Permian forms." Thus we see that the Permian floral elements were introduced at the same horizon as the genus *Fusulina*—at the Americus limestone.

It will now be shown that other evidence exists for placing the Pennsylvanian-Permian boundary below the Neva. In the Ardmore basin and north of the Arbuckle Mountains[21] the lowest formation resting on the folds of the Arbuckle Mountains is the Hart limestone, which forms the base of the Stratford formation. The Hart limestone traces northward probably into the upper part of the Buck Creek formation of northern Oklahoma, which in turn underlies the Elmdale shale. Therefore, the physical break representing the folding of the Arbuckles occurs at a position approximately equivalent to that of the appearance of *Fusulina* and the Permian flora, and to the horizon deduced as probably that of the *Uddenites* zone. Moreover, the upper part of the Vanoos formation, which underlies the Hart limestone, contains a flora in which David White identified *Walchia piniformis*, a type generally regarded as diagnostic of the lower Permian. This evidence indicates the very late Pennsylvanian age of the beds immediately below the unconformity. If the beds below the unconformity are so high in the Pennsylvanian, it is the more likely that the first beds above the unconformity would be Permian. An early Permian age for the first beds above the unconformity accords very well with the geologic history of the Marathon region, and it is not at all improbable that the folding was simultaneous in the two areas.

A still further evidence favoring lowering of the Pennsylvanian-Permian boundary is the fact that red sedimentation begins in Texas with the Putnam formation, which is placed by Plummer and Moore tentatively in the Cisco, though it is physically more similar to the Wichita than to the underlying beds of the Cisco. The base of the Putnam would approximately correspond to the horizon of the Americus limestone of Kansas. Romer (**139**, p. 97) states that in the Putnam there are Permian types of vertebrates, closely allied to those of the overlying Wichita.

[21]Morgan, George D.: Geology of the Stonewall Quadrangle, Oklahoma, Bur. of Geol. Bull. 2, 1924. Also Tomlinson, C. W.: Pennsylvanian System in the Ardmore Basin, Okla. Geol. Sur. Bull. 46, pp. 55-56, 1929.

In summary, it may be noted that in Kansas, Oklahoma, and Texas there are facts which indicate that the Pennsylvanian-Permian boundary should be shifted downward to approximately the horizon of the Americus limestone.

The remainder of the Permian section of Kansas is of less interest in connection with the present study. The Wichita equivalent is known as the Big Blue group. The equivalents of the Stillwater formation of Oklahoma are the Council Grove, Chase, and Marion, aggregating about 550 feet in thickness, and consisting of shale with layers of limestone and cherty limestone. The fauna differs from that of the underlying beds in containing fewer brachiopods and a large number of pelecypods, some of which are new types of Permian affinity. The Wellington formation consists of about 500 feet of blue-grey shale containing thick salt beds. The beds above the Wellington are known collectively as the Cimarron. The first member of the Cimarron is the Harper red sandstone, about 325 feet thick, the lower part of which is equivalent to the entire Clear Fork and the upper to the Duncan-San Angelo, the basal part of the Double Mountain. The Chickasha formation of Oklahoma is equivalent to the Salt Plain, Cedar Hills, and Flower Pot members, which consist of red sandstone and shale with layers of gypsum. This is followed by the Blaine gypsum and the remainder of the section as in the Double Mountain of Oklahoma (**122**, pp. 47–73).

Dunbar (**36**, pp. 187–188) has pointed out that two very distinctive species of molluscs, *Stenoporceras dumblei* and *Myalina copei*, occur in both the Chase formation of Kansas and the Wichita group of Texas. In the basal part (Wreford) of the Chase group there are migrant European species of the plants *Callipteris*, *Taeniopteris*, *Walchia*, *Sphenophyllum*, and *Odontopteris*, everywhere recognized as characteristic of the Permian. In the upper Wellington there are a few Pennsylvanian survivors associated with species of *Callipteris*, *Taeniopteris*, *Ullmania*, *Voltzia*, *Araucarites*, and *Glenopteris*.[25] A very large fauna of insects of lower Permian type has been collected from a thin limestone in the Wellington shale (**36**, pp. 171–209).

[25]White, David: Permian of Western America from the Paleobotanical Stand-point, Proc. Second Pan-Pacific Congress, pp. 1057-1058, 1926.

PERMIAN OF ARIZONA AND NEW MEXICO

The Permian of southwestern New Mexico and southeastern Arizona.—The Permian rocks in this region are of the Gym facies, resembling the Permian of the Hueco Mountains escarpment. In the mountains of Luna County, near Deming, New Mexico (**15**, pp. 35–39), the massive light-grey Gym limestone is about 1000 feet thick. The type locality is Gym Peak, in the Florida Mountains, 17 miles south-southeast of Deming. The formation rests with considerable structural unconformity on the underlying strata. In places it rests on the lower Ordovician El Paso limestone, elsewhere on the upper Ordovician Montoya limestone, while in the Cooks Range north of Deming it overlies shale of Pennsylvanian age. The unconformity below the formation is therefore comparable in every respect to that below the Gym in the Hueco Mountains.

The following invertebrates have been listed by Girty from the Gym of this area (**15**, pp. 38–39):

Fusulinella sp.
Echinocrinus ornatus
Meekella mexicana?
Chonetes platynotus?
Productus aff. P. semireticulatus
P. occidentalis
Linoproductus cora
Marginifera splendens?
Pugnoides osagensis
Ambocoelia? sp.
Squamularia perplexa
Composita subtilita
C. sp.
C. mexicana?
Astartella? sp.
Parallelodon politus?
Edmondia sp.
Monopteria marian?
Myalina sp.
Schizodus sp.
Pinna peracuta
Pleurophorus sp.
Plagioglypta canna?
Bellerophon crassus
B. crassus wewokanus?
B. majusculus?
Bucanopsis modesta
Pleurotomaria texana
P. 3 sp.
Murchisonia 4 sp.
Euomphalus aff. E. pernodosus
Meekospira sp.
Discohelix? n. sp.
Rhynchomphalus obtusispira
Sphaerodoma aff. S. humilis
S. aff. S. primitenia
Cyclonema sp.
Glyptobasis? sp.
Orthonema socorroense?
O. sp.
Pseudomelania? 4 sp.
Zygopleura n. sp.
Loxonema? 2 sp.
Phymatipher n. sp.
Naticopsis sp.
Bulimorpha inornata

The uncertainty of some of the identifications of the species and the lack of specific determination of most of them makes their use difficult, but certain general comparisons may be made. The *Fusulinella* sp. is probably not a true *Fusulinella* but it is likely the same as the form occurring abundantly in the lower Gym of the Hueco Mountains. *Meekella mexicana* occurs in the middle Gym of the Hueco Mountains. The *Productus* aff. *P. semireticulatus* might well be *P. inca*, the common fossil of the middle and upper Gym of Texas, while *Linoproductus cora* is common also in the middle Gym. *Pugnoides osagensis* probably corresponds to *P. texanus*, one of the most characteristic Gym fossils in Texas. The species of *Composita* correspond to *Composita subtilita* and *C. mexicana*, two of the most common species in the Gym of Texas. The great abundance of pelecypods and gastropods is a further resemblance with the Gym faunas of the Hueco Mountains. The species in the Texas section have not as yet been identified. The only notable difference between the fauna of the Gym of Luna County and of the Hueco Mountains is that in the latter there is a great abundance of *Schwagerina*, which has not been reported from the Luna County section.

In southeastern Arizona the Permian has not been differentiated, in mapping, from the Pennsylvanian. Both systems are included in the Naco limestone, which is 1500 to 3000 feet thick. This formation is largely light-grey, compact limestone in beds of moderate thickness. The Pennsylvanian part of the formation has a fauna entirely like that of the Pennsylvanian of the Hueco Mountains, with *Chaetetes milleporaceus* a common fossil. The Permian part, on the other hand, is faunally very similar to the Gym. Girty has listed the following forms from it in the Bisbee district[26]:

Fusulina cylindrica
Michelinia? sp.
Lophophyllum cf. proliferum
Echinocrinus several sp.
Productus, semireticulatus type
Worthenia sp.
Murchisonia? several sp.
Euomphalus sp.
Omphalotrochus, several sp.
Productus cf. norwoodi
Marginifera cf. wabashensis
Martinia sp.
Composita subtilita
Plagioglypta cf. canna
Cyclonema sp.
Orthonema sp.
Polyphemopsis sp.
Bellerophon cf. crassus
Euphemus sp.

On plate 11, fig. 1, of Professional Paper 21 there is an illustration of the form identified as *Fusulina cylindrica*. It is a large robust fusulinid, having exactly the appearance of the *Schwagerina* of the lower part of the Hueco Mountains Gym. A coral similar to *Michelinia* is common in the lower Gym of Texas, as is *Echinocrinus*. One of the forms identified by Girty as *Productus semireticulatus* is

[26]Girty, in Geology and Ore Deposits of Bisbee Quadrangle, Arizona, U. S. Geol. Sur. Prof. Paper 21, pp. 50-54, pl. 11, 1904.

figured on Plate 11, fig. 4; it is indistinguishable from *P. inca* of the Texas Gym. One of the species of the semireticulate type of *Productus* is said to be related to *P. ivesi* and another to *P. occidentalis*. One species of *Omphalotrochus* is probably *O. whitneyi* Meek, while another is related to *O. obtusispira* (Shumard), first described from the Gym of the Hueco Mountains. The species of *Echinocrinus* are said not to be related to Pennsylvanian forms, but to be more suggestive of the Kaibab. Girty states definitely that the fauna is very closely similar to that of the Hueco Mountains.

The Permian part of the Naco limestone is evidently rather widely distributed in southeastern Arizona. About 50 miles west of Bisbee, near the Mowry Mine, 8 miles south of Patagonia, there is a limestone containing the same fauna, the fossils of which have been listed by Darton (**16**, p. 73). It succeeds a Pennsylvanian fauna. Northwest of Patagonia and about 40 miles south of Tucson, there is fossiliferous lower Permian in Sawmill Canyon in the Santa Rita Mountains near the Onyx Mine. A collection from there made by Professor Schuchert and kindly turned over to me for study contains *Productus occidentalis*, *Camarophoria deloi*, *Hustedia mormoni*, and *Composita mexicana*, which indicates a Gym age for this horizon. A collection which I have studied from Snyder's Hill, 9 miles southwest of Tucson, made by Professor Schuchert, contains *Productus occidentalis*, *Avonia boulei*, *A. subhorrida rugatula*, *Composita mexicana*, *Camerophoria deloi*, and *Squamularia guadalupensis*. Girty also has identified *Pustula* aff. *P. porrecta (=Buxtonia peruviana)* from this locality. All these fossils are very characteristic of the Gym. This horizon is underlain by typical Pennsylvanian. Permian fossils have been listed by Darton (**15**, p. 75) from the Waterman Mountains, 30 miles west-northwest of Tucson.

According to Stoyanow (**161**, pp. 320–324) the Gym gastropod fauna occurs in the Naco limestone of the Little Dragoon Mountains, about 50 miles east of Tucson. *Bellerophon crassus*, *B. percarinatus*, *B. carbonarius*, *Euconispira taggarti*, *Murchisonia terebra*, *Straparollus pernodosus*, and *S. subquadratus* are listed. Farther to the northwest, however, in the Galiuro Mountains near Winkelman, the lower Pennsylvanian is well exposed, and the Gym equivalents appear to be absent from this region.

The fauna of the highest part of the Naco limestone is of particular interest. From this horizon 5 miles south of Tombstone, Darton collected *Meekella pyramidalis?*, *Productus leei?*, *P. ivesi*, and *Marginifera* sp., evidently a Kaibab-San Andres-Leonard fauna. In the Chiricahua Mountains, in southeasternmost Arizona, near Paradise, Stoyanow (**161**, pp. 318–319) found that above the Naco limestone there is a solid quartzite over 100 feet in thickness, overlain by an indistinctly bedded light-grey limestone, about 500 feet thick, containing the Kaibab fauna. *Productus ivesi*, *P. occidentalis*, *Meekella pyramidalis*, *Derbya* sp., *Squamularia guadalupensis*, and *Aviculopecten coloradoensis* are present in this fauna. From these facts, it appears that the upper Naco limestone, equivalent to the Gym of the Hueco Mountains and southwestern New Mexico, is here overlain by beds of Leonard-San Andres-Kaibab age. This makes still more probable the correlation of the Gym with the Yeso formation of central New Mexico and with the Hess of the Glass Mountains section. One is tempted to believe that the quartzite underlying the Kaibab fauna in the Chiricahua Mountains is equivalent to the Coconino of the Grand Canyon region and the Glorieta of central New Mexico.

It is to be hoped that future workers in southeastern Arizona will differentiate the Permian from the Pennsylvanian. If so, it will be appropriate to extend the name Gym to these Permian limestones, because their lithology and fauna are the same as that of the typical Gym and its equivalent in the Hueco Mountains.

Permian limestones are known to occur in northeastern Sonora in the mountains south of Bisbee and Douglas, but their stratigraphy and faunas have not been made known.

Permian of central New Mexico.—North of the Hueco and Guadalupe mountains, in the central and south-central parts of New Mexico, there are about 2500 feet of Permian sediments of a quite different lithologic character from the Permian of either the Guadalupe or the Gym facies.[27] The New Mexican section has been called the Manzano group, but it is best to discard this name, for at the type locality of the group, the Manzano range, only the lower member of it, the Abo sandstone, is present.

The Abo red sandstone, 400 to 800 feet thick, rests unconformably on the pre-Permian rocks,

[27] See Darton, N. H.: The Permian of Arizona and New Mexico, Bull. Am. Assoc. Petr. Geol., vol. 10, pp. 833-852, 1926.

lying on limestone of the Magdalena group (Pennsylvanian) except in the Zuni Mountains and part of the Nacimento range, where it overlaps upon the granite, and in the Pedernal Mountain region, where it abuts against pre-Cambrian quartzite. In most places the basal contact of the Abo is marked by little structural discordance, but by sharp change in the nature of sedimentation from that in the Magdalena, namely local conglomerates, and some channeling. Southward from central New Mexico toward the Texas boundary the Abo thins, and several miles north of the state line it has entirely wedged out between the Pennsylvanian and the overlying Permian.

The invertebrate fossils of the Abo are largely pelecypods and gastropods. A collection of ammonoids, said to be from the Abo, made by Baker east of Tularosa and studied by Böse (**9**, pp. 57–60), are of Pennsylvanian type, but according to Darton they may have been obtained from a red sandy member in the upper part of the Magdalena. The brachiopods described from the Abo by Girty (**98**) are mostly Pennsylvanian species, but Darton states that many of these actually came from the Magdalena. Fossil plants from the lower conglomeratic part of the Abo near Pecos City and Glorieta are said by David White to disclose a rather limited basal Permian flora. The upper Abo near Coyote has yielded many vertebrate fossils, comprising the genera *Diadectes, Spehenacodon, Ophiacodon, Clepsydrops, Elcabrosaurus, Diasparactus, Aspidosaurus,* and *Limnocolis.* They have been regarded as Permian types, but Romer (**139**, p. 98) doubts this. Few of the genera are present in the late Paleozoic vertebrate faunas of Texas, and those which do occur there are inconclusive. Romer's argument that the vertebrate fauna is probably of pre-Wichita age seems rather unconvincing. There is thus little direct evidence as to the age of the Abo, but since it contains Permian plants and is conformably overlain by the Yeso formation of Hess age while separated from the underlying Magdalena by a considerable unconformity, it is probably of Wolfcamp age. There can be little doubt that the pre-Abo unconformity is to be correlated with the Marathon disturbance in the Marathon region, the Pennsylvanian-Permian unconformity in the Hueco and Diablo mountains, and the break below the Gym in Luna County.

The Chupadera group of Darton comprises several members. The lower 500 to 800 feet of these beds was called by Lee the Yeso formation; it consists of red shale, pink and yellow sandstone, and thin limestone and gypsum layers. The upper part of this formation is generally termed the Glorieta sandstone, after its exposure on Glorieta Mesa. Above is the San Andres limestone of Lee, a massive white formation 500 or more feet in thickness. Darton states that these members are not continuously traceable, and therefore not natural groups; he prefers to refer to them collectively as the Chupadera group. The faunas of the Yeso and the San Andres as described by Girty (**98**) are, however, quite distinct from each other.

The following Brachiopods have been described from the Yeso:

Meekella mexicana	Pugnoides osagensis pusilla
Productus ivesi	Squamularia perplexa
P. mexicanus?	Composita mexicana
P. nebraskensis (=Buxtonia sp?)	C. subtilita?

Meekella mexicana is abundant in the middle Gym of the Hueco Mountains. *Productus nebraskensis* of Girty is probably a species of *Buxtonia,* perhaps *B. peruviana,* which is characteristic of the Gym. *Pugnoides osagensis pusilla* was not identified from the Gym, but may be related to *P. texanus.* *Composita mexicana* and *C. subtilita* are common Gym fossils. The only similarity to the Leonard formation is the presence of *Productus ivesi,* which occurs also in the Hess. The Yeso is therefore rather definitely of Gym and Hess age. The outcrop of the Yeso formation is continuous with that of the Gym, and near the Texas-New Mexico boundary there is a transition from the lithology of one to that of the other, the red beds and gypsum of the Yeso being replaced southward by limestone of the Gym facies. According to White,[28] the Yeso contains abundant *Taeniopteris, Walchia, Gomphostrobus,* and *Callipteris,* with several forms of *Sphenopteris* and *Pecopteris* identical with those of the Permian of western Europe.

The San Andres limestone has yielded the following brachiopods, described by Girty:

Meekella mexicana	Marginifera manzanica
Productus ivesi	M. cristobalensis
Productus inca (=P. leei)	Squamularia perplexa?
Productus occidentalis	Composita mexicana
Productus mexicanus?	C. subtilita?

[28]Permian of Western America from the Paleobotanical Standpoint, Proc. Second Pan-Pacific Sci. Congress, p. 1061, 1926.

Productus ivesi, P. occidentalis, Marginifera manzanica, M. cristobalensis, Squamularia guadalupensis (=*S. perplexa* as identified by Girty), *Composita mexicana*, and *C. subtilita* occur in the Leonard formation of the Glass Mountains. *Productus occidentalis* and *Squamularia guadalupensis* occur also in the Word and the Capitan, but none of the species occurring in the San Andres is restricted to higher beds than the Leonard, with the possible exception of *Productus mexicanus*, which is doubtfully identified. *Productus ivesi* does not occur above the Leonard, and its zone of abundance is in the Leonard, while the two species of *Marginifera* are definite indices to the Leonard in Trans-Pecos Texas. *Productus inca* occurs in Texas in the middle and upper Gym, which is certainly not younger than Leonard in age. In view of these facts, a correlation of the San Andres limestone with the Delaware Mountain or Capitan seems to be rather conclusively disproved, and its correlation with the Leonard fairly certain.

An actual physical connection between the Manzano and Guadalupe groups exists in southeastern New Mexico in the country between the Sacramento and Guadalupe mountains, and considerable geologic work has been done in this area. Unfortunately, there has been no general agreement as to the correlations between the two districts, though the interpretation which has been most widely advanced is that the Chupadera formation is the equivalent to the Guadalupe group* and, more specifically, that the San Andres is laterally continuous with the lower lagoonal member of the Capitan along the western side of the Guadalupe Mountains†. So confidently has this assertion been made, indeed, that Willis‡ is led to conclude that, in spite of the "disagreement between the paleontologists and the men who have studied the Guadalupian Permian in the field . . . . it seems reasonable to correlate the San Andres with the lower Capitan."

Many geologists find, with Lloyd,§ an explanation to these apparent contradictions of stratigraphy and paleontology by the easy recourse to the assumption that the Capitan and other reef barriers shut off the Guadalupian fauna from the interior Manzano seas, where faunas of another facies existed. Though this assumption is superficially reasonable, it is made without understanding the nature and distribution of the fossils concerned. We have already shown how the majority of the San Andres brachiopods occur far below the level of the Capitan formation in Texas, in the Leonard formation, to which many of them are restricted. In addition, most of the Phosphoria brachiopods occur in the Delaware Mountain and Word formations in Trans-Pecos Texas, and, as will be shown below, the Phosphoria formation clearly overlaps the Kaibab (northwestern extension of the San Andres) in central Utah.

In view of the lack of adequate maps of the northern Guadalupe Mountains, the meagerness of published geologic observations, and the almost complete absence of fossil determinations, it is difficult to evaluate the evidence on which the various stratigraphic conclusions are based. For these reasons the following analysis of the literature is attempted with some hesitancy.

We have shown in the description of the Delaware and Guadalupe mountains how the great Capitan reef mass passes northwestward into three lagoonal members: thin-bedded limestones below (not satisfactorily named), medial sandstone and gypsum (Queen and Seven Rivers members) and thin-bedded limestone above (the Carlsbad member)*. The Seven Rivers and Carlsbad members extend northeast down the back slope of the Guadalupe Mountains to the Pecos River north of Carlsbad, where the Carlsbad member has largely disappeared and the medial gypsums and red beds have attained considerable thickness. Since these two members do not extend into the northwest part of the mountains they are of no further concern to us. Most of the northwest part of the mountains is spread over by a great sheet of the lower lagoonal limestones, which are also downfaulted on the west. Limestones extend from here northwestward into the Sacramento Mountains. Part of these belong to the San Andres formation, for fossils characteristic of that formation were collected by

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*Darton, N. H., and Reeside, J. B., Guadalupe Group, Bull. Geol. Soc. Amer., Vol. 37, p. 419, 1926.

†Blanchard, W. G., and Davis, M. J., Permian Stratigraphy and Structure of Parts of Southeastern New Mexico and Southwestern Texas, Bull. Amer. Assoc. Petrol. Geol., Vol. 13. pp. 971-972. 1929.

‡Willis, Robin, Preliminary Correlation of the Texas and New Mexico Permian, Bull. Amer. Assoc. Petrol. Geol., Vol. 13, p. 1022, 1929.

§Lloyd, E. Russel, Capitan limestone and Associated Formations of New Mexico and Texas, Bull. Amer. Assoc. Petrol. Geol., Vol. 13, p. 665, 1929: "The San Andres . . . . contains a marine fauna which is . . . . quite different from the Guadalupian fauna of the Capitan. The difference in the fauna may be explained by differences in environment."

*For areal distribution see Darton and Reeside, *op. cit.*, figure 1, or Darton **17**, Plate 49.

Darton* at Russel Gap, 40 miles north of the state line, and farther north by Richardson* on the lower Penasco River. A large and abundant San Andres fauna is also known from near the summit of the Sacramento Mountains, at Cloudcroft,* which is definitely within the Manzano area.

Since the upper limestones are down-faulted along the western face of the Guadalupe Mountains, the lower beds are hidden in some of the most critical places and less is known of their stratigraphy. Our information is based on fortuitous local exposures resulting from structural accidents or deep erosion.

We have already remarked on the peculiar stratigraphic relations along the west side of the Guadalupe Mountains in Texas, where the Delaware Mountain formation rests with marked erosional unconformity on the Bone Canyon and Victorio Peak members of the Leonard formation. The limestone of probable Victorio Peak age thickens northward and at the state line Darton and Reeside say it has a "Chupadera character" (fig. 4). At the same time these lower beds rise northward in altitude with the Delaware Mountain sandstone layers disappearing one at a time by overlap against them, until that formation is only 100 feet thick at the state line (Darton and Reeside). Beyond this are no continuous exposures.

Darton and Reeside have collected fossils farther north from strata in the bottom of Last Chance Canyon and Rocky Arroyo, on the eastern slope of the Guadalupe Mountains, where dark slabby limestones underlie partly sandy limestone of "Chupadera character," evidently the northern extension of the Capitan lagoonal beds. They state that the fossils indicate a level "somewhat lower" than the upper dark limestone of the Delaware Mountain, "but by no chance the lower dark limestone number" (our Bone Canyon). That the latter interpretation is, however, rather likely is suggested by the citation of *Productus* aff. *ivesi* and *Composita mexicana* which range no higher than the Leonard, and it is not improbable that the Capitan lies unconformably here on rocks older than the Delaware Mountain sandstone. Various isolated sections are described by Blanchard and Davis on the west side of the Guadalupe Mountains from twc to nineteen miles north of the state line. At Tank Canyon they find "San Andres" (lower Capitan) resting directly on "Bone Springs" (Victorio Peak?), while to the south the Delaware Mountain formation intervenes and to the north "Yeso" underlies the "San Andres." These authors cite no fossils except fusulinids.

*Darton, N. H., **17**, p. 221.

*Cited by Girty, G. H., The Guadalupian Fauna and New Stratigraphic Evidence, Annals of New York Acad. Sci., Vol. 19, p. 141, 1909.

*Girty, *op. cit.*, p. 139.

If the Guadalupian and Manzano are separate entities, then the Capitan limestones must pass out by overlap against the unconformably underlying Victorio Peak-San Andres limestones between Tank Canyon, and the Russel Gap locality where Darton found the southernmost Manzano fossils. Such an interpretation has, however, not been offered by any of the field geologists except Baker.*

The stratigraphic anomalies of the northwestern Guadalupe Mountains would be simply a local field problem were it not that this district is the link between two widespread and uniform stratigraphic sequences, the Guadalupian on the south and the Manzano on the north. By following the widely advanced field interpretations, Girty* concludes that "evidence is such as to demand a consideration, if not an adoption, of the hypothesis that the facies of the Guadalupian fauna is a regional matter denoting not time relations but geographic relations." If this is the case, the highly distinctive Guadalupian fauna is then simply an unusual local facies of the lower Permian, and is not the highly developed upper Permian fauna indicated to us by the long evolutionary sequence in the Glass Mountains.

From the above discussion it may be concluded that the Abo is probably of Wolfcamp and Wichita age, the Yeso approximately of Gym, Hess, and Clear Fork age, and the San Andres of Leonard and lower Double Mountain age. The correlation of the San Andres with the lower Double Mountain is checked by the subsurface tracing of the Blaine into the San Andres.[30]

Permian of northern Arizona.—In northern Arizona[31] the Redwall limestone is overlain by the Supai red sandstone and shale. In the Grand Canyon, the Supai is from 800 to 1100 feet thick, and rests on Redwall limestone of Mississippian age.

*Baker, C. L., Contributions to the Stratigraphy of Southeastern New Mexico, Amer. Jour. Sci., (4), 49, pp. 99–126, 1920.

Also, Discussion of Permian Symposium. Amer. Assoc. Petrol. Geol., Vol. 13, pp. 1060 1062, 1929.

*Girty, *op. Cit.*, p. 141.

[30]Gould, C. N., and Willis, Robin: Tentative Correlation of the Permian Formations of the Southern Great Plains, Bull. Geol. Soc. Amer., vol. 38, pp. 435-438, 1927.

[31]Darton, N. H.: **16**, pp. 78-101. Also The Permian of Arizona and New Mexico, Bull. Am. Assoc. Pet. Geol., vol. 10, pp. 821-833, 1926.

Along the southern escarpment of the Arizona Plateau, especially on the scarp of the Mogollon Plateau and in the Holbrook Dome, there are 600 to 800 feet of red beds, which lie on Pennsylvanian limestone to the south and east but overlap upon pre-Cambrian granite to the northeast. The Pennsylvanian limestone was formerly included in the Redwall formation, but is now classified by the U. S. Geological Survey as the lower member of the Supai. This classification seems rather unnatural, for the remainder of the Supai is lower Permian in age, and is separated from the Pennsylvanian by a considerable time break. On the other hand the Supai red beds of the Mogollon Plateau and Holbrook Dome contain near the top rather thick limestones, which have yielded the following fossils, as listed by Girty:

Echinocrinus cratis	Allerisma capax?
Rhombopora lepidodendroides	Deltopecten coreyanus
Productus cora	D. occidentalis?
P. ieci	Myalina subquadrata?
Pustula nebraskensis	M. perattenuata?
Pugnoides utah	Monopteria marian
Spirifer triplicatus	Plagioglyptus canna?
Composita subtilita	Pleurotomaria alamillana
Hustedia mormoni	Phymatifer cornudanus, etc.

According to Girty[32] this is a Manzano fauna, and a similar Permian one occurs in a limestone member of the Abo formation in the Zuni uplift of New Mexico. Because of the similarity faunally, lithologically, and stratigraphically of the Supai to the Abo, it can hardly be doubted that the Supai is the Arizona representative of the Abo. In the Defiance uplift of northeastern Arizona the Supai is present again, and there it contains *Walchia*, a plant diagnostic of the Permian. Darton states that "the evidence of these various fossils shows that the Supai formation as originally defined (i.e., excluding the limestone formerly placed in the Redwall) is all of Permian age."[33]

Above the Supai is the Hermit shale, varying from 80 to over 500 feet in thickness. It is exposed along the upper slopes of the Grand Canyon, and does not occur on the south side of the Arizona Plateau. It is unconformable upon the Supai. Permian plant remains occur in it, including *Callipteris conferta*, *Walchia* cf. *W. gracilia*, *Gigantopteris* cf. *G. sphenophyllum*, *Alethopteris?*, and *Pecopteris* (**148**, pp. 353–360).

The succeeding unit, the Coconino sandstone, is very widespread over the Arizona Plateau. It is generally from 300 to 600 feet thick, and consists of massive light-grey to pale buff sandstone of remarkably uniform character. The only fossils that have been found in it are footprints. In places in the Kaibab Plateau the Coconino is not distinguishable, for in that region the entire Coconino is replaced at some localities by limestone of the Kaibab, which overlaps the Coconino by replacement.

The highest member of the Arizona Permian section is the Kaibab limestone, which covers a very large area in northern Arizona. To the north of the Grand Canyon the Kaibab is 1000 or more feet in thickness, and here the Coconino is not present. To the east and southeast the Coconino becomes distinguishable, and thickens, replacing the lower Kaibab so that in eastern sections the Kaibab may be but a few feet thick. The Kaibab varies in thickness also as a result of pre-Triassic erosion. Approximately the upper 150 feet of the Kaibab is distinguished as the Harrisburg gypsiferous member, the upper part of which is known as the "Bellerophon limestone."

The brachiopods occurring in the main part of the Kaibab are, as identified by Girty, with some modifications by myself:

Orbiculoidea convexa	Avonia subhorrida rugatula
Derbya aff. D. nasuta	Pugnoides osagensis var.
Meekella pyramidalis	Squamularia guadalupensis
Chonetes quadratus	Spiriferina campestris?
Productus ivesi	Composita mexicana?
P. occidentalis	C. subtilita
Waagenoconcha montpelierensis	Dielasma sp.
	Heterelasma n. sp.

Of the forms definitely identified, *Orbiculoidea convexa* and *Meekella pyramidalis* do not occur in Trans-Pecos Texas. *Chonetes quadratus* occurs in the upper Word, *Productus ivesi* is most abundant in the Leonard, and the others occur in several formations, all of them being present in the Leonard and some as low as the Wolfcamp and others as high as the Capitan. This evidence would seem to be conflicting, but it is a striking fact that the most abundant of all the Kaibab species, *Productus ivesi*, is also abundant in the Leonard and does not occur in Texas at a higher horizon. The other species, though mostly longer ranged, also occur in the Leonard, so that the Kaibab fauna as a

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[32] In Darton and Reeside, Bull. Am. Assoc. Pet. Geol., vol. 10, pp. 825 826, 1926.

[33] Op. cit., p. 89.

whole has much in common with that of the Leonard. Unfortunately, no ammonoids occur in the Kaibab, but the formation correlates definitely both faunally and lithologically with the San Andres of New Mexico, which in turn also has been correlated by us with the Leonard.

The fauna of the Bellerophon limestone is quite unlike that of the main part of the Kaibab, consisting almost wholly of molluscs, of which the characteristic species is *Bellerophon majusculus*.

With the age of the Kaibab definitely fixed as that of the Leonard and San Andres, the age of the beds below it may be approximately placed. The Coconino may represent the same phase of deposition as the Glorieta sandstone of New Mexico and the Hermit part of the Yeso.*

PERMIAN OF THE GREAT BASIN AND NORTHERN ROCKIES

Permian of southeastern and central Utah and southwestern Colorado.—In southeastern Utah[34] the lowest formation in the section is the Goodridge, consisting of dense, medium to massively bedded limestone, red and greyish-white sandstone, and red and dark-grey shale, with a total thickness of 1500 feet. In the lower 1200 feet there is a typical Pennsylvanian fauna with almost no molluscs; the upper 300 feet bears almost entirely a molluscan fauna, which is of lower Permian type and closely similar to that of the Rico formation of southwestern Colorado, the Supai of the south side of the Arizona Plateau, and the Abo. The Goodridge grades upward into Supai red beds, which are here about 400 feet thick. The upper Goodridge probably equals the lower Supai of the Grand Canyon region, while the Supai of southeastern Utah is probably of upper Supai and in part perhaps Hermit age. The overlying Coconino sandstone here attains a thickness of 1000 feet. The Kaibab is not over 150 feet thick, and it thins progressively northward, with a corresponding thickening of the Coconino sandstone. The fauna here is of the normal Kaibab type rather than that of the Bellerophon limestone.

In southwestern Colorado[35] and the Moab region of east-central Utah the Pennsylvanian Hermosa limestone is overlain by the Rico formation, which consists of sandstone and conglomerate with intercalated shale and sandy fossiliferous limestone, 250 to 600 feet in thickness. The fauna is almost wholly molluscan, and contains types similar to those of the Kansas Permian. The Rico grades upward without break into the unfossiliferous Cutler red shale, sandstone, grit, and conglomerate, having a total thickness of about 2000 feet. In places the upper Rico is laterally replaced by the Cutler. Girty believes that the fauna of the Rico is of Permian type.. It correlates with the upper Goodridge, while the Hermosa correlates with the lower Goodridge. In east-central Utah the Rico has been traced westward by measured sections into the Supai (the upper Goodridge not being present there), and the Cutler has been traced into the Coconino.[36] None of the Rico or upper Goodridge fossils is of use in making correlations with the Trans-Pecos Texas section of Permian.

In the San Rafael Swell of central Utah[37] there are 700 feet of Coconino overlain by 85 feet of Kaibab. There are two faunas here, one of which is that of the Bellerophon limestone, and the other a fauna having Phosphoria affinities, shown by the presence of *Waagenoconcha montpelierensis* and *Pustula nevadensis*. *Productus ivesi* and *P. occidentalis* are absent, and there is a large number of molluscs. This perhaps indicates a transition to the Phosphoria from the typical Kaibab facies. The presence of the Bellerophon limestone fauna in only 85 feet of the formation indicates that only the upper Kaibab is present here, the lower probably having been replaced by the Coconino.

The Phosphoria formation and its equivalents.—Throughout northern Utah, western Wyoming, southeastern Idaho, and western Montana the Permian is represented by the very widespread and remarkably uniform Phosphoria formation. In

*Since this paper was written, new observations have been published by A. A. Baker and J. B. Reeside on the Permian of northeastern Arizona and its surroundings, in which special emphasis is placed on interfingering and lateral replacements of different facies. These in general confirm our own briefer conclusions (Baker and Reeside, Correlation of the Permian of Southern Utah, Northern Arizona, Northwestern New Mexico, and Southwestern Colorado, Bull. Amer. Assoc. Petrol. Geol., Vol. 13, pp. 1413-1448, 1929).

[34]Longwell, C. R., Miser, H. D., Moore, R. C., Bryan, Kirk, and Paige, Sidney: Rock Formations in the Colorado Plateau of Southeastern Utah and Northern Arizona, U. S. Geol. Sur. Prof. Paper 132A, 1923.

[35]Cross, W., and Hale, Allen D.: Engineer Mountain Folio, Colorado, U. S. Geol. Sur. Folio 171, pp. 6–7, 1910. Also Baker, A. A., Dobbin, C. E., McKnight, E. T., and Reeside, J. B.: Notes on the Stratigraphy of the Moab Region, Utah, Bull. Am. Assoc. Pet. Geol., vol. 11, pp. 785-796, 1927.

[36]Prommel, H. W. C., and Crum, H. E.: Structural History of Parts of Southeastern Utah from Interpretation of Geologic Sections, Bull. Am. Assoc. Pet. Geol., vol. 11, pp. 809–815, 1927.

[37]Gilluly, James: Geology and Oil and Gas Prospects of Part of the San Rafael Swell, Utah, U. S. Geol. Sur. Bull. 806, pp. 80-83, 1928.

northernmost Utah and southeastern Idaho the Phosphoria rests on the Wells formation of Pennsylvanian age, in western Wyoming on the Tensleep sandstone, and in western Montana on the Quadrant.

The Phosphoria formation consists of from 80 to 450 feet of dark-grey cherty quartzite containing layers of nodular chert and shale, and one or more beds of phosphate rock. In different localities it is divisible into various members. In southeastern Idaho Mansfield (**108**, pp. 75–81) has divided it into the phosphatic shale member below and the Rex chert member above, the former 75–180 feet thick, and the latter 110–550 feet thick. The fauna of the phosphatic shale member has been described by Girty (**70**), and that of the limestone and chert members of the formation by Meek and Girty in various places.[38]

The fauna of the phosphatic shale is considerably different from that of the remainder of the formation, but together the faunas of the two members form a rather varied aggregation of forms of similar stratigraphic affinities. In the limestone and chert division of the formation the following are characteristic brachiopods:

Productus multistriatus
Linoproductus waagenianus (=Productus eucharis)
Pustula nevadaensis
Avonia subhorrida
Aulosteges hispidus
Camarophoria sp.
Spirifer pseudocameratus
Spiriferina pulchra
Composita mira
C. persinuata

Spiriferina pulchra is such a common form that this fauna has come to be known as the *Spiriferina pulchra* fauna, and it is much more widespread than that of the phosphatic shale, for the biota occurs also throughout central and eastern Nevada (where most of the type specimens of its species were collected by the King survey) and as far south as the Inyo Mountains of southeastern California, where the Owenyo limestone[39] 125 feet thick, carries an abundant fauna of this type.

The characteristic species of the phosphatic shale fauna are:

Lingula carbonaria?
Orbiculoidea missouriensis
Chonetes ostiolatus and vars.
Productus geniculatus
Linoproductus waagenianus (=Productus eucharis)
Waagenoconcha montpelierensis
Linoproductus phosphaticus
Liorhynchus weeksi
Pugnoides swallovianus (Pugnax osagensis var. occidentalis)
Ambocoelia guadalupensis (Ambocoelia arcuata)
Leda obesa
Plagioglypta canna
Omphalotrochus ferrieri
O. conoideus
Gastrioceras simulator
Hollina emaciata occidentalis

In the Uinta Mountains the phosphate-bearing Permian was originally known as the "Bellerophon limestone," after one of its characteristic fossils; the presence of *Bellerophon* may indicate faunal relationship to the "Bellerophon limestone" at the top of the Kaibab, which, as shown below, is probably of the same age. The Permian of the Uinta Mountains is underlain by the Weber quartzite, which may be the equivalent of the Coconino.

Considering the species themselves that occur in the Phosphoria fauna, there is little to indicate their age. Many of them are related to species of the *Schwagerina* horizon and the Artinsk of the Russo-Arctic region. Such are *Chonetes ostiolatus, Productus multistriatus, P. geniculatus, Linoproductus waagenianus, Waagenoconcha montpeliernsis, Linoproductus phosphaticus*, and species of *Omphalotrochus* and *Gastrioceras*. Other forms are closely related to Pennsylvanian species, and apparently have descended from them; these are *Pustula nevadaensis, Spirifer pseudocameratus, Ambocoelia guadalupensis, Composita mira, C. persinuata*, and *Pugnoides swallovianus*. *Aulosteges hispidus* and *Avonia subhorrida* are Permian types, but so far as their structure would indicate, they might occur in any part of the Permian system. As a result of the nondescript nature of the Phosphoria fauna, there has been much controversy as to its age. It was long regarded as Pennsylvanian, but in 1920, in the "Ore Deposits of Utah," Girty classed it as Permian, because of its affinity to the lower Permian of Russia, though admitting that the evidence was inconclusive. In 1927, Girty[40] discussed the age of the Phosphoria at some length. It was pointed out that the Phosphoria fauna was very similar faunally to the lower Permian of Alaska.

[38] Girty, G. H.: **73**, pp. 611-617. Also, Meek, F. B.: **118**.
[39] Kirk, Edwin: U. S. Geol. Sur. Prof. Paper 110, p. 43, 1918.
[40] In U. S. Geol. Sur. Prof. Paper 152, pp. 79-81, 1927.

The stratigraphic evidence of the age of the Phosphoria, the fact that the formation appears to trace southward into the upper part of the Kaibab in the San Rafael Swell, is in opposition to the correlation of the Phosphoria with the lower Permian, for the Kaibab is very certainly of middle Permian age. The stratigraphic evidence is conclusively supported by the correlation of the Phosphoria fauna in the Trans-Pecos Permian section. Most of the Phosphoria species occur in the Texas fauna; they are *Orbiculoidea missouriensis, Chonetes ostiolatus, Productus multistriatus, Linoproductus waagenianus, L. phosphaticus, Avonia subhorrida, Waagenoconcha montpelierensis, Leiorhynchus weeksi, Pugnoides swallovianus, Spirifer pseudocameratus, Ambocoelia guadalupensis, Composita mira,* and *C. persinuata.* Only *Pustula nevadaensis, Productus geniculatus, Aulosteges hispidus,* and *Spiriferina pulchra* have not been found in Texas. Of the Phosphoria species occurring in the Texas section, 7 are restricted to the Word, 0 to the Leonard, 4 occur in the Leonard and Word, and 2 in the Hess, Leonard, and Word. Furthermore, *Gastrioceras simulator* of the Phosphoria is very closely similar to *G. roadense* of the Word. The evidence of numbers, therefore, favors a Word age for the Phosphoria.

It is obvious that in two faunas containing species in common with one another, some species would have migrated from the region of the first fauna into that of the second while others would have migrated from the second into the first. In this instance it seems reasonable to suppose that the species occurring in both the Leonard and Word originated in Texas and in Word time migrated northward into Idaho. *Composita mira, Spirifer pseudocameratus,* and *Ambocoelia guadalupensis* almost certainly originated in Texas, for their immediate ancestors occur in the lower part of the Texas section.

If the Phosphoria is of Word age, the question arises as to how the Phosphoria and the Word succeeded in interchanging their invertebrate species when the rocks intervening between the Phosphoria and the Word-Delaware Mountain do not contain these species. The only Phosphoria brachiopod species occurring in the Kaibab is *Waagenoconcha montpelierensis,* while the common Kaibab species are entirely lacking in the Phosphoria. In the San Rafael Swell, however, the upper or "Bellerophon" limestone of the Kaibab contains *Waagenoconcha montpelierensis* and *Pustula nevadaensis*, and does not have the Kaibab species. This fact suggests that the Phosphoria fauna was contained in an uppermost member of the Kaibab, probably above the *Bellerophon* fauna, and has now been eroded away in most places. The "Bellerophon" limestone itself was generally eroded away before the Triassic, so that it is quite possible that still higher beds, no longer preserved, were once present. The same circumstance might have occurred in southern Arizona, where even the Kaibab equivalents are seldom seen between the Naco limestone and the Mesozoic, because of the large amount of erosion following the retreat of the Permian sea from the region. It therefore seems probable that a marine connection, traces of which are lost, existed between the Phosphoria of the northwestern United States and the Word of Texas.

The reason for the lower Permian aspect of the Phosphoria fauna remains to be explained. A large proportion of the Phosphoria species have close affinity to Russo-Arctic lower Permian species, and some of the resemblances may prove to be identities. Girty has shown[41] that the Phosphoria fauna is very similar to the Alaskan "Artinsk" fauna. There can hardly be any doubt that there was direct marine connection between the Phosphoria and the Alaskan Permian seas. It seems likely, therefore, that the species of Russo-Arctic affinity migrated into the Phosphoria and thence to Texas by way of the Alaskan Permian seas. Whether the Alaskan sea derived its fauna from the northeast alone, by way of Spitzbergen, north Greenland, and Ellesmere and Heiberg Islands, or from both the northeast and the west, connecting also with the lower Permian of Ussuriland, is a matter for conjecture; at any rate, both the Permian of Ussuriland and that of Ellesmere and Heiberg Islands is undoubtedly lower Permian, of the age of the *Schwagerina* horizon and lower Artinsk. Therefore, the lower Permian faunas must have entered the Alaskan sea from the north, and remained there with little change until middle Permian time, when marine connection opened up toward the south. The marine connections with the Russian seaways having in the meantime been cut off, middle Permian forms did not gain access to Alaska, and when the sea spread southward into the Phosphoria region the accompanying fauna

[41] U. S. Geol. Sur. Prof. Paper 152, pp. 79 81, 1927.

was merely a slightly modified lower Permian fauna lacking middle Permian types.*

Permian of the Canadian Rockies.—There is little record of Permian rocks in the Canadian Cordillera, but they are known to exist in several places. In the section near Banff, Alberta, the Rocky Mountain quartzite,[42] about 600 feet thick, consists of an alternation of light grey quartzite and light grey limestone; in the upper part there is a phosphate bed associated with chert, quartzite, and shale. It contains an abundance of *Euphemus carbonarius arenarius* and *Plagioglypta canna*, besides *Orbiculoidea arenaria, Productus semireticulatus, Paraphorhynchus obscurum, Bakewellia parva, Myalina wyomingensis,* and *Deltopecten occidentalis latiformis. Plagioglypta canna* occurs also in the Phosphoria, while *Euphemus carbonarius arenarius* is stated by Shimer to be similar to *E. subpapillosus* of the Phosphoria, and the two may be identical. *Paraphorhynchus obscurum* would unhestitatingly be referred to *Leiorhynchus weeksi,* were it not for the statement by Shimer that it is radially lirate. One is tempted to think that this feature may be the result of some peculiarity of preservation. At any rate, there can be little doubt that the Rocky Mountain quartzite is a northern equivalent of the Phosphoria.

Kindle has described[43] from French Mountain in northern British Columbia an occurrence of *Lyttonia* associated with other Permian types, all imperfectly preserved. Strangely enough, this fauna has no resemblance to either the Phosphoria or the Alaskan faunas.

PERMIAN OF NORTHERN CALIFORNIA

In northern California[44] the upper Mississippian Baird shale is overlain by the McCloud grey limestone, containing *Schwagerina robusta, Fusulina gracilis, F. californica, Clisophyllum gabbi, Omphalotrochus whitneyi* (**6**, pp. 55-56), and *Hustedia compressa.* It is followed by the Nosoni sandstone and tuff, in Shasta and Plumas counties, with *Fusulina elongata.* Smith has listed *Productus* cf. *spiralis* from this horizon; it is quite possible that this is actually *P. invesi.* His *Camarophoria* cf. *purdoni* may be *C. venusta,* while *Productus* cf. *abichi* may be *Waagenoconcha montpelierensis.* The highest Paleozoic formation is the Wildwood limestone of Trinity County, with a Guadalupian fauna, including *Stacheoceras.* It is unfortunate that we know nothing further concerning this interesting section, as it might throw considerable light on the origin of some of our Permian species.

PERMIAN OF ARCTIC AMERICA

Permian of Alaska.—The Permian faunas of Alaska are little known as yet, and the best known ones are in Kuiu Island in southeastern Alaska, and on the west bank of the Yukon opposite the mouth of Nation River. The rock at the first locality is a white cherty limestone, unconformably overlain by Triassic. The fauna is, as has been stated above, similar to that of the Phosphoria, and closely related to that of the *Schwagerina* horizon and the Artinsk of the Russo-Arctic region.

Permian of the Parry Islands.—In Banks Island, Victoria Island, and Melville Island there is a considerable thickness of Lower Carboniferous non-marine plant bearing beds. This is succeeded in the northern parts of the Parry Islands by limestone containing fossils which were described by Haughton.[45] Haughton's descriptions did not, however, appear to be adequate, and later workers[46] have shown that his species have different relations from what Haughton supposed. His *Productus sulcatus* var. *borealis* has been shown to be identical with *Horridonia timanica* (Stuckenberg), one of the most common fossils in the Permian faunas of Ellesmere Island and northeast Greenland. The name *P. borealis* considerably antedates *P. timanicus,* and perhaps should be the proper name for that species. So little is known of the faunas of this region that all that may be said definitely is that there is here a connecting link between the "Artinsk" of Alaska and the Permian of Ellesmere and Heiberg Islands, which, it will

*After this manuscript was written a paper appeared in which the Phosphoria fauna is described (Branson, C. C., Paleontology and Stratigraphy of the Phosphoria Formation, Univ. Mo. Studies, Vol. V, 1930). In the light of the facts presented above, Branson's conclusion that the formation lies on the boundary between the Pennsylvanian and Permian must be considered as unlikely.

[42]Shimer, H. W.: Upper Palaeozoic Faunas of the Lake Minnewanka Section, near Banff, Alberta, Canadian Geological Sur. Bull. 42, pp. 1-85, 1926.

[43]Trans. Royal Soc. Canada, ser. 3, vol. 20, pp. 109-111, 1926.

[44]See Smith, J. P.: Geological Record of California, Jour. Geol., vol. 18, p. 217, 1910. Also Mesozoic Changes in the Faunal Geography of California, Jour. Geol., vol. 3, pp. 372-374, 1895.

[45]Reminiscences of Arctic Ice-Travel in Search of Sir John Franklin and His Companions. By Captain F. L. McClintock. With Geological Notes and Illustrations by Samuel Haughton. Jour. Royal Dublin Soc., vol. 1, pp. 183-250, 1856-1857. Not seen.

[46]See Grönwall, K.: The Marine Carboniferous of North-East Greenland and Its Brachiopod Fauna. Medd. om Gronland, vol. 43, pp. 599-604, 1917.

be shown, are connected by way of northeast Greenland to the lower Permian of Spitzbergen.

Permian of Ellesmere and Heiberg Islands.—The lower Permian fauna of Ellesmere and adjacent islands has been made known as a result of the work of Whitfield and of Tschernyschew and Stepanow.[47] It has been collected from a white cherty limestone at Store Bjornekap, southern Ellesmere Island, from a dark grey limestone at Svarte Veg, at the north end of Heiberg Island, and from limestone in northeastern Ellesmere Island at Fielden Peninsula and Cape Sheridan. Tschernyschew and Stepanow have described 61 species of fossils from the first two localities, of which 34 are of brachiopods. Practically all of these species are identical with forms in the Russian *Schwagerina* horizon and Artinsk, and most of them occur in the lower Permian of Spitzbergen. Many are close to Phosphoria and Word-Delaware Mountain species, as the following table shows:

Species in Ellesmere and Heiberg Islands

Productus arcticus (=P. inflatus T. & S.)
Avonia pseudoaculeata
Waagenoconcha irginae
Linoproductus aagardi
L. simensis
L. cancriniformis
Productus weyprechti
Horridonia timanica
Derbya grandis
Squamularia guadalupensis
Spirifer lyra
Rhynchopora nikitini
Spiriferina cristata

Related Phosphoria or Word forms

Productus arcticus
Avonia subhorrida
Waagenoconcha montpelierensis
Linoproductus waagenianus
L. nasutus
L. phosphaticus
Productus multistriatus
Horridonia texanus
Derbya nasuta
Squamularia guadalupensis
Spirifer sulcifer
Rhynchopora taylori
Spiriferina laxa

Other species have relatives only at lower horizons than the Word, as *Buxtonia porrecta (=B. peruviana)*, *Spirifer fasciger* (related to *S. costella)*, and *S. marcoui* (related to *S. marcoui infraplica)*. The *Spirifer condor* figured by Tschernyschew and Stepanow is very obviously incorrectly identified, for it has a very high cardinal area. The nature of this fauna strongly suggests that it lived in the seaway connecting the Russian Permian basin, by way of the Spitzbergen Permian sea, with the Alaskan embayment, for most of the Alaskan Permian forms as identified in a preliminary way by Girty correspond to species from Ellesmere and Heiberg Islands. Moreover, the presence of a large number of similar and some identical species in the Word indicates that those species must have migrated into the Alaskan basin and lived there until middle Permian time, when the Arctic faunas invaded Trans-Pecos Texas by way of the Phosphoria seaway. Some of the species such as *Productus arcticus* and *Horridonia texana*, occur in the Word and in the Arctic fauna but are not known in the Phosphoria. Perhaps further collecting will eventually reveal these forms in the Phosphoria.

Permian of northeast Greenland.—Grönwall has described in detail the "Upper Carboniferous" faunas of northeast Greenland and their relations.[48] In Holm's and Amdrup's Lands, between lat. 80° and 81°, there are at the base of the section 200–500 meters of sandstone and shale with Lower Carboniferous plant fossils. This formation is obviously equivalent to the other widespread Lower Carboniferous terrestrial formations of the Arctic, such as that above-mentioned which occurs in Banks Island and the southern parts of the Parry Islands, and the Culm sandstone of Spitzbergen. Overlying this unit unconformably are 200–300 meters of limestone interstratified with sandstone and shale. The fossils in this formation are quite unlike those in the overlying limestone. Most of them are not particularly diagnostic, but the presence of *Spirifer supramosquensis* indicates that the fauna is earlier than that of the *Schwagerina* horizon of Russia, and the absence of *Horridonia timanica* and *Productus arcticus (=P. inflatus* Grönwall, non McChesney), which occur in the overlying limestone, also indicates a pre-Permian age. On the other hand, the Permian species *Chonetella nasuta* is figured from this horizon, and its occurrence, in view of the other

[47] Whitfield, R. P.: **187**, pp. 51-58.

[48] Grönwall, K.: The Marine Carboniferous of North-East Greenland and Its Brachiopod Fauna. Medd. om Grønland, vol. 43, pp. 511–618, 1917.

evidence, seems to be anomolous. Yet it seems most reasonable to suppose that this unit is equivalent to the *Cyathopyllum* limestone of Spitzbergen, a conclusion which is borne out by the lithologic similarity of the two. The upper member of the Carboniferous of northeast Greenland consists of 500 to 1000 meters of fine-grained light limestones and white detrital limestone with "pebbles" of fragments of organic origin, and dolomites. Fossils are common. *Schwagerina princeps* is abundant in places. Most of the other fossils are not particularly diagnostic. *Horridonia* and *Productus arcticus* are, as in the Permian faunas farther west in the Arctic archipelago, common and characteristic.

It seems logical to conclude that the *Schwagerina* limestone of this section is equivalent to the lower Permian limestones of the Parry Islands and Ellesmere and Heiberg Islands. The *Spirifer supramosquensis* horizon, however, is probably of Upper Carboniferous age and is unrepresented farther to the west. The connection with the Carboniferous and Permian sections of Spitzbergen and Russia is even closer, as is shown by the following table, taken from Wiman (**183**, pp. 9-22):

unconformity between the *Cora* limestone and the *Spirifer* limestone (*Schwagerina* horizon) in Bear Island seems to be physical evidence for placing the *Schwagerina* horizon in the Permian.

From the facts above brought out, it may be seen that a sheet of limestone was deposited in lower Permian time in a seaway extending from the Urals by way of the Timan ranges, Novaya Zemlya, Bear Island, Spitzbergen, northeast Greenland, Ellesmere and Heiberg Islands, and the Parry Islands to Alaska. In this seaway lived a rich invertebrate fauna, with very little difference in composition from Russia to Alaska. The sea may have withdrawn from most of this Arctic region at the close of lower Permian time, but in Alaska it lingered until the middle Permian, when an Arctic invasion of western North America (the Phosphoria sea) carried the Russo-Arctic faunas as far south as Trans-Pecos Texas.

"UPPER CARBONIFEROUS" OF THE ANDES

The fauna of the "Upper Carboniferous" limestone of Bolivia and Peru was first made known by d'Orbigny in 1842,[50] but remained imperfectly known until the publications of Kozlowski[51] and Meyer (**120**, pp. 590–652) appeared in 1914. In 1914 Douglas (**34**, pp. 30–37) outlined the stratigraphy and palaeontology of the "Carboniferous" of the Lake Titicaca region, and in 1929 Steinmann (**158**, pp. 34–53) summarized our knowledge of the "Upper Carboniferous" stratigraphy and

Series	Ne. Greenland	Spitzbergen		Bear Island	Russia
Artinsk	Upper limestone	*Productus*-bearing siliceous limestone		Absent	Artinsk
Schwagerina horizon		*Spirifer* limestone		*Spirifer* limestone	*Schwagerina* horizon
	Break?	Break		Decided unconformity	Break?
Uralian	Lower limestone	*Cyathophyllum* limestone	*Fusulina* ls. Cora limestone with *Fusulina*	Cora limestone Coral sandstone Break *Fusulina* ls.	Cora horizon *Omphalotrochus* hor.
Moscovian	Absent?		Limestone with *Spirifer mosquensis* Basal conglomerate	Unfossiliferous sandstone Sandstone with *Composita ambigua*	*Mosquensis* limestone
	Break	Break?		Break	Break
Lower Carboniferous	Sandstone and shale	Culm sandstone		Absent	Lower Carboniferous

Following Beede and Kniker and Schuchert,[49] the *Schwagerina* horizon is regarded as Permian, the greatest faunal change in the Russian section taking place between the *Cora* and *Schwagerina* horizons, rather than between the *Schwagerina* horizon and the Artinsk. *Schwagerina* is regarded as an index to the lowest Permian. The notable

[49]**6**, pp. 60-71. Also **150**, pp. 806 807.

[50]Voyage dans l'Amérique méridionale.

[51]Kozlowski, Roman: Brachiopodes du Carbonifére supérieur de Bolivie. Ann. de Pal., t. 9, 1914.

faunas of Peru. The faunas of the "Carboniferous" of the Lake Titicaca region appear to come from a limited thickness of siliceous limestone, probably not representing a very great lapse of geologic time.

Kozlowski described 33 species of brachiopods from this horizon, of which 15 occur in the Pennsylvanian of North America and 21 in the Permian of Trans-Pecos Texas. Another species, *Enteletes andii*. is very close to, if not identical with the Texas species. *E. dumblei*. Of the species occurring in the Texas Permian, 9 do not occur in the Pennsylvanian, namely, *Productus inca*, *Linoproductus* cf. *cancriniformis*, *Buxtonia peruviana*, *Waagenoconcha irginae* (=*W. montpelierensis*), *Avonia boulei*, *Derbya buchi*, *Orthotichia kozlowskii* (=*O. morgani* Kozlowski non Derby), *Spirifer condor*, and *Camarophoria thevenini*. Two other species, *Marginifera capaci* and *Linoproductus villiersi*, do not certainly occur in the Pennsylvanian. Only 3 of the Bolivian species occur in the Pennsylvanian of the United States but not in the Permian of Texas; these are *Chonetes geinitzianus* (=*C. glaber* Kozlowski non Hall), *Spiriferina campestris*, and *Pugnoides utah*. None of these is particularly diagnostic of any horizon, and any might occur in the lower Permian. On the other hand, several of the forms restricted to the Permian are generally diagnostic of the Permian, such as the genus *Waagenoconcha* and *Buxtonia peruviana*. Therefore, it is very probable that the Andean "Upper Carboniferous" fauna is of Permian age. We will now consider to what part of the Permian section the Andean faunas belong. Some of the species occur in the *Uddenites* zone and the middle and upper Wolfcamp formation, and many of the same species and some others of the Andean fauna are present in the Gym formation. *Productus inca* is one of the most characteristic species of the middle and upper Gym, while other forms are equally characteristic of the Wolfcamp. The explanation of this may be that the Andean fauna is of both Wolfcamp and Gym (=Hess) age, or that it represents a relatively short time, such as that of the Wolfcamp, and that certain species, such as *Productus inca*, originated in South America and did not reach Texas until later than the remainder of the fauna, which was indigenous to Texas, or originated in neither Texas nor the Andean region.

The Amazonian Carboniferous fauna described by Derby has commonly been regarded as of the same age as the Andean fauna, and some specific identities have been pointed out. The differences are, however, far more striking than the similarities, and it is a notable fact that the Amazonian fauna contains lower Pennsylvanian species, such as *Spirifer rockymontanus*, and lacks such Permian types as *Waagenoconcha* and *Buxtonia peruviana*. For two faunas in the equatorial region of the same continent these are remarkably dissimilar. The true relations of the faunas are probably demonstrated in Trans-Pecos Texas and southeastern Arizona. Near Winkelman, Arizona, in the Galiuro Mountains, there is a fauna in the Naco limestone with very close affinity to that of Brazil (**161**, pp. 324-327). *Orthotichia morganiana* and *Derbya tapajotensis* occur there in association with such lower Pennsylvanian fossils as *Productus morrowensis* and *Spirifer rockymontanus*. The lower Pennsylvanian age of this horizon can hardly be questioned. In the Gym formation, the lower part of the Permian, overlying the beds containing this fauna, there occurs the fauna of the Andean "Upper Carboniferous." It is probable, therefore, that there are two different ages of late Paleozoic faunas in northern South America.

PALEONTOLOGY

SUMMARY OF THE PERMIAN FAUNAS

General character.—The Permian section of Trans-Pecos Texas is the most complete of that age in North America, and for a long, unbroken sequence it is perhaps not exceeded in any other Permian sequence in the world. A study of its faunas not only reveals, in a way which has not been possible before, the evolution of the Pennsylvanian faunas into the highly specialized Permian ones, but also makes possible the accurate chronological placing of many late Paleozoic faunas in other widely separated regions, the age relations of which until now have been uncertain. It is therefore one of the most important standard sections of Permian rocks in the world, and is comparable to the sections in the Salt Range of India, the island of Timor, and the Urals.

The Permian faunas of Trans-Pecos Texas are a remarkable contrast to those of the mid-continent region and of New Mexico, Arizona, and northwestern North America, which, though abundant in individuals, are poor in numbers of species. In Trans-Pecos Texas almost all the forms of invertebrate life of the time are found, a fact which indicates the presence there in Permian time of a sea in which conditions were very favorable to invertebrate life, having such free communication with the other Permian epicontinental seas that there was considerable intermigration of faunas throughout most of Permian time. An analysis of the Texas fauna shows a derivation from many different sources, so that there was a mingling of types from the Andean region, the Arctic, and the Tethyan seaways with those which seem to have been indigenous and to have descended from American Pennsylvanian species.

In the present report there are described 185 species and varieties of brachiopods in 47 genera; of these, 62 species, 12 varieties, and 4 genera are new.* Of the species and varieties described by myself or by Girty in "The Guadalupian Fauna," 22 were described originally from the Pennsylvanian, 17 by Shumard from the Guadalupe Mountains, 67 by Girty in "The Guadalupian Fauna," 3 by Girty from the Permian of New Mexico, 2 by Newberry from the Kaibab limestone, 7 by Girty from the Phosphoria, 4 by Meek from the Phosphoria, 9 by d'Orbigny and Kozlowski from the Andean "Upper Carboniferous," and the remaining 14 by various authors from scattered sources. The total of 219 species and varieties does not recognize the questionable forms noted by Girty and some of the species named by Girty which here are regarded as synonyms.

The Trans-Pecos Permian faunas differ markedly from those of the Pennsylvanian in their greater number of species and genera. In the large collections studied by Plummer and Moore from the Pennsylvanian of central Texas, for example, 95 species and varieties of brachiopods, in 31 genera, were recognized, while in the present paper 185 species and varieties in 46 genera are described from the Permian. Contrary to the general belief that Permian life was greatly restricted, this fauna compares favorably with that of other Paleozoic periods. In his "Mississippian Brachiopoda," Weller describes 308 species of Mississippian brachiopods in 63 genera.[52] Although this number considerably exceeds that of the present fauna, it should be remembered that the forms handled by Weller were collected throughout the entire northern Mississippi valley over a period of more than 40 years, while the Permian faunas now described represent the collections made in a much smaller area during a few field seasons. There can be no doubt that further collecting will bring forth a large number of new species, and probably genera, heretofore unrecognized.

The species here described are mostly very short ranged. The number restricted to the Permian is 158. Of these, 74, or 40%, are limited to one formation, 72, or 39%, to two, and 28, or 15%, to three, while only 8, or 4%, range through four formations and 3, or 1.5%, through five.[53]

Biological summary of the brachiopods.—The Atremata are, so far as known, unrepresented in this fauna. The Neotremata are not much better known, for only two genera were found, each represented by a single specimen.

Of the Orthacea only the groups typical of the late Paleozoic are present. There are 5 species of *Rhipidomella*, a larger number than has been recognized in other Permian faunas. Except for *R. hessensis*, which is closely related to the Asiatic species *R. subquadrata*, the species of this genus seem to be of American origin. The genus *Orthotichia*, derived from *Schizophoria*, is characteristic of the Pennsylvanian and lower Permian, and is present in the lower part of the Glass Mountains section. *Enteletes* is represented by 5 species. One of these, *E. dumblei*, is very close to the Andean "Upper Carboniferous" species *E. andii*, while *E. plummeri* finds its closest affinity with species of the Tethyan region. *Parenteletes* is an upper Pennsylvanian and lower Permian genus of rather wide distribution in rocks of the Mediterranean faunal facies. The orthids are much more diversified in

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*After the present manuscript had been completed and submitted for publication, and after the writer had departed for work in South America, a short paper was published by Girty, describing seven species of brachiopods from the Diablo Plateau. Professor Dunbar has made a preliminary comparison and suggested the following probable relationships:

Chonetes victorianus Girty = *Chonetes spinoliratus* King
Chonetes consanguineus Girty = *Chonetes verneuilianus* King (non-Norwood and Pratten)
Chonetes quadratus Girty = [?]*Chonetes quadratus* King
Schizophoria huecoensis G. = [?]*Orthotichia kozlowski* King
Camerophoria inaequalis G. = *Camerophoria venusta* King (in part)
C. huecoensis Girty = *C. deloi* King (in part)
Pugnoides mesacostalus Girty = *Pugnoides transversus* King

In view of the author's absence, it has seemed undesirable to alter these names in his finished manuscript.—Editor's note.

[52]Probably at least 10 additional genera would be recognized in the productids, etc., if the standard of the present report were followed.

[53]In computing these figures, the species occurring in the Gym were disregarded except where a species was restricted to it, because of the uncertainty as to its correlation. Species occurring also in the Pennsylvanian were regarded as occurring in one additional formation. If the species was recognized also by Girty, the information given by him regarding its range was incorporated with my own data.

the present fauna than in the American Pennsylvanian and Mississippian. The same genera are present in the former, but in the Permian they contain many more forms, while the Mississippian contains a good many species but only two genera.

Most of the late Paleozoic genera of the Orthothetinae are present. Six species of *Streptorhynchus* have been found by Girty and myself. *S. lamellatus* is a very peculiar species without close relation in either America or Europe. The group of *S. pelargonatus*, so common in Europe, is represented by *S. pyramidalis*. The plicated type of *Streptorhynchus*, which has been called *Kiangsiella*, has not been found in this country, though it is rather common in Asiatic Permian formations. The new genus *Orthotetella* is without known relative. *Orthothetina*, a type common in the Permian faunas of LoPing and Djulfa, is represented by a few specimens in the Wolfcamp and the Capitan, the latter reported by Girty. There are 9 species of *Meekella*, only one of which, *M. irregularis texanus*, shows foreign affinity, so that this group, like *Rhipidomella*, may be regarded as largely of American origin. This genus is unrepresented in the Salt Range faunas and is rare in all other Permian faunas but that of the Trogkofel formation and the *Schwagerina* horizon of Russia. *Geyerella*, a genus occurring also in the Trogkofel and Sosio limestones, is present in the Hess and the Capitan. Of the 5 species of *Derbya*, *D. crenulata* probably evolved from *D. crassa* of the Pennsylvanian, *D. cymbula* occurs also in the Pennsylvanian, and *D. buchi* and *D. nasuta* are very similar to some Eurasian forms. The genus *Orthothetes*, which was found by Girty to be rather common in the Capitan, was not identified from the present collection. It is rare above the Mississippian, and present in few Permian faunas. On the whole, the Orthotetinae are more varied than in the Pennsylvanian. They are like the Pennsylvanian forms but with the addition of several foreign elements such as *Geyerella* and several species of *Streptorhynchus*. There is about the same number of species as in the Mississippian, but the generic types are quite different, the genera *Schuchertella*, *Schellwienella*, and *Leptaena*, which are important in the Mississippian, being quite absent in the Permian, while *Meekella*, *Geyerella*, and *Derbya* are absent from the Mississippian.

The representation of the genus *Chonetes* is rather diversified, as in most other Permian faunas, 11 species being present. Two of these occur also in the Pennsylvanian, 5 have Eurasian affinities, and the remainder are descended from American species or are so different from other described types as to be of uncertain origin. The striate and smooth types of ornamentation are the only ones present in these species. Forms bearing large costae, which are common in some Asiatic faunas, are absent, as well as the genera *Chonetella* and *Chonetina*, which likewise occur in Asia. Several of the species of *Chonetes* in this fauna are modifications of Pennsylvanian species, but many additional types are introduced. A large number of species of *Chonetes* is present in the Mississippian, but they are mostly quite unrelated to those in the Permian faunas.

The genus *Isogramma* ranges up into the Wolfcamp formation, but is unknown elsewhere in Permian faunas except in Mongolia.

About a third of the entire fauna consists of the species formerly placed in the genus *Productus*. Ten genera in that group are here recognized. Nineteen species of *Productus* s. s. were distinguished. No other Pennsylvanian or Permian faunas have yielded as many species of this genus except the Uralian fauna described by Tschernyschew. For example, only 7 species of *Productus* s. s. are present in the Salt Range fauna. Of the species in the Texas Permian, only 2 occur in the Pennsylvanian. *Productus inca*, common in the Gym fauna, is present in the Andean "Upper Carboniferous." Four species are identical with northwestern North American and Arctic forms, while 4 have very close affinity with Eurasian species. The remaining species probably are purely American types.

The genus *Linoproductus* is represented by 6 species, 2 of which belong to the group of *L. cancrini (Cancrinella)*. *L. cora* is abundant in the lower beds of the section and a variety of it extends as high as the Leonard formation. *L. waagenianus* is the most abundant Permian species of the genus, being one of the most common fossils of the Leonard, Word, and Capitan formations. It is related on the one hand to *L. aagardi*, a common Russo-Arctic species, and on the other is apparently identical with forms from the upper Permian of the Himalayas. In the *L. cancrini* group, *L. phosphaticus* is close to if not identical with *L. cancriniformis*, while *L. villiersi* is closely related to several Upper Carboniferous and lower Permian species of the group in Eurasia and America.

The genus *Striatifera,* which is generally a less common type than *Linoproductus,* is represented by a single form. A species apparently belonging to this genus occurs also in the Gaptank formation, but the group is unrepresented elsewhere in the Pennsylvanian.

Pustula, so common in the Mississippian and Pennsylvanian, is represented solely by the Pennsylvanian species *P. semipunctata.* There are three species of *Buxtonia,* one of them a Pennsylvanian one, and another, *B. peruviana,* identical with Andean and Uralian forms. Two species of Buxtonia, *B. occidentalis* and *B. longa,* are present in the American Pennsylvanian. *Waagenoconcha,* the group of *Productus humboldti,* is represented by two species, one of Andean and Uralian affinities and the other related to a Salt Range species. It is probably almost wholly a Permian type. *Overtonia* is doubtfully identified on the basis of its resemblance to an Andean species in which the generic characters were definitely determined. It is present in the Cisco and possibly in the Mississippian.

Avonia, a genus almost absent from the American Pennsylvanian, is represented by 7 species, two of which are related to Eurasian forms and one identical with an Andean species, most of the others being of undeterminable origin. The group of *Productus horridus* and *P. timanicus, Horridonia,* though very common in the Eurasian boreal realm during Upper Carboniferous and Permian times, here contains but a single species, of which only one specimen was found.

There are 13 species of *Marginifera,* which is a very characteristic member of Permian faunas in other parts of the world. Two forms are very similar to those of the Tethyan region, another is identical with an Andean species, while two others occur in the Pennsylvanian. Several groups may be recognized in this genus. The typical group has a semireticulate ornamentation, as in *M. capaci, M. dugoutensis, M. lasellensis,* and *M. reticulata. M. cristobalensis* has a tuberculose decoration. *M. manzanica, M. whitei,* and *M. wordensis* have pustules and wrinkles in the early stages, which are replaced later by costae. *M. opimus. M. popei,* and *M. texana* are costate only, while *M. sublaevis* is nearly smooth. Independent evolution appears to have taken place during the Permian along these different lines.

On the whole, the productids of this fauna are very much like those of other Permian assemblages. The main difference is the small representation of *Horridonia,* but in this respect the Texas fauna resembles those of the Tethyan region, where *Horridonia* is seldom present. A definite Permian aspect is given by the presence of *Waagenoconcha, Linoproductus waagenianus, Avonia signata,* and the abundance of *Marginifera.* There are striking differences from the Pennsylvania faunas. The species of *Productus* s. s. which do not have a wrinkled surface over the visceral area (as *P. guadalupensis)* are foreign to the Pennsylvanian, as well as *Striatifera, Waagenoconcha, Avonia, Horridonia,* and the tuberculose, costate, wrinkled, and smooth types of *Marginifera.* On the other hand, the genera *Pustula* (group of *P. semipunctata)* and *Juresania* (group of *P. nebraskensis)* are practically unrepresented in the Permian, but are very abundant in the Pennsylvanian. The productids of the American Mississippian are somewhat less diversified generically than those of the Permian, only *Productus, Linoproductus, Striatifera* (in the Cordilleran region), *Avonia, Pustula,* and possibly *Overtonia* being present, of the genera occurring in the Permian. The Mississippian genera *Productella, Diaphragmus,* and *Kensuella* (group of *P. giganteus,* present in the Cordilleran region) do not occur in the Pennsylvanian or Permian.

The genus *Scacchinella* is a characteristically Permian form occurring also in the Trogkofel and Sosio limestones, the Permian of Ferghana, and the Akasaka limestone of Japan. The related genus *Tschernyschewia* has not been found in the Permian of North America.

There is an exceptional representation of *Aulosteges,* 8 species having been recognized. *Aulosteges guadalupensis* and *A. medlicottianus* are related to or identical with Salt Range species. The genus does not occur in the Pennsylvanian, and may be regarded as characteristic of the Permian.

Strophalosia is rare, in contrast to its abundance in the Permian of Eurasia. It is likewise uncommon in the Pennsylvanian, but perhaps more abundant in the Mississippian.

The Richthofenidae are abundant in the Permian of west Texas, but present a peculiarly American aspect, to some extent unlike that seen in Europe and Asia. Primitive species of the genus *Teguliferina* occur in the Pennsylvanian in North America, but apparently not in Eurasia. It appears from this fact that the family is of American origin. The Wolfcamp species *T. bösei* is very similar to the genotype *T. deformis*, of the Trogkofel limestone. This species gave rise to *Prorichthofenia teguliferoides* of the Hess formation, and that in turn to the three more advanced species of *Prorichthofenia*. It is very likely that the Eurasian genus *Richthofenia*, which has not been found in America, arose from the American genus *Prorichthofenia* by specialization of the muscle-bearing organs. The genera *Gemmellaroia* and *Tectarea* are further Eurasian specializations of this group and have not been found in America. Probably the early part of the evolution of this family took place in America, only occasional migrants being present in Eurasian faunas until early middle Permian time, when the American genus *Prorichthofenia* sent its modified descendant *Richthofenia* into the Tethyan region, the later modification and specialization of the family taking place there. The presence of *Prorichthofenia* in the Permian is a striking difference from the Pennsylvanian, while neither *Prorichthofenia* nor *Teguliferina* occurs in the Mississippian.

Unlike the Richthofenidae, the Lyttoniidae appear to have been of Eurasian origin, for the complete chain of evolution of that family can be reconstructed from Eurasian faunas, but only disconnected links are present in America. The most primitive genus of this family, *Keyserlingina*, occurs in the *Schwagerina* stage of the Uralian, but is not present in America. Somewhat lower stratigraphically is the occurrence in the Cisco of *Poikilosakis*, but as that genus is more specialized than *Keyserlingina* it is very probable that the latter actually made its first appearance at a lower horizon. In Russia, *Poikilosakos* occurs above the first appearance of *Keyserlingina*. *Parakeyserlingina*, probably the direct descendant of *Keyserlingina*, occurs in the lower Permian of Asia and in the Wolfcamp formation. *Lyttonia*, derived from *Parakeyserlingina*, is of worldwide distribution in middle and upper Permian faunas between lat. 40° north and 10° south. It is abundant in the Hess, Leonard, Word, and Capitan formations. The genus *Oldhamina*, which is common in the upper Permian of India and China, has not been found in America. The presence of the group of lytoniids is a very striking contrast to the faunas of the Mississippian and Pennsylvanian.

The Rhynchonellidae are more diversified than those of the Pennsylvanian, but contain practically the same genera. The genus *Leiorhynchus*, which is represented also in the lower and middle Pennsylvanian by *L. rockymontanus*, has two Permian species, one of which occurs in the Phosphoria, and the other is related to the Phosphoria species. *Leiorhynchus* cannot be definitely identified from Eurasian Permian faunas. *Pugnoides* contains 7 species, most of them very close to the Pennsylvanian *P. osagensis*. *Pugnoides* is almost wholly an American type, being very rare in most of the Upper Carboniferous and Permian faunas of Eurasia. There are two species of *Rhynchopora*, which is a very characteristic genus of the European Permian. *R. illinoisensis*, which occurs rarely in the Wolfcamp formation, is present, perhaps somewhat modified, in the Upper Carboniferous and Permian faunas in North America, the Andean region, and Europe. *R. taylori*, the Word species, is probably more closely related to *R. illinoisensis* than to the European Permian forms; it probably is an Arctic modification of the *R. illinoisensis-R. nikitini* type, which entered Texas by way of the Phosphoria seaway. There is but one abundant species of *Camerophoria*, *C. venusta*, which is very close to the common Eurasian species, *C. purdoni*. *C. thevenini* is present in the "Upper Carboniferous" of Bolivia, while *C. deloi* is a form occurring in the Gym facies of southern Arizona. The new genus *Uncinuloides* is probably an American representative of a widespread Eurasian group which has been called *Uncinulus*. It is one of the most characteristic forms of the Permian of the Tethyan geosyncline. One genus which is common in Eurasian Permian faunas, *Terebratuloida*, has not been found in America. Thus it may be said that the rhynchonellids are, on the whole, very similar to those of the Permian faunas of Eurasia, but differ in the presence of *Leiorhynchus*, the abundance of *Pugnoides*, and the absence of *Terebratuloidea*. In the Pennsylvanian, *Camarophoria* and *Uncinuloides* are not present, and the group of rhynchonellids is much less diversified than in the Permian. The Mississippian, on the other hand, is remarkable for the abundance and variety of its rhynchonellids. While the Permian contains the genus *Uncinuloides*, that does not occur in the Mississippian, the latter deposits contain a large number of genera, most of them represented by many species, which do not occur in either the Pennsylvanian or Permian.

There are 10 species of *Spirifer*, of which 8 show the typical late Paleozoic expression, *Neospirifer*, having fasciculate costae. *Spirifer condor* occurs in the Andean "Upper Carboniferous" and in the Uralian, and *S. marcoui infraplica* is very close to the common Eurasian species *S. marcoui*. *S. costella* is the American variant of the Eurasian species *S. fasciger*. The most abundant *Spirifer* is *S. pseudocameratus*, which clearly descended from *S. triplicatus*, the common Pennsylvanian species. *S. mexicanus*, which is apparently the most common form of the Capitan, is closest to *S. oldhamianus* of the Salt Range faunas. An important member of the fauna is *S. sulcifer* Shumard, which is abundant in the middle and upper Word. It is extremely close to *S. rajah*, a very common species in the upper Permian of Asia, and to *S. lyra*, a Russo-Arctic species. The genus *Spiriferella* common in the Russo-Arctic realm of late Paleozoic faunas, is completely lacking in the Texas Permian.

The Pennsylvanian species *Squamularia perplexa* occurs in the basal Permian; it is succeeded in higher beds by *S. guadalupensis*, the longest ranged species of the Glass Mountains section, which is close to the Indian species *S. indica*. The Pennsylvanian *Ambocoelia planoconvexa* also occurs in the basal Permian; in the upper part of the Glass Mountains section there is another species of the genus, which occurs also in the Phosphoria. *Ambocoelia* is all but absent from Eurasian Permian faunas. It occurs only in the Zechstein fauna. *Martinia*, a genus not present in the American Pennsylvanian, is abundant in the basal Permian of the Glass Mountains. The nearest relative of the Wolfcamp species is *M. triqueta* of the *Schwagerina* horizon of the Uralian. *M. rhomboidalis* of the higher Permian is likewise of Eurasian affinity. The genus *Martiniopsis*, which is very common in Eurasian Permian faunas, does not occur in Texas.

As a whole, the Spiriferidae are similar to those of the Pennsylvanian, but with some different elements. As in the Pennsylvanian, the neospiriferoid type predominates in the genus *Spirifer*. The Permian fauna is, however, very strikingly different from that of the Mississippian. In that system, the genus *Spirifer* is represented by quite different specific groups. *Syringothyris*, *Pseudosyrinx*, *Spiriferella*, *Brachythyris*, *Delthyris*, and *Cyrtia*, which are rather common in the Mississippian, do not occur in the Permian. The representation of species, as well as of genera, is much greater in the Mississippian than in the Pennsylvanian or Permian.

As in the Mississippian and Pennsylvanian, the *Spiriferina* group comprises *Spiriferina* s. s. and *Punctospirifer*. The species of these genera in the American Permian are very similar to those in the Tethyan region. The genus *Cyrtina*, which occurs in the Mississippian and in the Permian Sosio limestone, is unrepresented in the American Permian.

The Rhynchospirinidae are represented solely by *Hustedia*, which contains 6 species, one of which, *H. meekana*, is close to or identical with the common Salt Range species, *H. indica*. The genus *Uncinella*, which occurs in the Permian of India, is not found in Texas. In the Pennsylvanian the only genus belonging to this family is *Hustedia*, but in the Mississippian *Hustedia* is uncommon, while *Eumetria*, *Ptychospira*, and *Acambona* are well represented.

The Meristellidae and Atrypidae have each one genus in the Mississippian, but none in either the Pennsylvanian or Permian.

Among the Athyridae, only *Composita* is present, but this genus shows considerable diversity. Most of the species are related to the Pennsylvanian *C. subtilita*, but *C. emarginata affinis* is very close to *C. xetra* of the Himalayan Upper Permian. The genera *Spirigerella* and *Cliothyridina*, which are conspicuous elements of Eurasian Permian faunas, are quite absent from the Texas Permian. This is the only family in which a common Pennsylvanian genus is unrepresented, for *Cliothyridina*, an abundant fossil in places in the lower and middle Pennsylvanian, does not occur higher in this country. The Athyridae of the Mississippian resemble those of the Permian in having *Composita*, but contain also the genera *Camarophorella*, *Rowleyella*, *Athyris*, and *Cliothyridina*.

The terebratulids are rare in the present collection, and are represented by few species and genera, and two genera (*Notothyris* and *Heterelasma*) described by Girty were not recognized. As in other late Paleozoic faunas, *Dielasma* is the most important terebratulid genus. One species of it is very close to several forms of the Salt Range Permian, while *D. bovidens* occurs in the lower part of the Texas Permian section. There are one or two species of *Dielasmina*. *Notothyris* and *Heterelasma* have been identified by Girty from the Capitan; the former is rather doubtful. The genus *Hemiptychina*, which is rather common in the Permian of Eurasia, is entirely absent from the present collection. The Permian of West Texas resembles the Pennsylvanian in the rarity of the terebratulids, and contrasts strikingly with the Mississippian, where there are 6 genera, of which only *Dielasma* occurs in the Permain.

In summary it may be said that the Permian faunas resemble in a general way those of the Pennsylvanian, but contain practically all the Pennsylvanian genera with the addition of a good many that are either restricted to the Permian, or occur in pre-Pennsylvanian faunas but not in the American Pennsylvanian. The presence of the Richthofenidae and Lyttoniidae and the large number of Productidae are among the most striking features of the Permian faunas. In contrast to the Mississippian, the Permian probably will prove to be as rich when fully collected, but has some notable differences. The Orthacea and Orthotetinae are more diverse in the Permian, and are represented by almost entirely different genera. There is a much larger number of productids, including several different genera. *Scacchinella, Aulosteges,* the Richthofenidae, and the Lyttoniidae, though common in the Permian, are quite unlike anything in the Mississippian. On the other hand, the Permian contains but few rhynchonellids and spiriferids, in contrast to the large number of these stocks in the Mississippian. The Rhynchospirinidae and Athyridae are much less varied than they are in the Mississippian, and the Terebratulidae are rare and of different types than those of this period.

DESCRIPTIONS OF BRACHIOPOD GENERA AND SPECIES

Order NEOTREMATA

Family DISCINIDAE

Genus ORBICULOIDEA d'Orbigny

Diagnosis (after Weller): Shell subcircular or subelliptical in outline, inequivalved. Pedicle valve nearly flat or depressed-convex, with apex excentric and inclined slightly toward the posterior margin; a pedicle groove originates at the apex of the valve, passes backward for a short distance, beyond which point it is continued as a pedicle tube which pierces the substance of the valve very obliquely, opening to the interior near the posterior margin. Brachial valve depressed conical, with the apex excentric and inclined backward. Surface of the valves smooth, or more commonly marked by concentric lines, and more rarely by fine radiating costae.

Genotype: *Orbicula morrisi* Davidson.

Geologic range: Ordovician to Cretaceous.

ORBICULOIDEA MISSOURIENSIS (Shumard)?

Pl. I, Fig. 1

1858 *Discina Missouriensis.* Shumard, St. Louis Acad. Sci., Trans., vol. 1, p. 221.

1910 *Lingulidiscina missouriensis.* Girty, Fauna of the Phosphate Beds of the Park City Formation, U. S. Geol. Surv. Bull. 436, pp. 22–24, pl. 1, figs. 6–10. (See for synonymy.)

Phosphate beds of the Park City formation: Woodruff Creek, Utah; Sublette Range, Wyoming; Thomas Fork, Wyoming; Montpelier, Idaho.

Description: Shell phosphatic, subcircular in outline. The apex of the brachial valve lies at about a fifth the diameter from the posterior margin, and is distinctly curved downward, so that the highest point is a little anterior to the apex. There are numerous fine concentric growth lirae. Width, 8 mm.

Observations: This identification is made on the authority of Girty's discussion in the "Fauna of the Phosphate Beds," and is not based on study of typical representatives of the species from the Pennsylvanian. There is but a single specimen, which is, however, well preserved, as it came from a limestone concretion.

Distribution: Waagenoceras horizon (Las Delicias) at section 2, bed 4.

Family CRANIIDAE

Genus CRANIA Retzius

Diagnosis (after Weller): Shells subcircular in outline, generally more or less unsymmetrical in growth, inequivalved. Pedicle valve without perforation for the passage of a fleshy pedicle, attached by its apex or by its entire external surface to some external object. Brachial valve depressed-subconical, with a subcentral, erect, or backward directed apex. The interior of each valve is marked by two pairs of large adductor muscle scars, the posterior pair being close to the margin and widely separated, the anterior pair being much closer together and subcentrally located. The external surface of the brachial valve marked by more or less irregular concentric lines of growth, by regular radiating costae, or by fine setae or pustules.

Genotype: *Anomia craniolaris* Linne.

Geologic range: Ordovician to Recent.

CRANIA? sp.

1908 *Crania* sp. Girty, The Guadalupian Fauna, U. S. Geol. Surv. Prof. Paper 58, p. 156.

Middle Capitan, Capitan Peak (sta. 2926); dark limestone, Pine Spring (sta. 2930).

Observations: Under this heading is placed a single brachial valve, 7 mm. in diameter, depressed conical, with a somewhat excentric apex. The surface is marked by concentric lirae. It agrees well with the description by Girty of two specimens of Crania from the Guadalupe Mountains.

Distribution: Middle Word formation (Glass Mountains) at 239.

Superfamily ORTHACEA

Genus RHIPIDOMELLA Oehlert

Diagnosis: Shells subcircular, biconvex, brachial valve somewhat deeper than the other. Hinge-line short. Surface covered by fine, rounded subequal lirae* which are hollow and open out to the surface. Pedicle valve bearing two strong diverging teeth; from the base of each there extends forward a more or less strongly defined curving ridge, bordering the muscular area, which is large, deeply impressed, and flabelliform. Adductor scars small and completely enveloped by the diductors. Cardinal process erect, strongly arched on its posterior face, posterior surface trilobate. Dorsal muscular area small, quadruplicate, divided longitudinally by a broad, low median ridge extending forward from the base of the cardinal process.

Genotype: *Terebratula michelini* L'Eveille.

Geologic range: Silurian to Permian.

RHIPIDOMELLA CARBONARIA (Swallow)

1858 *Orthis carbonaria.* Swallow, Trans. Acad. Sci. St. Louis, vol. 1, p. 218.

1877 *Orthis pecosii.* White, U. S. Geol. Expl. w. 100 Mer., vol. 4, p. 125, pl. 9, figs. 5a-e.

Observations: Except for two specimens that are exceptionally large and one from loc. 90 having rather coarse lirae, these specimens are quite like the average form of the Pennsylvanian species in so far as their characters may be seen in their fragmentary condition. The specimens identified by Waagen, Schellwien, and Tschernyschew as *R. pecosi* are almost certainly not this species. Fliegel* was evidently wrong, however, in believing the Salt Range and Alpine forms to be identical with the Chinese *R. subquadrata*, a species which is much more closely related to *R. hessensis.*

Distribution: Gaptank formation at 75 and 273. Wolfcamp formation (Glass Mountains) at 86, 87 low?, 88, 90, 93, 189x, 196?, and 198. Not common.

RHIPIDOMELLA HESSENSIS King. n. sp.

Pl. I, Figs. 2-4

Description: Shell medium-sized, strongly biconvex, brachial valve very convex, pedicle valve smaller and less convex, or even flattened anteriorly. Greatest width at about a third of the length behind the anterior margin, which is straight or very slightly convex, and not at all emarginate. Cardinal area of the pedicle valve triangular, well-defined, rising at about 50° from the dorsal area, then incurving so as to lie parallel to it; delthyrium an equilateral triangle, nearly filled by the projecting cardinal process. Cardinal area of the brachial valve lower than the other, slightly incurved ventrally. Cardinal process large, projecting ventrally through the delthyrium and divided posteriorly into three diverging lobes, of which the median one is much the largest and most elevated. Muscle scars deeply impressed.

Surface marked by fine, rounded lirae, separated by narrower striae. On the anterior lateral parts of the pedicle valve and on most of the surface of the brachial valve there are large, equal-sized, forward-projecting tubules arising from the lirae; they are closely spaced near the anterior margin on large shells, but are widely scattered over the posterior halves of the valves. Growth lamellae present anteriorly on mature shells. The shell is very thick.

Dimensions in mm. of three specimens from locality 107:

	1	2	3
Length	16	17	20
Width	17	17	21
Thickness	8	9	11
Height of ventral area	1.5		2

Comparisons: This species differs from most other species of *Rhipidomella* having similar configuration and size (such as *R. penniana, R. nevadaensis, R. oweni,* and *R. michelini)* in the large size and the abundance of tubules. It is closest to *R. subquadrata* (Fliegel) as figured by Frech; both species have abundant and large tubules and have similar convexity, but the Chinese species differs in having a broader posterior part and a slight sinuosity of the front margin.

Distribution: Upper Hess formation (Glass Mountains) at 1, 3, 8, 15, 98, 105, 106, 107 (abundant, types), T107, T108, and 222. Upper Hess formation (Sierra Diablo) at 478 and 479.

RHIPIDOMELLA LEONARDENSIS King n. sp.

Pl. I, Figs. 5-7

Description: Shell small, pentagonal in outline, with the greatest width at mid-length, hinge-line a little more than half the greatest width of the shell, anterior and lateral margins nearly straight but curving evenly into each other.

Pedicle valve deepest at about a third the length from the beak; median part of the shell flattened or slightly depressed; beak not incurved. Cardinal area a third as high as wide, lying at about 75° to the plane of the valve margin, flattened but curving toward the beak; delthyrium a fourth to a fifth as wide as the hinge, higher than wide. Dental lamellae strong and somewhat diverging; a strong but low median septum arises close under the beak and extends about half the length of the shell; muscle scars very elongate, with nearly parallel borders.

Brachial valve equally convex with the other, with the greatest convexity at about the middle, beak short and extended, with the cardinal area nearly in the plane of the valves.

Surface marked by lirae of very irregular size, each strong one being generally separated from the next of the same size by from one to three finer ones which do not reach back to the beak, but are intercalated between the coarse lirae; lirae 3 to 4 in the space of one mm. at the anterior margin. Striae punctate, so that the lirae have a crenulated appearance. The lirae open out into tubules fairly closely spaced in the posterior part of the shell but

*In this and the following descriptions, the word "lirae" will be used for the radial ridges on a brachiopod shell and "striae" for the grooves.

*Palaeontographica, Bd. 48, p. 126.

sparse in the anterior part. Strong concentric widely-separated growth lines are present.

Dimensions in mm. of two specimens:

	1 (loc.123)	2 (loc.240)
Length	8	11
Width	8	12
Height of ventral area	1.5	2.5

Observations: This species differs from *R. carbonaria* by its flattened median part of the pedicle valve, higher cardinal area, narrow delthyrium, strong dental lamellae, and different type of liration. The last character is not easily seen in badly silicified specimens.

Distribution: Leonard formation (Glass Mountains) at 12, 26S, ?82, 120, 123 (types), 232?, T240, and 484? This species is not abundant at any of the localities named, but is fairly common at 26S and 123. Word formation? (Glass Mountains) at 44–45?

RHIPIDOMELLA MESOPLATYS KING, n. sp.

Pl. I, Figs. 10–11

Description: Shell small, subovate, with the greatest width at mid-length, hinge-line equaling a third the greatest width of the shell, anterior margin rounded.

Pedicle valve depressed at about a third of the length from the beak; beak slightly incurved. Cardinal area a fourth as high as wide, lying at about 80° to the plane of the valve margin, strongly incurved near its end. Delthyrium higher than wide.

Brachial valve equally convex with the other, the greatest convexity being near the center. Beak as high as that of the pedicle valve, incurved at the end. A broad, low median depression or flattening originates about 4 mm. in front of the beak and expands gradually toward the anterior margin.

Surface marked by even lirae, 2 or 3 in the space of 1 mm. at about mid-length, opening out on the anterior part of the shell into unevenly distributed tubules.

Dimensions in mm. of two specimens:

	1 (loc. 123)	2 (loc. 256)
Width	14	13
Length	14	13
Thickness	9	8
Height of ventral area	1.75	—

Observations: This species differs from *R. leonardensis* in the different character of its liration, its shorter hinge, the generally more rounded outline, and probably also by a lower convexity. It differs from *R. hessensis* in its constantly smaller size, higher cardinal area and much coarser liration. The two species are, however, very closely related, and it is likely that *R. mesoplatys* descended from *R. hessensis*.

Distribution: Leonard formation (Glass Mountains) at 20, 26s?, 123 (types), T233?, D3, D5, D8, D12, and D22. Word formation (Glass Mountains) at T41, 54, T144a, 241, and 256.

RHIPIDOMELLA MESOPLATYS BAYLORENSIS King, n. var.

Pl. I, Figs. 8–9

Description: This variety differs from typical *R. mesoplatys* in having a slightly lower ventral area, which diverges at about 56° from the plane of the shell margin, then curves up against the dorsal area, which is inclined ventrally at an angle of about 30°. The ventral beak is higher than the other. Apparently more tubules arise from the lirae than in the typical form of the species.

Distribution: Leonard formation (Baylor Mountains) at 502 and 503 (type). Bone Canyon member (Sierra Diablo) at 485.

RHIPIDOMELLA TRANSVERSA King, n. sp.

Pl. I, Figs. 12–13

Description: Shell small, transversely subovate, rather strongly biconvex. Ventral cardinal area narrow and high, its width being approximately equal to about two-fifths that of the shell, and its height about half as great as its width. Delthyrium narrow. The ventral area lies at an angle of about 60° to the shell margin, and is evenly curved upward toward its tip. The dorsal cardinal area is less than half as high as the other. Surface marked by narrow radial lirae separated by broad striae, and on one shell, bearing concentric growth undulations. One specimen has a shallow, narrow dorsal sinus. Shell finely punctate.

Dimensions in mm. of two specimens:

	1 (loc. 123)	2 (loc. T15a)
Length	10	9
Width	12	11
Height of ventral area	2	—

Observations: This species is distinguished by its greater width than length, its high, narrow ventral cardinal area, and its narrow lirae with broad striae.

Distribution: Hess formation (Glass Mountains) at 4 and 17a. Leonard formation (Glass Mountains) at T15a, 123 (type), and D5.

Genus ORTHOTICHIA Hall and Clarke

Diagnosis: Externally like *Schizophoria*. Ventral muscular area not impressed in the shell, divided longitudinally by a thin, elevated median septum and bordered laterally by prominent dental lamellae, which lie at a low angle to the septum; at the anterior end of the muscular area the dental lamellae are united to the septum by a thickened margin. Dorsal interior similar to that of *Schizophoria*.

Genotype: *Orthis? morganiana* Derby.

Range: Pennsylvanian and Permian.

Observations: This genus is generally regarded as representing an intermediate stage between *Schizophoria* and *Enteletes*. Schellwien[1] has argued that it is not a natural group, but is composed both of species intermediate between *"Orthis"* and *Enteletes* and of species of *Enteletes* which have arisen from an evolution of plicated to unplicated forms, supposedly in the early Permian. However, most Permian species of *Enteletes* are even more strongly plicated than the Pennsylvanian ones, and those Permian species which have faint plications do not approach the *Schizophoria*-like external form of a true *Orthotichia*. Even more significant is the fact that the arrangement of muscular areas in the pedicle valve of *Enteletes*

[1] Die Fauna der Trogkofelschichten, pp. 3 5.

(but not *Paraenteletes*) is quite unlike that in *Orthotichia* and *Schizophoria* in the former the internal plates lie parallel, while in the latter they diverge at a greater or less angle. It would be surprising if, in losing its plications, a regressive *Enteletes* would also assume primitive internal characters. *Enteletes derbyi demissa* Schellwien appears clearly not to be a variety of *Orthis derbyi* Waagen, for the dental lamellae are nearly parallel to the median septum in Schellwien's figure,[2] while in Waagen's figure[3] the typical internal characters of *Orthotichia* are shown. Girty* has discussed Schellwien's opinions regarding *Orthotichia*, but he fails to emphasize the importance of internal characters in permitting easy distinction between smooth-shelled orthids transitional between *Schizophoria* and *Enteletes*, and those arising from the loss of plications in *Enteletes*.

ORTHOTICHIA KOZLOWSKII King, n. sp.*

Pl. I, Figs. 14–15

1914 *Orthotichia Morgani*. Kozlowski (non Derby). Brachiopodes du Carb. Super. de Bolivie, Ann. de Pal., t. 9, p. 62, pl. 3, figs. 11–12.

Description: Shell medium-sized, wider than long; brachial valve much deeper and more inflated than the other. Pedicle valve sinuate.

Pedicle valve longitudinally of flattened curvature, and transversely of low convexity. Hinge-line equal to half the width of the shell; cardinal area high, lying at about 70° to the plane of the shell margin, slightly concave. Beak pointed, slightly incurved. Median sinus originating about 10 mm. in front of the beak, extending forward and slightly indenting the margin. Lateral parts smooth. In the interior the median septum and dental lamellae extend more than half the distance to the anterior margin; the dental lamellae are connected at the front to the median septum by transverse plates.

Brachial valve much more strongly convex in the posterior than in the anterior part. Beak strongly incurved over the cardinal area. A very low and broad median fold appears to be present corresponding to the sinus of the other valve. The crural plates diverge from the median septum at an angle of 40°.

Surface marked by fine subequal lirae. Certain ones are slightly stronger than others, and give rise to tubules.

Dimensions in mm. of two specimens:

	1 (loc. 92– type)	2 (loc. 456)
Length of brachial valve	22	15
Length of pedicle valve	20	14
Width	24	19
Thickness	19	—
Height of ventral area	3.5	—

Observations: This species differs from *O. morgani* (Derby) in being much smaller and less strongly sinuate, and from *O. schucherti* Girty, from the Hermosa of Colorado, in being much more strongly convex and having a larger cardinal area. *O. kozlowskii* was identified from Bolivia by Kozlowski as *O. morgani*, but seems clearly to be conspecific with the lower Permian form of Texas. *O. derbyi* (Waagen) is very similar to *O. kozlowskii*, but has a nearly erect beak, while the beak of the Texas form is strongly incurved. The sinus is on the brachial valve in *O. indica* (Waagen), and *O. marmorea* (Waagen) differs by having no sinus at all.

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at T88 and 175. Wolfcamp formation (Glass Mountains) at 90, 92 (type), and 196–197. Upper Wolfcamp formation (Sierra Diablo) at 456. Gym formation (Hueco Mountains) at 395? Leonard formation (Glass Mountains) at D1 and D16.

Genus ENTELETES Fischer von Waldheim

Diagnosis: Shells biconvex, the brachial valve being the deeper. Hinge-line short. Anterior part of the shell more or less plicated. If, as is generally the case, the median plication is a fold or sinus, the fold is in the brachial valve and the sinus in the pedicle valve. Ventral interior bearing two strong elongated teeth on both sides of the delthyrium, supported by strong dental lamellae, which extend forward, first approaching each other, then lying parallel and close together. Median septum lying between the dental lamellae, highest near its anterior end, where it rises to a sharp crest. Crura sickle-shaped, directed laterally; crural plates strong, diverging at a high angle antero-laterally. Cardinal process a short narrow ridge.

Genotype: *Enteletes choristites* Fischer de Waldheim.

Range: Pennsylvania and Permian.

ENTELETES DUMBLEI Girty

Pl. II, Figs. 4–8

1908 *Enteletes dumblei*. Girty, The Guadalupian Fauna, U. S. G. S. Prof. Paper 58, p. 295, pl. 26, figs. 4-4b. Hueco formation, Diablo Mountains (sta. 3764).

1908 *Enteletes angulatus*. Girty, The Guadalupian Fauna, U. S. G. S. Prof. Paper 58, pp. 295–296, pl. 26, figs. 3-3a.
Hueco formation, Diablo Mountains (sta. 3761).

Description: Shell large, wider than long, the brachial valve very convex, the pedicle valve a little less so, with the greatest convexities at about mid-length.

Cardinal area of the pedicle valve well-defined, about half as long as the greatest width of the shell and about one-fourth as high as long, its basal part flat and lying at approximately right angles to the plane of the shell margin, with its apical part curving sharply over it under the beak. Ventral beak incurved over the delthyrium, which occupies nearly a third of the area. Sinus originating about 10 mm. in front of the beak, fully twice as large as the lateral sulci; lateral plications coarse, subrounded to angular, numbering 4 on each side of a shell 3.5 mm. wide. The three septa on the inside of the valve are straight and slightly diverging. They extend half the length of the shell. The median septum rises to its highest point about two-thirds the distance from the beak to its anterior end; this point is sharply angular, the top of the septum curving from it to each end.

Brachial valve rather evenly convex, bearing a subrounded median fold and 3 or 4 plications on each lateral

[2]Ibid., p. 1, fig. 7.

[3]Waagen: Pal. Indica, ser. 13, vol. 1, pl. 56, fig. 2.

*U. S. Geol. Sur. Prof. Paper 58, pp. 291 293.

*This may be the species described by Girty as *Schizophoria huecoensis*, Jour. Wash. Acad. Sci.

slope; the median fold has a similar form to but fully twice the size of the adjacent plications. Entire surface covered with fine lirae, which are narrower than the striae.

Dimensions in mm. of typical specimens:

	Girty's type	1 (loc. 222)	2 (loc. 264)	3 (loc. 240)	4 (loc. 479)
Length	22	30	22	29	17
Width	26	33	29	29	22
Thickness	26	25	—	—	—
Height vent. area	4.5	3.5	—	—	4.5

Observations: The only distinguishing characters given by Girty between *E. dumblei* and *E. angulatus* are the high arching of the ventral valve and the angularity of the plications of the latter, characters which are somewhat variable in this species. The fact that the types of both species were from the same lot (sta. 3764) strengthens the conclusion that *E. angulatus* is a synonym. Even if *E. angulatus* Girty were not a synonym, Girty's name cannot be used, as it is preoccupied by the name *Rhynchonella angulata* Geinitz (probably synonymous with *E. hemiplicatus).*

E. dumblei differs from *E. hemiplicatus* in being much larger, in its stronger plication, and in its higher cardinal area. According to Girty, the two are distinguished also by a different type of liration, *E. dumblei* having supposedly narrower lirae and broader striae, but this character appears to vary on different parts of a single specimen. Girty believed *E. dumblei* to be close to *E. elegans* Gemmellaro, but that form has much smaller plications than *E. dumblei* has at the same distance from the beak. However, the Texas species is very close to *E. waageni* Gemmellaro, but does not attain nearly as large a size. *E. dumblei* can hardly be distinguished from the specimen of *E. andii* d'Orbigny figured by Kozlowski,[1] the greater depth of the median sinus of the Bolivian shell being the only distinctive feature noticeable. The Bolivian species has been figured also by Douglas,[2] who comments on the close similarity to species from the Hueco formation *(=E. dumblei).* To judge from his figures, they are indeed very similar.

Distribution: Wolfcamp formation (Glass Mountains) at 93? Hess formation (Glass Mountains) at 35, 107 (common), 108 (abundant), T108, 164, 191, and 222 (abundant). Probable Hess formation (Glass Mountains) at T9, T15a, and Tba. Hess formation (Sierra Diablo) at 465, 476, 478, and 479. Bone Canyon member (Sierra Diablo at 484 and 485. Gym formation (Diablo Plateau) at 435? and 443?. Gym formation (Hueco Mountains) at B392 and 389. Word formation (Glass Mountains) at 137, 141, 154, T239, 241, T249, T264, Tx148, and Tx. Leonard? formation (near Shafter) at 515, Tj, and Tq.

Enteletes dumblei is apparently nearly confined to the Hess and Word formations and their equivalents. Its absence from the typical Leonard would seem to be good evidence for the supposition that the Hess and the Word specimens are actually different species. Since, however, no distinguishing characters were discerned, it is not possible to separate them.

[1] Ann. de Pal., 1914, pl. 3, figs. 10a-c.

[2] Quart. Jour. Geol. Soc., vol. 70, pp. 35-36, pl. 8, figs. 2a-2c.

ENTELETES LEONARDENSIS King, n. sp.

Pl. III, Figs. 10–12

Description: Shell medium-sized, with a highly inflated brachial valve and a pedicle valve of low convexity, the mid-part of the valve being nearly flat. In an old shell the pedicle valve is only half as long, measured along the curvature, as the brachial, but in most specimens the disparity is less. In all, however, there is a greater difference than in other species of *Enteletes* in this fauna. The anterior margin is so flattened by the strong curvature of the brachial valve that the valves meet at a very obtuse angle. Ventral cardinal area high and not much incurved at its end. The median fold and sinus originate about 10 mm. anterior to the beaks, and are not much larger than the lateral plications and sulci. The plications are low and rounded, and number three to four on each side of the fold and sinus.

Dimensions in mm. of several specimens:

	1 (loc.128)	2 (loc.37)	3 (loc.288)
Length of pedicle valve	19	19	20
Length of brachial valve	23	24	21
Width	24	23	24
Thickness	22	22	19
Height of ventral area	4	—	4

Observations: E. leonardensis is closely related to *E. wordensis*, having, like it, relatively small fold and sinus and a similar number of lateral plications. The low convexity of the pedicle valve and the large, strongly convex brachial valve, however, distinguish it from that and other species of *Enteletes.* It differs from *E. dumblei* in its smaller size, lesser width in proportion to length, greater difference between the size of the two valves, and narrower fold and sinus.

Distribution: Leonard formation (Glass Mountains) at T15, 16, 26s, 28s, 37, 120, 128, T128, D1, and D4.

ENTELETES LIUMBONUS King, n. sp.

Pl. II, Figs. 9–11; Pl. III, Figs. 1–2

1908 *Enteletes* sp. c. Girty, The Guadalupian Fauna, U. S. G. S. Prof. Paper 58, pp. 297–299, pl. 24, figs. 4-5a, pl. 26, figs. 1-2b.
Basal black limestone, Guadalupe Point (stas. 2920 and 2967). Diablo Mountains (sta. 3764).

Description: Shell medium-sized or large when mature, but mature forms are less common than the immature ones. Since, however, all gradations exist from small, nearly unplicated shells to the mature ones, there is evidently but one species. Brachial valve considerably larger than the other, mature shells very strongly inflated, while the pedicle valve is rather strongly convex but much lower.

The cardinal areas and beaks resemble in every respect those of *E. dumblei.* The internal characters likewise are similar. The umbonal regions for about 13 mm. anterior to the beaks are unplicated. Plications low and rounded, numbering, on mature shells, three, with a faint fourth, on each side of the fold and sinus. One shell from loc. 381

has the fold and sinus divided respectively into two lesser folds and sinuses. Lirae rounded, separated by narrower striae.

Dimensions in mm. of several specimens:

	1 (loc. 17)	2 (loc. 17)	3 (loc. 106)	4 (loc. 17)
Length of brachial valve	14	19	22	25
Length of pedicle valve	15	17	20	21
Width	17	21	26	29
Thickness	12	12	22	25
Height of ventral area	1.5	2	2.5	2.5

Observations: This species is clearly very close to *E. dumblei*. It is distinguishable by its more strongly inflated brachial valve when mature, by its unplicated umbonal region, and by its low, rounded plications. The immature individuals collected by Girty were almost unplicated, but his description leaves no doubt that this is the form designated by him as *E.* sp. c. The great number of half-grown shells is very striking; the fact that all gradations in size may be collected from the same piece of rock shows that there is but one species. Girty compared *E.* sp. c with many faintly plicated foreign species, but since his faintly plicated shells were immature, such comparison is unnecessary here.

Distribution: Hess formation (Glass Mountains) at 1, T15, 17 (abundant types), 105, 106, and 210. Probably also immature specimens from 3 and 8. Leonard? formation (Glass Mountains) at 245. Gym formation (Hueco Mountains) at 381, 383?, and 384? Hess formation (Sierra Diablo) at 467 and 479. *E Liumbcnus* occurs at the same horizon in the Hess as *E. dumblei*, and in some places the two occur together.

ENTELETES PLUMMERI King, n. sp.

Pl. III, Figs. 3-8

Description: Shell small, slightly wider than long, valves evenly convex, the brachial valve being somewhat larger than the other. Ventral cardinal area equal to or somewhat less than half the greatest width of the shell, and about a third as high as wide; beak strongly incurved. There are three pairs of angular lateral plications on the pedicle and four on the brachial valve of most specimens. The fold and sinus are distinctly larger than the lateral plications and sulci; they originate about 8 mm. in front of the beaks.

Dimensions in mm. of several specimens:

	1 (loc. T9)	2 (loc. T9)	3 (loc. 231)	4 (loc. 104)
Length	18	17	19	—
Width	19	18	20	27
Thickness	16	17	—	26
Height of ventral area	3.5	3.5	4	6.5

The specimen from loc. 104 is exceptionally large, the others being about normal size.

Observations: *E. plummeri* is most nearly related to *E. hemiplicatus*, but may be distinguished from it by the relatively smaller size of the plications, and the relatively smaller fold and sinus. It is very similar to the group of Eurasian forms which have been divided into the species *E. oehlerti* Gemm., *E. contractus* Gemm., *E. elegans* Gemm., *E. meridionalis* Gemm., *E. subaequivalvis* Gemm., *E. haugi* Gemm., and *E. tschernyscheffi* Diener. As Diener[1] has pointed out, these species are so narrowly restricted that there is considerable doubt as to their validity. If, as is quite possible, they all are members of one variable species, then it would not be possible to distinguish *E. plummeri* from it. *E. plummeri* is similar in every detail to *E. oehlerti* as figured by Schellwien.[2]

Distribution: Upper Hess formation (Glass Mountains) at 8. Lower Leonard formation (Glass Mountains) at T9, 104, T205, 231, 232, T232, 128? (having smaller plications than typical specimens), and Tb. *E. plummeri* is common at nearly all these localities; it is apparently restricted to the highest beds of the Hess and the lowest of the Leonard.

ENTELETES WOLFCAMPENSIS King n. sp.

Pl. III, Fig. 9

Description: Shell small, globose. The posterior parts of a mature shell have a very low curvature; at about three-fifths the length of the shell from the beak there is a rounded geniculation, anterior to which the curvature is very low to the front margin, where the two valves meet at an angle of about 120°. This is seen only on mature specimens; some immature forms are too small to have reached the stage of geniculation. The brachial valve is somewhat deeper than the other. The flattened posterior regions show the beginnings of a fold and sinus on the brachial and pedicle valves respectively, but the lateral plications originate at the geniculation: they are low and rounded and are two to three in number on each side. One specimen shows strong growth undulations. Lirae strong and even. The shell is finely punctate. The internal plates of the pedicle valve are arranged as is characteristic of *Enteletes*.

Dimensions in mm. of two specimens:

	1 (loc. 196)	2 (loc. B88)
Length	16	17
Width	17	18
Thickness	18	19

Observations: This species is easily distinguished by the geniculation of both valves, the slight curvature anterior and posterior to the geniculations, and the absence of plications over the entire posterior three-fifths of the shell. *E. contractus* Gemm. is similar in having a geniculated profile, but has much stronger plications.

Distribution: Wolfcamp formation (Glass Mountains) *Uddenites* zone at B88, middle Wolfcamp at 93 and 93s, upper Wolfcamp at 196. The species is rare at each locality.

ENTELETES WORDENSIS King, n. sp.

Pl. III, Figs. 13-15

1908 *Enteletes* sp. a. Girty, The Guadalupian Fauna, U. S. G. S. Prof. Paper 58. pp. 296–297, pl 30, figs. 2 and 2a.

"Comanche Canyon," Glass Mountains.

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[1]Pal. Indica. ser. 15. vol. 1. part 5. pp. 28-30.

[2]Die Fauna der Trogkofelschichten. vol. 16. pl. 1. figs. 11-13.

1908 *Enteletes* sp. b. Girty, The Guadalupian Fauna, U. S. G. S. Prof. Paper 58, p. 297.
"Comanche Canyon," Glass Mountains.

1908 *Enteletes* sp. d. Girty, The Guadalupian Fauna, U. S. G. S. Prof. Paper 58, pp. 299-300, pl. 21, fig. 23.
Delaware Mountain formation, Guadalupe Point, Guadalupe Mountains (sta. 2919). Delaware Mountain (sta. 3501). "Delaware Mountain formation," Glass Mountains (sta. 3763?).

Description: Shell medium-sized to large, subcircular in outline, evenly biconvex, the brachial valve being somewhat the larger. Cardinal area of the pedicle valve flat for most of its length, strongly incurved at the beak; its length equals half the width of the shell and its height a little more than a fourth its length. Fold and sinus only slightly larger than the lateral plications and sulci; in some specimens they are of nearly equal size. Plications originate about 8 mm. anterior to the beaks; there are three to four on each side of the fold and sinus. Internal septa of the pedicle valve parallel, the median septum reaching its highest point near its anterior end, as described for *E. dumblei.*

Dimensions in mm. of several specimens:

	1 (loc. 264)	2 (loc. 251)	3 (loc. 265)
Length	21	32	27
Width	23	28	26
Thickness	20	—	—
Height of vent. area	2.5	..	...

Observations: This species is distinguishable by its relatively narrow and numerous plications and the proportionately much smaller fold and sinus than in *E. dumblei* and *E. hemiplicatus.* It is constantly larger than *E. plummeri,* but has about the same number and relative size of plications at the growth stage when *E. wordensis* is the size of mature *E. plummeri. E. wordensis* is unlike *E. leonardensis* in having even convexity and no great difference in the size of brachial and pedicle valves. Several imperfect specimens of *Enteletes* were described by Girty. *E.* sp. a is, with little doubt, to be assigned to this species, the size and number of plications being the same as those of *E. wordensis. E.* sp. b Girty is less certainly identical, but it is likely that that shell was flattened from its normal profile. The character of the liration, cited by Girty as a distinction, is so easily obscured on silicified specimens such as he had that any differences between the ornamentation of one shell and another are probably to be regarded as due to silicification.

Distribution: Word formation (Glass Mountains) at 154?, 241, 251, 255, 264, 265, and Te. Delaware Mountain formation (Sierra Diablo) at 504. It is not common. At localities 241 and 264 it is associated with *E. dumblei.*

Genus PARENTELETES King, novum

Diagnosis: Plicated and finely lirate Enteletinae in which the fold is in the pedicle valve and the sinus in the brachial. The oldest species of the genus, *P. suessi* and *P. cooperi*, have, as in *Orthotichia,* divergent dental lamellae united anteriorly to the median septum by a thickening of the shell at the anterior ends of the adductor muscle scars. Middle and late Permian species described by Waagen have sub-parallel dental lamellae as in *Enteletes.*

Genotype: *Parenteletes cooperi* King, n. sp.

Geologic range: In America the earliest representative of *Parenteletes* is *P. cooperi,* which first appears in the lower Gaptank, in beds of middle Canyon age. The same form occurs again in the *Uddenites* zone of the basal Wolfcamp, of very earliest Permian age. The only other American species is *P. globosus* (Girty), which probably was collected from the Word formation. The earliest Eurasian representative is *P. suessi acuticosta* (Schellwien), from the Auernig formation of Upper Carboniferous age. The overlying Trogkofel formation contains typical *P. suessi* (Schellwien). In the Salt Range the earliest *Parenteletes* is *P. ferrugineus* (Waagen) from the Katta; then follow successively *P. sublaevis* (Waagen) and *P. pentameroides* (Waagen) from the Virgal, *P. latesinuatus* (Waagen) from the Kalabagh, and *P. acutiplicatus* (Waagnen) from the Khundghat or Jabi. *P. akasakensis* (Ozawa) is a species similar to *P. suessi* which occurs in Japan in the lower Akasaka limestone of lower Permian age.

Origin and relations of the genus: It has been suggested by Waagen and Girty that the "dorsisinuate *Enteletes*" *(Parenteletes)* evolved from the "ventrisinuate *Enteletes*" *(Enteletes)* through the development of a median plication in the sinus. Three arguments are used in favor of this: first, that *Schizophoria* and *Orthotichia* are ventrisinuate, and that it would be unlikely for a dorsisinuate shell to evolve from such a form without an intermediate stage in which a plication appeared in a ventral sinus; second, that the "dorsisinuates" appeared only in the late Carboniferous or Permian, while the "ventrisinuates" appeared earlier; and third, that *E. lamarcki* and *E. hemiplicatus* show transitionary forms toward "dorsisinuate" shells in the appearance in the fold and sinus of a plication and a sulcus. While it is possible that the first argument is valid, the second and third are quite wrong. Actually, the "dorsisinuate group" *(Parenteletes)* was the first to appear. In North America *Parenteletes* appears in the middle Canyon (lower Gaptank), while *Enteletes hemiplicatus* is first found in the Thrifty (Cisco) and Lansing (Missouri). In Europe it is impossible to determine the sequence, for *Parenteletes* occurs first in the Upper Carboniferous of the Alps (Auernig formation) and *Enteletes lamarcki* in the *Spirifer mosquensis* zone of Russia; probably these formations are of approximately the same age. Further, the presence of a plication in the sinus and a sulcus in the fold of a true *Enteletes* is of common occurrence, but in every instance the plication and sulcus are distinctly smaller than the fold and sinus and could not be mistaken for it. But by far the most convincing fact is the *Orthotichia*-like arrangement of septa and muscle scars in the early *Parenteletes (P. suessi* and *P. cooperi),* in contrast to the specialized narrow muscular areas bounded by parallel dental lamellae and median septum in the earliest species of *Enteletes hemiplicatus* and *E. lamarcki.* It would be a reversal of evolution for the primitive internal characters to have appeared in a species which had developed from *Enteletes,* with its specialized internal characters. Apparently, then, *Parenteletes* appeared before *Enteletes* in the Pennsylvanian, and both genera evolved independently from *Orthotichia*.

It must be made clear that specimens of *Enteletes* which contain a plication in the sinus and a sulcus in the fold are not to be included in *Parenteletes*. It is possible that some species included in *Parenteletes* did evolve from *Enteletes* in the manner suggested by Girty, but certainly *P. suessi* did not, and probably the rest of the genus is monophyletic.

PARENTELETES COOPERI King, n. sp.

Pl. I, Figs. 16–20; Pl. II, Figs. 1–3

Description: Shell medium-sized to large, wider than long, the brachial valve much larger than the other and strongly convex, the pedicle valve very slightly convex. Pedicle valve transversely elliptical, beak erect, the curvature being only slight along the median line of the valve. Ventral cardinal area deeply concave, erect, equaling about two-fifths the width of the shell and about one-half as high as wide. Delthyrium large, equaling in width slightly more than a third that of the area. Dorsal cardinal area smaller than the other and lying at somewhat less than right angles to it. The pedicle valve bears a large, high, sharp median fold, originating about 8 mm. anterior to the beak, the curvature being so slight that its crest lies nearly parallel to the plane of the shell margin. Lateral plications number three on each side of the fold, the first one being about half the size of the fold; their crests are much lower than that of the fold. The brachial valve has a deep median sinus originating about 5 mm. anterior to the beak; it curves evenly downward to meet the fold of the other valve. Lateral plications three or four on each side of the sinus, the sulci being about half as large as the sinus. Lirae fine and even, separated by very narrow striae.

In the pedicle valve the dental lamellae diverge from the median septum at an angle of about 15°; at their anterior ends they are connected by a ridge extending backward to join the end of the median septum.

Dimensions in mm. of several specimens:

	1 (loc. 199)	2 (loc. 199)	3 (loc. 273)
Length of brachial valve	22	29	25
Length of pedicle valve	19	25	24
Width	26	37	32
Height of ventral area	6	6	—

The specimen from 273, as all the other Gaptank specimens, has been crushed, so that the original ratios of dimensions cannot be determined.

Observations: This species is very close to *P. suessi* (Schellwien) and its variety *acuticosta* (Schellwien). It differs from them in having a narrower fold and sinus and larger lateral plications. It is likewise similar to *P. latesinuatus* (Waagen), but has a narrower fold and sinus, and the dental lamellae diverge and are united anteriorly to the median septum, rather than lying subparallel as in Waagen's species.[1]

[1]This species has been erroneously identified by Beede (U. of Tex. Bull. 1753, p. 39) as *E.* aff. *waageni* Gemm. and by Schuchert (A. J. S., ser. 5, vol. 11, pp. 385 and 391) as *E. hemiplicatus* and *E. angulatus.* All these names are those of species of true *Enteletes* rather than *Parenteletes.*

Distribution: Lower Gaptank formation at 273 and T65 (common at both). *Uddenites* zone of Wolfcamp formation at 88, 89, 94, 95, 95s, 199 (abundant), 201, and Tba.

Genus STREPTORHYNCHUS W. King

Diagnosis: Shell biconvex, hinge-line short, lateral and anterior margins rounded. Pedicle valve high and generally distorted, its cardinal area high, with a large delthyrium which is closed to the apex by the deltidium. Internally the delthyrial supporting plates are reduced to mere thickenings of the inner surface of the cardinal area at the margins of the deltidium; median septum absent. Brachial valve with a very rudimentary area or no area at all. Cardinal process high and without a very transverse base, the height depending on the elevation of the umbonal region of the pedicle valve.

Genotype: *Terebratulites pelargonatus* Schlotheim.

Geologic range: Mississippian to Permian.

STREPTORHYNCHUS LAMELLATUM King, n. sp.

Pl. IV, Figs. 1–3

Description: Shell small, hinge-line shorter than the greatest width of the shell. Pedicle valve high, conical. Cardinal area of the pedicle valve lying at about 120° to the plane of the shell margin, flat, somewhat higher than wide, with a convex deltidium occupying about the median fourth. Brachial valve convex, slightly wider than long. Along the hinge is a broad cardinal area lying parallel to that of the pedicle valve, with a slightly convex chilidium.

Surface marked by small, rough costae, about 6 occurring in the space of 5 mm. on the anterior part of the shell but finer in the posterior part. The costae are truncated at intervals by closely spaced concentric lamellae, which give the shell a scalloped appearance, as in *Atrypa*.

Internal characters obscured; cardinal process apparently large.

Dimensions in mm. of two specimens:

	1 (loc. 245—type)	2 (loc. 105)
Length of brachial valve	10	8
Width	12.5	9
Height of ventral area	5	—
Height of dorsal area	1.5	—
Length of hinge	10	8

Observations: This species differs from the other Orthotetinæ in this fauna by its ornamentation and by the presence of a large dorsal area. Though the internal characters are not definitely known, they appear to be like those of *Streptorhynchus.*

Distribution: Upper Wolfcamp formation (Glass Mountains) at 105 and 211. Leonard formation (Glass Mountains) at 83, 228, and 245 (type).

STREPTORHYNCHUS PYGMAEUM Girty

Pl. IV, Figs. 4–6

1908 *Streptorhynchus pygmaeum.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 178–180, pl. 30, figs. 3–6b.

Delaware Mountain formation, "Comanche Canyon," Glass Mountains; Delaware Mountain formation, southern Delaware Mountains (sta. 2962?).

1908 *Streptorhynchus?* sp. a. Girty, *idem*, pp. 178–180, pl. 30, fig. 7.
Delaware Mountain formation, "Comanche Canyon," Glass Mountains.

Description: Shell very small, unsymmetrical, outline polygonal, the greatest width being near mid-length. Pedicle valve larger than the brachial, with its beak strongly twisted to one side. The cardinal area lies at 90 to 140° to the margin, and its height is equal to about .4 the width; it is defined by an angulation from the main part of the shell. Deltidium convex in the median part, its width equal to 0.3 that of the cardinal area. Internal characters not determinable. According to Girty, "the progression of the hinge teeth is marked by two prominent ridges, which are not, however, prolonged as plates, while anything in the nature of a median septum is quite absent."

Brachial valve somewhat wider than long, the hinge-line shorter than the greatest width below. Cardinal process of a small brachial valve from loc. 26s lying at right angles to the plane of the margin, relatively small, marked by 4 ridges perpendicular to the hinge; crural plates diverging from each other at right angles, straight, short.

Surface marked by thin, high, more or less irregular and alternating, widely spaced and somewhat crenulated lirae. Undulations of growth present near anterior margin. Scars of attachment were not seen on the specimens examined, though all three of Girty's showed scars.

Dimensions in mm. of several specimens:

	1 (loc. 26s)	2 (loc. 26s)	3 (loc. T240)	4 (loc. T148)
Length of brachial valve	7	6	7	13
Width	9	8	9.5	17
Length of hinge	8	6	7	13
Height of cardinal area	3	—	3.5	4

The specimen from loc. T148, as well as one from Tx148, is unusually large.

Observations: Girty divided his specimens of this type from the Glass Mountains into two groups, one of which, represented by a single specimen, he described as *S.* sp. a. He notes the fact that the latter is possibly immature, as indicated by its thin shell. The differences between *S.* sp. a. and *S. pygmaeum* were the thinner and higher lirae of *S.* sp. a, the absence of crenulations and varices of growth, and the smallness of the cardinal process. The specimens above described show very little crenulation of the lirae, the lirae being probably more like those of *S.* sp. a than of typical *S. pygmaeum,* but varices of growth are present as in typical *S. pygmaeum.* The cardinal process of the small, thin valve described above also is like that of *S.* sp. a. These features point to a greater similarity to *S.* sp. a than to *S. pygmaeum,* but the nature of the internal characters is probably affected by the immaturity in both *S.* sp. a and the small brachial valve above described. The differences in the character of the liration are so slight, and this feature is so variable even on different parts of the same shell, that it can hardly be regarded as of specific importance. The likelihood that they are the same species is further indicated by the fact that they occur together at the place from which they were originally described.

S. pygmaeum shows no close similarity to any foreign species of the genus, nor is there any American species except *S. undulatus* that has such coarse liration.

Distribution: Leonard formation (Glass Mountains) at T9 and 26s. Word formation (Glass Mountains) at T148, Tx148, and T240. Hess formation (Sierra Diablo) at 478. Upper Gym formation (Hueco Mountains) at 440a.

STREPTORHYNCHUS PYRAMIDALE King, n. sp.

Pl. IV, Figs. 7–10

Description: Shell medium-sized, with very elongate ventral beak. Pedicle valve with a very large cardinal area, beak not sharply pointed or twisted to any great extent. Cardinal area a little wider than the shell beneath it, so that it forms a flange-like projection at its sides; the area is inclined at about 135° to the valve margin and is more than twice as high as wide. Median septum and dental lamellae absent.

Brachial valve subcircular, hinge-line equaling in length about a third the width of the shell. Cardinal process long, bifid, curving backward until nearly parallel to the valve margin. Anterior face of the process with a deep, broad depression extending from the end nearly to the center of the valve, where it broadens out into the deeply impressed muscular area, which is divided by a low median septum; the posterior face of the process divided by three shallow grooves radiating from the beak, separating 4 low ridges; process united anteriorly with broad, diverging socket plates, from which slight ridges are prolonged around the muscular area.

Surface marked by strong radial lirae, 9 to 11 occupying the space of 5 mm., separated by very narrow striae; the lirae are unequal because of the intercalations of small ones which do not reach complete equality with the older lirae for some distance anterior to the point of origin. Interruptions of growth are indicated by periodic, widely spaced, thin concentric striae. Shell very thick.

Dimensions in mm. of a brachial valve from loc. 93: length, 12; width, 14; length of hinge, 10. One pedicle valve must be more than 25 mm. long. A valve from loc. 93, evidently a pedicle valve, which appears to belong to this species, has a slight mesial depression and a rather incurved beak. These characters do not appear to agree with those of the other pedicle valves of this species from the same locality. The specimen from loc. 511 has a strong deflection of the margin in a ventral direction; this may be in part due to crushing. This specimen agrees well with the Wolfcamp ones, though from a much higher horizon. The type material is fragmentary, the specific characters being determined from several specimens. The range in size and in form could not be determined.

Observations: This species belongs to the group of *S. pelargonatus,* the common Eurasian Permian species, but differs from that form in having a much higher and flatter cardinal area, more strongly defined from the rest of the shell, and by lacking the mesial depression of the brachial valve so prominent in the foreign species. The ornamentation is very much alike. *S. lenticularis* Waagen is similar, but it differs in the same respect as *S. pelargonatus,* and may be identical with the latter species. *S. pseudopelargonatus* Broili, from Timor, is related, but even more different than the others, especially differing in the nature of its sculpture. *S. subpelargonatus* Fliegel from Lo Ping is evidently similar, as it has no sinus, but as it was not figured, satisfactory comparison cannot be made.

The most similar American species is *S. pygmaeum* Girty, which is much smaller at maturity, has its cardinal area lower and less well defined from the antero-lateral margins, and has a much shorter cardinal process.

Distribution: Wolfcamp formation (Glass Mountains) at 88? and 93 (type). Leonard formation (Baylor Mountains) at 503?. Leonard formation (Finlay Mountains) at 511. Limestone of Cerro Caballo (Las Delicias), at section 1, bed 11?.

STREPTORHYNCHUS? UNDULATUM King, n. sp.

Pl. IV, Figs. 11–13

Description: Shell rather large, with a high, conical pedicle valve distorted by very strong irregular undulations. Cardinal area lying at right angles to the plane of the margin as high as or higher than wide, flat except for an upward curving at the beak, which is twisted to one side. Deltidium narrow, occupying about a fourth of the area, but where the shell has been exfoliated exposing the interior mold it appears to be much broader. The surface of the area is vertically striated. Within the pedicle valve there are thickened ridges under the edges of the delthyrium. Internal plates probably not present, as sections across the beaks show no such structures.

Surface marked by fine, uneven radial lirae, about 18 of which occur in the space of 5 mm., separated by broad striae.

Dimensions in mm. of several specimens:

	1 (loc. T9)	2 (loc. T9)	3 (loc. 211)
Length of pedicle valve	35+	32	39
Length of brachial valve	32	24	30
Width	18+	20	15
Height of cardinal area	22	21	24
Length of hinge-line	30	26	30+

Observations: This species is very similar externally to *Orthothetina* sp. but differs in having a higher cardinal area and more undulating surface. It resembles also some of the species of *Orthotetes* described by Girty. The cardinal area is high as in *O. distortus*, but the shell is larger and has a less even surface. The specimen figured by Schellwien as *Streptorhynchus* aff. *operculatus* Waagen is very similar, and, indeed the two may prove to be identical.

Distribution: Hess formation (Glass Mountains) at T9, 17, 105, and 211 (type).

Genus ORTHOTETELLA King, novum

Diagnosis: Shell similar externally to *Orthotetes*, the pedicle valve being flat in longitudinal profile, the brachial valve slightly convex. Surface radially lirate, unplicated. Cardinal area very wide, rather high, divided into a primary and secondary area as in *Orthotetes*. Internally the deltyrial supporting plates are produced forward and inward, joining to form a cone or spondylium of subcircular cross-section, its apex at the beak. No median septum present.

Genotype: *Orthotetella wolfcampensis* King, n. gen., n. sp.

Geologic age: Lower Permian (Wolfcamp formation).

Observations: The determination of the internal characters, on which the above description was based, was made from a single excellently preserved large pedicle valve. The other specimens referred to the type species were so classified because of their external features.

The presence of a spondylium would appear to indicate that *Orthotetella* is a pentamerid, but the other characters make it clear that it is one of the Orthotetinae, and the presence of uniting delthyrial supporting plates show that it is closely related to *Orthotetes*, the only difference being the absence of a median septum and the complete merging of the two plates without a line of division at their junction. It is likely, therefore, that this is a further specialization of the camerate Orthotetinae, the group of *Orthotetes*, in which the median septum is lost and the delthyrial supporting plates fuse to form a spondylium. *Orthotetella* would therefore be one of the most highly specialized genera of the Orthotetinae.

ORTHOTETELLA WOLFCAMPENSIS King, n. sp.

Pl. IX, Figs. 27–28

Description: Shell large, symmetrical, wider than long, the hinge-line equaling or slightly less than the greatest width of the shell. Pedicle valve flat or slightly concave in longitudinal profile; beak pointed but low; cardinal area .25 as high as wide, rising nearly perpendicularly from the plane of the margin, with a deltidium occupying about a sixth of the width of the area which is convex and transversely striated. The lateral parts of the area are divided in two parts by a line extending diagonally from the beak, on the outer part of which the striae run at right angles to the hinge. Delthyrial supporting plates join to form a conical spondylium, with its point at the beak, firmly joined to the posterior part of the shell by a thickening around the top of the cone. Median septum absent. Muscular scars large and flabellate, causing the outer surface of the spondylium to be grooved.

Brachial valve very slightly convex, with strong crural plates, and the cardinal process marked on its posterior face by four ridges.

Surface marked by low, thin lirae, about 6 to 8 in the space of 5 mm., separated by very broad, flat striae, about 3 times as broad as the lirae. The lirae increase by intercalation, and as a result are somewhat alternating.

Dimensions in mm. of two specimens from loc. 93:

	1	2
Length of pedicle valve	40+	25+
Width	100	50?
Height of cardinal area	29	9
Width of cardinal area	100	50
Width of deltidium	15	6

Observations: This species may easily be recognized even without the knowledge of the internal characters by its narrow lirae and very broad, flat striae.

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at 88, T88, 95?, 175?, 195, and 201? Wolfcamp formation (Glass Mountains) at 2?, 85?, 87, 89?, 90, 92, and 93 (type). Lower Gym formation (Hueco Mountains) at 394?. Middle Gym formation (Hueco Mountains) at 421?.

Genus ORTHOTHETINA Schellwien

Diagnosis: Shell biconvex, similar in form to *Orthotetes* or *Meekella.* Surface lirate but not plicated. Within the pedicle valve the delthyrial supporting-plates are, as in *Meekella,* long, and reach to the floor of the valve, which they meet along the median line. Other internal structures probably also as in *Meekella.*

Genotype: *Streptorhynchus crenistria* var. *eusarkos* Abich.

Geologic range: Upper Mississippian to Permian.

Observations: As various authors have pointed out, especially Thomas,* this genus is probably heterogeneous, including shells both transitional from some primitive form to *Meekella,* and shells which have descended from *Meekella* by the loss of their plications. Since the only real difference from *Meekella* is the absence of plications, it may be best to regard *Orthothetina* as a synonym of *Meekella.* On the other hand, some species that have been placed in *Orthothetina,* such as *O.* cf. *mutabilis* of the present collection, have much more the form of *Orthotetes* than that typical of *Meekella.* It is possible that these species have arisen independently of *Meekella* from *Orthotetes,* a change which would not be great, as it would necessitate only the splitting apart of the delthyrial supporting plates near the floor of the shell so that they would not lie together to form a septum as in *Orthotetes.* Because of this uncertainty it seems well to make use of the name *Orthothetina* for such forms.

ORTHOTHETINA cf. ORTHOTHETES MUTABILIS Girty

Pl. IV, Figs. 14-15

Description: Shell medium-sized, wider than long, with the greatest width at mid-length; length of the hinge equal to 0.7 the width of the shell. Pedicle valve high, larger than the brachial, with a flat cardinal area extending at right angles from the plane of the shell margin; height of the area equal to from half the length of the hinge to as high as the hinge-line is long. The deltidium occupies about a third the width of the area. No median fold or sinus is present. Growth very irregular, the pedicle valve being undulated transversely and with the beak more or less twisted. Brachial valve moderately convex, with the greatest depth at about a third the length; beak low. Within the pedicle valve the delthyrial supporting plates converge from the inner side of the area to meet along the median line of the floor of the shell. Median septum absent.

Surface marked by very fine subequal radial lirae, which do not have straight courses, but swerve very slightly from side to side; about 20 lirae occur in the space of 5 mm.

Dimensions in mm. of the specimen from loc. 91: length of pedicle valve, 24; length of brachial valve, 22 width, 28; height of cardinal area, 12?; length of hinge, 23; width of deltidium, 7?.

*Thomas, Ivor: British Carboniferous Orthotetinae. Mem. Geol. Sur. of Gt. Britain, Pal., vol. 1, pt. 2, pp. 91-92.

Observations: Externally the specimens in the present collection are quite like the types from the Pennsylvanian of Idaho of *Orthotetes mutabilis*.* However, three of the Texas specimens show clearly that the delthyrial supporting plates do not converge as in *Orthotetes* before reaching the floor of the shell, forming a median septum, but lie apart as in *Meekella.* Girty did not figure the part of the shell showing the arrangement of the internal plates, but one cannot help but think that an apparent camerate structure was given his specimens by deformation, possibly by the crushing together of the lower parts of the delthyrial supporting plates to form an apparent septum. The presence in the Pennsylvanian of trans-Pecos Texas of other forms in common with faunas of the same age in the northern Cordilleran region indicates the similarity of the faunal association in Idaho and Texas.

An unnamed form of *Orthothetina* was found by Girty in the Capitan. It cannot be compared adequately with the forms here under consideration. No foreign species of *Orthothetina* shows great similarity, probably the most closely similar is *O. circularis* Fliegel, of the Lo Ping fauna.

Distribution: Captank formation (Marathon Basin) at 75. Strawn group (Hueco Mountains) at 354. Wolfcamp formation (Glass Mountains) at 71?, 91, and 196?.

Genus MEEKELLA White and St. John

Diagnosis: Shell biconvex, commonly sub-pyramidal. Hinge-line shorter than the greatest width of the shell. Ventral cardinal area elevated and generally distorted; deltidium occupying approximately a third of the area, its median part strongly convex. Hinge-teeth prominent. Delthyrial supporting plates relatively very elongated, reaching nearly to the center of the shell, sub-parallel to parallel in direction, converging downward. Brachial valve gibbous in the umbonal region; dorsal cardinal area rudimentary or linear. Crural plates strongly divergent, extended forward more than a third the length of the valve, supporting a high, erect cardinal process, which may extend nearly to the apex of the umbonal cavity of the other valve; the process is a somewhat curved, thin crescentric plate, bearing on its summit two slender median apophyses, below which are two stouter lateral projections having the form of extended, rounded lobes, which form the bases of the crura. Surface marked by more or less strong radial plications and by fine lirae.

Genotype: *Plicatula striatocostata* Cox.

Geologic age: Middle Pennsylvanian to Upper Permian (the citation from the Morrow by Mather is regarded as doubtful).

Observations: Unplicated shells having the internal characters of *Meekella* are here split off for convenience as *Orthothetina,* not, however, without some doubt as to the importance of this distinction.

MEEKELLA ATTENUATA Girty

Pl. V, Figs. 2-7

1908 *Meekella attenuata.* Girty, The Guadalupian Fauna, U. S. G. S. Prof. Paper 58, pp. 205-206, pl. 24, figs. 7-9a, pl. 25, figs. 4-4d.

*Girty, U. S. Geol. Surv. Prof. Paper 152, p. 433, pl. 27, figs. 9-15.

Delaware Mountain formation (probably actually Hess), Diablo Mountains (sta. 3764). Basal black limestone, Guadalupe Point (sta. 2967).

Description: Shell medium-sized to large. Pedicle valve high, subconical, inclined backward; hinge-line equal to about half the greatest width of the shell. Beak somewhat contorted; one specimen has a truncated beak, as if due to attachment. The cardinal area makes at the base an angle of 90–150° with the plane of the shell margin, but curves upward toward the beak until parallel or nearly so with the plane of the valve margin. It is well-defined, flat transversely and concave longitudinally. Deltidium equal to about .4 the width of the area, slightly convex, poorly defined. Delthyrial supporting plates converge toward the bottom of the shell, where they lie subparallel. One specimen from loc. 144 shows a double angulation, resulting in lateral offset, similar to the structure described by Girty for *M. difficilis*, but since other specimens fail to show it, this character may be accidental.

Brachial valve subcircular, widest near mid-length, regularly rounded; very convex near the beak and slightly convex anteriorly. Cardinal process long, with two extended median apophyses and a small lateral projection on each side, forming the base of the crura.

Surface marked by 11–28 strong, sub-angular plications, which subside toward the beak and resolve more or less abruptly into a prominent unplicated region, on which the lirae are conspicuous, or (as is most common in the Hess and Leonard specimens) they may extend to the beaks, near which each plication bears only one or two lirae. A specimen from loc. 38 has very fine plications to the number of about 38; were it not that intermediate forms to the normal type are present it would surely be regarded as distinct. Lirae number 4–5 in the space of 1 mm., counting the smaller incipient lirae intercalated between the larger ones; they show some tendency on the anterior part to curve up toward the crests of the plications.

Dimensions in mm. of several individuals:

	1 (242)	2 (144)	3 (Tx148)	4 (123)	5 (481)	Girty's type
Length of pedicle v.	24		21	16	24	14
Length of brachial v.	18	—	17	12	20	10
Width	18	32	19	15	23?	10
Thickness	16	—	16	12	—	—
Length of hinge	11	24	10.5	10	—	7
Height of card. area	7	18	7.5	11	13	6.5

Observations: The posterior part of large specimens of this species agrees exactly with the small specimen taken by Girty for the type of *M. attenuata*. *M. attenuata* differs from *M. difficilis* in having a high cardinal area, fine, regular plications, and narrow form.

Distribution: Wolfcamp formation (Glass Mountains) at 75?. Hess formation (Glass Mountains) at 35, 107, 215, and 223. Hess formation (Sierra Diablo) at 476, 478, 479, and 481. Leonard formation (Glass Mountains) at 5, T9, 12, 14, 22, 24, 31, 37, 98?, T119, 120, 123 (common), 128, 226, 232, Tx, D5, D7, 10, and D17. Bone Canyon member (Delaware Mountains) at 490 and 491. Word formation (Glass Mountains) at 46, 51, 54, 55, 144, T144a, 148, Tx148, 150, 153, 170, 192, 238, 239, T239, T240, T240a, 242, 252, 264, and 265. Limestone of Cerro Caballo, near Las Delicias, Coahuila, about .25 mile south of 21 on bed 12. Leonard formation (Baylor Mountains) at 502. Victorio Peak member (Sierra Diablo) at 495.

MEEKELLA DIFFICILIS Girty

Pl. IV, Figs. 16–17; Pl. V, Fig. 1

1908 *Meekella difficilis.* Girty, The Guadalupian Fauna, U. S. G. S. Prof. Paper 58, pp. 207–208, pl. 30, figs. 10–10g.
"Delaware Mountain formation," Comanche Canyon, Glass Mountains (sta. 3763), and mountains northwest of Marathon (sta. 3840).

1908 *Meekella mutilirata.* Girty, The Guadalupian Fauna, U. S. G. S. Prof. Paper 58, pp. 208–209, pl. 24, figs. 6–6b.
Basal black limestone, Guadalupe Point (sta. 2967).

Description: Shell medium-sized. Pedicle valve low and subpentagonal. Hinge equal to about 0.5 the greatest width of the shell; in the specimen from loc. 235, however, the ratio is 0.8, and in one from loc. 26s it is 0.7. Cardinal area inclined backward, well-defined, generally low and slightly incurved or, as in two specimens from loc. 128, nearly flat. Deltidium broad, poorly defined, occupying more than a third the width of the cardinal area. Delthyrial supporting plates subparallel, median septum absent. Brachial valve transverse, rounded, but contracting near the hinge-line, its convexity moderate, greatest near the umbo.

Plications angular and somewhat nodose, 9–14 in number, subequal, becoming less distinct laterally, extending in most specimens nearly to the beaks; they are separated by broad, less sharp sulci. Lirae rounded and subequal, generally numbering 4 in the space of 1 mm., or more in some specimens, curving up toward the crests of the plications, and in some specimens not paralleling the plications but diverging laterally and crossing them.

Dimensions in mm. of several specimens:

	1 (120)	2 (26s)	3 (235)	4 (128)	5 (D1)
Length of brachial v.	26	25	25	16	17
Width	31	30	35	15	20
Thickness	19	—	—	13	15
Width of cardinal ar.	20	24	30	11	11
Height of cardinal ar.	9	—	9	9	6

Observations: Specimens of this species, as noted, show considerable variation. They are, as a whole, characterized by a longitudinally concave cardinal area, fine lirae, sharp, medium-sized, nodose plications originating near the beaks, and transverse outline. *Meekella pyramidalis* of the Kaibab differs in its larger size, and in the pyramidal shape of the pedicle valve due to the high cardinal area. *M. striatocostata* has less angular plications, which originate much farther from the beaks. In *M. skenoides* there is a much higher, flatter cardinal area and a conical pedicle valve, and its plications are generally more rounded and do not reach as near the beak. *M. attenuata* is proportionally narrower, and has much finer plications and a higher cardinal area.

The specimens in the present collection do not differ in any important particular from Girty's description of *Meekella difficilis*, except that the peculiar internal characters noted in the original description were not seen here. It is very likely that *M. mutilirata* of Girty is identical with this species. The differences noted between them were the fact that the former has lower and less angular plications and finer lirae. From Girty's figures of *M. mutilirata*, however, it may be seen that the surface was largely exfoliated, so that the plications would appear to be rounded. In the collections at hand it appears that the strength of the lirae is very variable, and not a specific character.

Distribution: Leonard formation (Glass Mountains) at 4, 13, 15, T15a, 20, 22, 24, 26s, 27, 38, 104, T119, 120, 123, 124, 127, 128, 226, 228, T233, 235, Tb, D1, D3, D12, and D15. Leonard formation (Baylor Mountains) at 502. Bone Canyon member (Sierra Diablo) at 499. Leonard formation, transition beds (Shafter) at Th. Near Las Delicias, limestone of Cerro Caballo, bed 11, section 1; and bed 12, section 2. The species does not occur abundantly at any of these localities, most of the collections being of less than 4 specimens.

MEEKELLA GLOBOSA King, n. sp.

Pl. V, Figs. 10–12; Pl. XXXII, Fig. 8

Description: Shell very large, globose, symmetrical. Pedicle valve strongly convex, with a greatly extended, conical posterior part. The cardinal area makes near the hinge an angle of about 120° with the plane of the shell margin, but curves upward toward the beak; cardinal area well-defined, evenly concave longitudinally. Deltidium prominent, equal in width to about 0.4 that of the area, with a sharply raised narrow median part. Delthyrial supporting plates sub-parallel; median septum absent.

Brachial valve subhemispherical, widest in front of mid-length, joining the pedicle valve along the anterior margin with a regular curve. Convexity great, deepest point a little back of the center. Cardinal process very long, supported by strong sub-parallel crural plates. The anterior face of the process is deeply concave and bordered on each side by the extensions of the crural plates. On the posterior face the hinge sockets are very deep, and lie near the hinge. The greater part of the process consists of the two median apophyses, which are greatly prolonged.

Surface marked by 14–21 sharp equal-sized plications, which extend to the beaks. Posterior part marked by equal sized lirae, about 5 of which occupy the space of 1 mm.; they disappear on the plications about 15 mm. in front of the beaks, but persist over the unplicated lateral margins of the shell. The anterior parts of the plications are marked by closely arranged chevron-shaped growth lines.

Dimensions in mm. of the type specimen:

Length of brachial valve	45
Width	45
Thickness	46
Width of cardinal area	25
Probable height of cardinal area	24

Observations: There is some variation among specimens of this species. The type specimen has exceptionally large plications and seems to be more strongly convex than the other less complete examples. The species is distinguishable, even if only small or incomplete specimens are found, by its narrow, sharp, regular plications extending to the beaks, and the absence of lirae except in the umbonal regions. Girty's type of *M. difficilis* has a somewhat similar aspect, but differs in having much larger plications in proportion to the size of the shell. *M. attenuata*, the only other similar type, differs from this in being smaller, incompletely plicated and completely lirated, and in having less angular plications.

Distribution: Leonard formation (Glass Mountains) at 128 (abundant), T128, and 151 (which may be the same as 128). The species appears to be restricted to a single locality: the fossiliferous limestone on the cuesta northeast of Split Tank on the Old Word Ranch.

MEEKELLA GRANDIS King, n. sp.

Pl. VI, Figs. 5–7

Description: Shell large, transversely elliptical, the hinge-line equaling a little more than half the greatest width of the shell. Pedicle valve flat in profile, twisted in the posterior part. Cardinal area flat and high, lying at about 120° to the plane of the margin. Delthyrial supporting plates subparallel; median septum absent. Brachial valve of low convexity, the greatest curvature being in the umbonal region. A shell from locality 105 which is doubtfully referred to this species has a broad trilobate cardinal process, the median part of which consists of a high raised ridge, not very clearly bilobed as in most other Meekellas; the sides of the process consist of strong plates which, near the beak, bear dental-sockets. These lateral plates extend antero-laterally into short but strong crural plates. In a specimen from Tq the cardinal process appears to have a much broader posterior face, but this may be due to wearing off of the surface.

Plications low and generally broad, about 12–18 in number, bifurcating toward the front margin, separated by broad, round-bottomed sulci. The umbonal regions are unplicated. The badly worn specimen from 105 appears quite smooth over most of its surface, the first plications appearing 40 mm. in front of the beak; near its anterior margin the plications number only about 6, and are low and broadly rounded. Lirae medium-sized and rounded, about 4 occurring in the space of 1 mm., converging toward the crests of the plications near the anterior margin of the shell.

Dimensions in mm. of several specimens:

	1(174)	2(Tq)	3(211)	4(105)
Length	55	48	49	52
Width	68	60	62	56
Height of cardinal area	24	—	—	—
Length of hinge-line	38	—	—	—

Observations: The important characters of the shells referred to this species are the large size, low convexity of both valves, unplicated umbonal region, and low plications separated by shallow, broad sulci.

Distribution: Wolfcamp formation (Glass Mountains) at 90?. Hess formation (Glass Mountains) at 105? and 211. Leonard formation (Glass Mountains) at 8–14?, and 174 (type). Leonard formation, transition beds (Shafter) at Tq (several specimens). Victorio Peak member (Brackett Draw) at Taa?.

MEEKELLA IRREGULARIS TEXANA King, n. var.

Pl. VI, Figs. 1–4

Description: Shell medium-sized to rather large; the hinge-line equal to 0.7 the greatest width of the shell. Pedicle valve very high, distorted. Beak high and sharply pointed. Cardinal area poorly defined, about as high as, or higher than wide, deeply concave longitudinally. Deltidium about a third as wide as the area, with a narrow projecting elevation in the middle, the remaining part being flat, with longitudinal striae and some irregular transverse folds. The delthyrial supporting plates diverge from the margins of the deltidium and extend downward to the median line of the shell. Brachial valve only slightly convex. Within are strong, diverging crural plates and a weak median septum.

Surface marked by fine radial lirae which, near the shell margins, converge toward the crests of the plications. Plications, numbering about 12–15, low, narrow, rounded, and irregular, being nodose at intervals, particularly near growth crenulations, and somewhat crooked, especially on pedicle valves; in some specimens they increase toward the margins by bifurcation. Some shells are plicated nearly to the beaks, while on others they become faint and indistinguishable in the umbonal region. Irregularities in growth resulting in concentric depressions on the brachial valve and strong transverse folds on the pedicle valve give a very uneven form to the shell.

Dimensions in mm. of several specimens:

	1(199-type)	2(95)	3(88s)	*M. irregularis* Sch.
Length of pedicle v.	23	---	37+	33
Length of brachial v.	17	29	26+	26
Width	24	37	30	33
Length of hinge	13	—	23	28
Height of cardinal a.	17?	--	21	17
Width of deltidium	5	—	—	—

Observations: These specimens are evidently nearly identical with *M. irregularis* Schellwien of the lower Permian Trogkofel formation of the Karnic Alps.* They have, however, a proportionately shorter hinge-line and wider deltidium. *M. procera* Schellwien, which occurs with *M. irregularis*, has a much greater length in proportion to width and less strongly developed incisions of growth. *M. evanescens* Schellwien is distinguished especially by weak plications, but also by the angular form and the extreme size and height of the cardinal area. *M. irregularis texana* is distinguishable from other American species of *Meekella* by its high cardinal area and small nodose plications. *M. striatocostata* has a low cardinal area and broad, regular plications originating some distance from the beak.*

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at 88, 88s, T88, 94, 95, 175a, 199 (type), 201, and 202. Middle and upper Wolfcamp formation (Glass Mountains) at 70?, 90?, 92, 93?, 93s, 169a, 196, and 205.

MEEKELLA MEXICANA Girty

Pl. VII, Figs. 1–5

1909 *Meekella mexicana.* Girty, Manzano Group, U. S. G. S. Bull. 389, pp. 53–54, pl. 6, figs. 1–5.
San Andres limestone, Engle and Elephant Butte; Yeso formation, San Andres.

Description: Shell medium-sized, slightly unsymmetrical. Pedicle valve subtriangular, subconical, flattened or depressed, and extended backward. Length of hinge equal to about four-fifths the greatest width. Cardinal area high, nearly flat, and inclined strongly backward; its inclination varies from a position nearly normal to the margin to a position nearly parallel thereto, generally forming an angle of about 45° to the shell margin. Narrow median part of the deltidium sharply raised. Brachial valve strongly inflated, especially in the umbonal region; in many specimens somewhat extended in the median anterior part to produce a ventral deflection of the margin.

Plications low, originating between 10 and 40 mm. (but generally about 15–20 mm.) anterior to the beak of the brachial valve. In some specimens there are plications on the pedicle valve but none on the other. Lirae fine, narrow, and sharp, numbering 3–4 in the space of 1 mm.; they are introduced by intercalation, especially at varices of growth, where commonly they suddenly become smaller and more numerous. In general the lirae do not converge toward the crests of the plications, and they may even cross them at an angle.

Dimensions in mm. of several specimens, all from loc. 434:

	1	2	3	4	5
Length of brachial v.	23	27	20	22	20
Width	30	37	31	28	27
Height of cardinal a.	12	---	13	7	7
Distance from the beak of first plications	23+	15	16	18	20

Observations: This species is extremely variable in the strength of plications and the inclination of the cardinal area. Some shells, as numbers 1 and 5 above, show no

*Schellwien, E.: Fauna der Trogkofelschichten, Abh. der K. K. Geol. Reichsanst., bd. 16, heft 1, pp. 20–21, pl. 2, figs. 8 9.

*Yakowlew (Mém. du Com. Géol. Russ., n. s., Liv. 79, 1912, pp. 2–3) places *Meekella striatocostata*, *M. irregularis*, *M. procera*, *M. evanescens*, *M. depressa* Schellwien, and *M. uncitoides* Tschernyschew in synonymy with *M. eximia* Eichwald. Such an opinion is hardly tenable when we consider the constant differences from one another shown by these species. It may be that some of Schellwien's species are identical (a fact suggested by their general similarity and their having been collected from the same locality, so that their differences may be merely variations of a single species) and perhaps also some of Tschernyschew's, but *M. eximia* can in no case be the same as *M. striatocostata* or *M. irregularis*. True *M. eximia* is apparently closer to the former than to the latter, for it has a much lower cardinal area and stronger plications than Schellwien's species.

plications and would, were it not for the associated individuals, be mistaken for *Orthothetina*. *M. mexicana* is distinguishable from *M. striatocostata* by the flat, strongly inclined cardinal area, and the faintness of the plications. The lirae are less regular than those on the Pennsylvanian species.

Distribution: Middle Gym formation (Hueco Mountains) at 421? (one specimen with exceptionally high plications), 425, and 434 (extremely abundant). Upper Gym formation (Hueco Mountains) at 440? and 443. Wolfcamp formation (Sierra Diablo) at 465? (two small faintly plicated shells). Wolfcamp formation (Glass Mountains) at 178?.

MEEKELLA HESSENSIS King, n. sp.

Pl. V, Figs. 8–9

Description: Shell medium-sized, wider than long. Pedicle valve low, with little convexity between the beak and the anterior margin. The cardinal area lies at a little more than right angles to the plane of the shell margin, its width equaling 0.6 0.7 that of the shell and its height twice its width, flat transversely and also longitudinally near the beak. Delthyrium only a fourth the width of the area. Delthyrial supporting plates subparallel; median septum absent. Brachial valve widest a little behind mid-length, anterior margin regularly rounded. Convexity moderate, greatest near center of the shell. Beak very low; umbonal region undefined by greater convexity, the transverse profile showing very little elevation in the median posterior part.

Surface marked by 10–15 fairly regular plications of variable coarseness, originating 5–10 mm. in front of the umbos. The specimen from loc. 122 has exceptionally fine plications. In some specimens the plications bifurcate near the margin. Lirae, numbering about 4 in the space of 1 mm., subequal, narrow; there is some tendency for them to curve upward toward the crests of the plications, and in some places near the margins of the shell the lirae do not parallel the plications but cross them, being directed more laterally. Strong varices of growth cross the surface at intervals.

Dimensions in mm. of several individuals:

	1 (122-type)	2 (222)	3 (208)
Length	24	21	27
Width	33	30	38
Thickness	18	18	—
Length of hinge-line	23	17	29
Height of cardinal area	13?	9?	15

Observations: This species is distinguished from *M. striatocostata* by its proportionately greater width, its broad and low cardinal area, and its indistinct dorsal beak. It is similar to *M. skenoides* but has a much broader and lower cardinal area, greater proportional breadth, and, in some specimens, finer plications. It is distinguished from *M. difficilis* by its flat, broad cardinal area, lying near a right angle to the margin, and generally also by its more transverse form.

Distribution: Hess formation (Glass Mountains) at 17, 122 (type), 208, 209, 211, and 222. Uncommon.

MEEKELLA SKENOIDES Girty

Pl. VII, Figs. 6–8

1908 *Meekella skenoides*. Girty, The Guadalupian Fauna, U. S. G. S. Prof. Paper 58, pp. 206–207, pl. 30, figs. 8–9.

Delaware Mountain formation, Comanche Canyon, Glass Mountains (sta. 3763); Delaware Mountain formation (?), southern Delaware Mountains (sta. 3501).

Description: Shell medium-sized to large. Pedicle valve high, more or less distorted, subconical, inclined backward so that the area makes slightly more than a right angle with the plane of the valve margins. Longitudinal profile flat or slightly curved. Cardinal area well-defined, high, flat transversely, slightly concave longitudinally; height about equal to or somewhat less than the width. Deltidium medium-sized, at its base equal to a third to a fourth the width of the area; the median part strongly convex. Delthyrial supporting plates long and sub-parallel; median septum absent. Brachial valve transverse, widest at about mid-length, anterior margin regularly rounded. Convexity moderate, greatest near the umbo.

Surface marked by 9–13 sub-angular, nearly equal plications, the number depending on the size of the shell. The shells are unplicated as far as 9 mm. in front of the beaks. Lirae thin, 3–4 in number in the space of 1 mm., subequal or somewhat alternating, and persistent over the whole surface. Toward the anterior margin of large specimens they curve up toward the crests of the plications, with implantation in the sulci corresponding to convergence at the crests of the plications; over the posterior surface, however, the lirae are parallel.

Dimensions in mm. of several specimens:

	1 (192)	2 (192)	3 (46)	4 (147)	Girty's type
Length of pedicle v.	22	25	45	50	11
Length of brachial v.	18	22	—	—	11
Width	21	28	44	52	13
Thickness	14	24	—	—	—
Length of hinge-line	15	18	23	24	8
Height of cardinal a.	12?	20	20?	35	9

Observations: Typical specimens of this species differ from Girty's type only in their larger size, generally smaller number of plications in specimens of the size of the type, and, in some instances, their lower cardinal areas and broader delthyria. This species is characterized by its medium-sized plications, high, flat, pyramidal pedicle valve, and high, slightly incurved cardinal area. It is unlike any foreign species, none of which is as strongly plicated. It somewhat resembles *M. striatocostata*, but has a much higher cardinal area, and attains a much greater size.

Distribution: Word formation (Glass Mountains) at 6, 44–46, 46, 132, 143, 144, T144, T144a, 147, 148, T148, Tx148, 153, 162, 192, 239, 240, T240, 243, T243, 247, 248?, 250, and Ta. Delaware Mountain formation (Sierra Diablo) at 504.

MEEKELLA STRIATOCOSTATA (Cox)

Pl. VII, Fig. 9

1857 *Plicatula striatocostata*. Cox, Geol. Sur. Ky., vol. 3, p. 568, Pl. 8, fig. 7.

1909 *Meekella striatocostata.* Girty, The Manzano Group, U. S. G. S. Bull. 389, pp. 54–55, pl. 6, fig. 6. See for synonymy.

Abo sandstone, Mesa del Yeso and Abo Canyon.

Observations: In the Wolfcamp formation there are a few specimens that cannot, so far as their characters may be seen, be distinguished from the common Pennsylvanian species.

Distribution: Wolfcamp formation (Glass Mountains) at 87 low?, 93, 93s, and T93.

MEEKELLA sp.

Many fragmentary specimens of *Meekella* could not be classified. Probably most of them belong to species described above. Several, however, may be different. The specimens from the Hess at 223, for example, are pieces of rather large shells marked by very strong rounded plications, except in the umbonal regions, which are marked only by coarse lirae. In profile the pedicle valve is nearly flat. These shells approach closer to *M. pyramidalis* (Newberry) than any others in this fauna. A medium-sized specimen from the Hess at 106 has only 7 high plications, which are as broad as those of *M. grandis* but much higher, and extend nearer the beak. The specimens from the Word at 54 and 265 have very broad, high, sharp plications.

Distribution: Wolfcamp formation (Glass Mountains) at T91. Hess formation (Glass Mountains) at 1, 8, 105, 106, 219, and 223. Leonard formation (Glass Mountains) at 26, 39, 82, 83, 125, 126, T226, and Tba. Word formation (Glass Mountains) at 54, 55, 237, and 265. Gym formation (Diablo Plateau) at 449. Hess formation (Sierra Diablo) at Te.

Genus GEYERELLA Schellwien

Diagnosis: Shell sub-conical, distorted. Hinge-line much shorter than the greatest width of the shell. Ventral cardinal area very high and narrow, not sharply set off from the rest of the surface. Delthyrial supporting plates extend to the middle of the shell or beyond, and merge into a septum to form a very elongated chamber below the deltidium. Brachial valve of low convexity. Cardinal process very long and bilobed. Surface marked by radial plications and by fine lirae.

Genotype: *Geyerella gemmellaroi* Schellwien.

Geologic age: Permian.

Observations: Whether this genus descended from *Orthotetes* to which it is internally similar, or whether the acquisition of a camerate internal character was an independent evolution from some other member of the *Orthothetinae* has been the subject of some debate. Girty* was inclined toward the former interpretation. He stated that the internal structure is precisely that of "the camerate group of *Derbya*, a fact to which Schellwien does not, in my view, give sufficient weight—indeed, I do not know that he calls attention to it at all." In this connection, however, Girty seems to have overlooked the fact that Schellwien* discusses at some length the similarity of *Geyerella "Derbya" correana* Derby which is a typical example of *Orthotetes* (the "camerate group of *Derbya*" of Waagen). Ivor Thomas* pointed out that the much more strongly developed internal plates of *Geyerella* than of *Orthotetes* was an important distinguishing character. To me it seems quite as likely that the arrangement of the internal plates in *Geyerella* is due to the joining together of the anterior part of the delthyrial supporting plates of *Meekella* as to development from *Orthotetes*.

*The Guadalupian Fauna, U. S. G. S. Prof. Paper 58, pp. 203–204.

GEYERELLA AMERICANA Girty

Pl. VII, Figs. 10–13

1908 *Geyerella americana.* Girty, The Guadalupian Fauna, U. S. G. S. Prof. Paper 58, p. 204, pl. 11, figs. 2–2b.

Middle Capitan, Guadalupe Point (sta. 2926).

1908? *Orthotetes distortus campanulatus.* Girty, The Guadalupian Fauna, U. S. G. S. Prof. Paper 58, p. 202, pl. 10, figs. 10–10c.

Middle Capitan, Guadalupe Point (sta. 2926).

Description: Shell attaining a very large size, with a high, conical distorted pedicle valve and a moderately convex brachial valve. In large shells the valves may meet at the anterior margin in a right angle. Pedicle valve deformed by strong concentric undulations. Hinge-line equal in length to about half the width of the shell. Cardinal area very high, and generally twisted to one side. Axis of the deltidium elevated into a narrow ridge; the rest of this plate is flat and not distinctly set off from the rest of the cardinal area. The delthyrial supporting plates converge to form the median septum at about a third the distance between the deltidium and the floor of the valve. These internal plates are very long, extending from the beak nearly to the anterior margin. Cardinal process long and massive.

Surface marked by 18–26 strong but rounded and very irregular plications, which originate 10–20 mm. in front of the beak and generally bifurcate near the anterior margin. The sides of the shell near the cardinal area are unplicated. Lirae fine and rounded, separated by broader flat striae.

Dimensions in mm. of three specimens:

	1(17)	2(35)	3(T15)
Length of pedicle valve	35	55	47+
Length of brachial valve	28	40	30+
Width	39	38	44
Length of hinge	13	11	—
Height of cardinal area	17	40	40+

Observations: Girty's specimen, though from a much higher horizon, agrees well with those from the Hess insofar as can be told from such an incomplete type specimen. *Orthotetes distortus campanulatus* is much like *G. americana*, but has plications only at a distance of nearly 20 mm.

*Fauna der Trogkofelschichten, Abh. der K. K. Geol Reichsanst. bd. 16, heft 1, p. 25. In this paper he also gives the name *Geyerella distorta* n. sp. to the same form which he had previously (N. Jahrbuch f. Minéralogie, etc., 1900, bd. 1, p. 13) named *G. alpina*. It would appear that the latter name has priority and should be used.

*British Carboniferous Orthotetinae, Mem. Geol. Surv. Gt. Brit., vol. 1, pt. 2, p. 90–91.

anterior to the beak. Girty suggested that this might warrant the assignment of this variety to *Geyerella*, but himself believed them to be accidental features. The fact that *O. distortus campanulatus* and *G. americana* were collected from the same locality is in favor of their identity. The two south European species of *Geyerella* are not nearly as high and distorted as *G. americana*.

Distribution: Hess formation (Glass Mountains) at T15, 17, 35, and 208?. Upper Wolfcamp or lower Hess formation (Glass Mountains) at 85.

Genus DERBYA Waagen

Diagnosis: Shell subplano-convex to biconvex, either regular or more or less distorted in growth. Pedicle valve flat or convex, the cardinal area more or less high and sloping posteriorly from the hinge-line, divided into a primary and secondary area; delthyrium closed to the apex by the deltidium. Within the pedicle valve there is a strong median septum which extends from the inner side of the deltidium to the floor of the valve; it is formed by the fusion of the delthyrial supporting plates. Brachial valve convex, with a narrow cardinal area or no area. Surface unplicated, marked by radial lirae.

Genotype: *Derbya regularis* Waagen.

Geologic range: Mississippian to Permian.

DERBYA BUCHI (d'Orbigny)

Pl. VIII, Figs. 4–6

1842 *Orthis Buchi.* d'Orbigny, Voyage dans l'Amérique méridionale, p. 49.

1842 *Productus Andii.* d'Orbigny, *idem*, p. 54, pl. 5, figs. 1–3.

1914 *Derbya Buchi.* Kozlowski, Brachiopodes du Carb. supér. de Bolivie, Ann. de Pal., vol. 9, pp. 54–59, pl. 8, figs. 1–6.

Description: Shell variable in form, large, slightly biconvex, wider than long, with the greatest width at about mid-length, somewhat unsymmetrical. Cardinal angles obtuse and rounded; front margin regularly rounded.

Pedicle valve slightly convex in the umbonal region, and sloping evenly toward the front; beak erect and pointed, not elevated above the cardinal area. Cardinal area 4–6 times as wide as high, inclined 120°–130° from the plane of the valve margin, striated parallel to the base, and with a median triangular part which is likewise vertically striated. The deltidium occupies about a fifth of the area; it is strongly convex and is divided by a longitudinal furrow. Internally there is a strong median septum.

Brachial valve moderately and unevenly convex, with a slight flattening at the sides in the posterior part, in some specimens bearing a slight mesial depression. Hinge-line bordered by a narrow, linear area. Cardinal process broad and thick, projecting at right angles to the plane of the margin, divided by a broad, deep notch into two parts, each of which is grooved at the end. Crural plates strongly diverging.

Surface marked by subequal broad, rounded, crenulated, radial lirae, with intervening flat striae of either greater or less width, about 14 to 20 of each occurring in the space of 10 mm., increasing by intercalation. Growth undulations present but not prominent.

Dimensions in mm. of several specimens:

	1 (93— ped. v)	2 (93 — bracht. v.)	3 (441)	4 (424)
Length	43	47	36	31
Width	54	64	50	45
Height of card. area	11	--	6	6

Observations: Fragments of certain specimens have been questionably assigned to this species because of their similar ornamentation—strong, regular, closely spaced lirae. *D. cymbula* is distinguished from this species by its smaller width in proportion to length, greater convexity, higher beak, higher cardinal area, and coarser liration. *D. nasuta* is more convex, and has a much higher beak and larger cardinal process. *D. crassa* is smaller, flatter, narrower in proportion to length, and less irregular. *D. crenulata* is much narrower in proportion to length, smaller, and has a higher cardinal area. *D. buchi* is very similar to *D. regularis* Waagen of the Salt Range section, but, as Kozlowski has pointed out, the Indian species is more regular and has the cardinal process enlarged at its end.

Distribution: Wolfcamp formation (Glass Mountains) at 91?, 93, 93s, 197?, and 198?. Middle Gym formation (Hueco Mountains) at 424. Upper Gym formation (Hueco Mountains) at 441.

DERBYA? CRENULATA Girty

1908? *Derbya? crenulata.* Girty, The Guadalupian Fauna, U. S. G. S. Prof. Paper 58, pp. 183–184, pl. 26, figs. 5–5d.

"Delaware Mountain formation," Diablo Mountains (sta. 3764). Delaware Mountain formation, southern Delaware Mountains (stas. 2969 and 3500).

Description: Shell medium-sized, transversely ovoid. Pedicle valve rather low. Surface marked near the margins by concentric undulations, otherwise nearly flat, except for the depressed ears. Hinge-line slightly shorter than the greatest width of the shell (in Girty's type the hinge is very long), the greatest width being near mid-length. Cardinal area lying at about 135° to the plane of the margin. Beak pointed and twisted to one side. Brachial valve moderately convex. Ventral median septum large. Surface marked by coarse, strongly elevated, rounded lirae, separated by broad, flat grooves of about the same width. The lirae number 7 to 8 in the space of 5 mm., and are crossed by crenulations, which in the striae appear as fine transverse wrinkles. New lirae are introduced by intercalation, giving the liration an alternating character.

Dimensions in mm. of two specimens:

	1 (loc. 248)	Girty's type
Width	39	30
Length of brachial valve	27	19.5
Width of cardinal area	35	30
Height of cardinal area	--	5

Observations: The specimens here referred to this species differ from *D. crassa*, a closely related form, in having slightly stronger, crenulated lirae, and a higher cardinal area. Several differences from Girty's type make absolute identification doubtful. *D.? crenulata* Girty has greatly produced cardinal extremities and apparently more strongly crenulated lirae. The high cardinal area and coarse lirae are, however, important points of agreement.

Distribution: Word formation (Glass Mountains) at 54?, 138?, T144, Tx148, 150, 153?, 241?, 246?, 248 (the best specimen), Ta, and Tx. It is uncommon, no more than one specimen having been collected at most of these localities.

DERBYA CYMBULA Hall and Clarke?

Pl. VIII, Fig. 3

1892? *Derbya cymbula.* Hall and Clarke, Pal. New York, vol. 8, pt. 1, p. 348, pl. 11B, figs. 2–3.

Observations: This identification is based on a single brachial valve, which agrees in every particular that can be seen with typical *D. cymbula* from the Cisco. It differs from *Orthothetina* sp. in having a coarser ornamentation, from *D. buchi* in its even convexity, less proportionate width, and finer liration, and from *D. crenulata* in its much finer liration. The shell is penetrated by many holes, about 2 mm. long by 0.75 mm. wide, probably made by some boring organism.

Distribution: Wolfcamp formation (Glass Mountains) at 169a.

DERBYA ELEVATA King, n. sp.

Pl. VIII, Fig. 7

1908 *Derbya* sp. b. Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 185–186, pl. 10. fig. 12.

Top of Capitan, Capitan Peak (sta. 2966). Delaware Mountain formation, southern Delaware Mountains (sta. 2969).

Description: This species is represented by two imperfect examples. The first is from a boulder which apparently came from the upper Word. Its shape is conical; cardinal area sharply defined, extending at right angles to the plane of the valve margin, flat in so far as observed. Deltidium fairly wide and slightly convex. Median septum very high and strong. Near the anterior wall it divides into two plates, each diverging laterally to unite with the floor of the valve. Just beneath the deltidium it appears to split and to join the ridges bordering the deltidium on the inside. Surface marked by fine subequal lirae, 12 of which occupy the space of 5 mm.; also by low undulations of growth.

The other example is very doubtfully referred to this species, because of the poor preservation of its surface. The pedicle valve is very high and conical. Cardinal area flat, extending at right angles to the plane of the shell margin, 0.6 of its width occupied by the deltidium. Hinge-line equal to 0.7 the greatest width of the shell. The median septum extends from the middle of the deltidium probably to the anterior wall of the valve; as the shell is not preserved it cannot be told if it actually joins the floor of the valve, or if it is split in the lower part as is the Word specimen. Brachial valve convex, particularly at the beak, showing two strong diverging crural plates but no median septum. Surface marked by fine radial lirae, on this specimen very poorly preserved.

Dimensions in mm. of three specimens:

	1 (loc. 265)	2 (El Tordillo)	3 (Girty's *D.* sp. b)
Length of pedicle valve	36+	45+	—
Length of brachial valve	43?	40	10
Width	56	49	16
Width of cardinal area	30	35	16
Width of deltidium	15	21	4.5
Height of cardinal area	15+	38+	12

Observations: The specimen from loc. 265 resembles Girty's typical specimen of *D.* sp. b. in every detail except that it is much larger. The other is more doubtful, but the internal characters and the nature of the ornamentation can hardly be those of anything but a *Derbya.* The two specimens agree in having a high cardinal area, but the Glass Mountains one probably did not have as high an area as that from Mexico.

Distribution: Word formation (Glass Mountains) at 265. Limestone of Cerro Caballo (Las Delicias) at section 2, bed 12, between El Tordillo and Cerro Caballo.

DERBYA NASUTA Girty

Pl. VIII, Figs. 1–2

1908 *Derbya nasuta.* Girty, The Guadalupian Fauna, U. S. Geol. Surv. Prof. Paper 58, pp. 182–183, pl. 26, figs. 6–6c.

"Delaware Mountain formation," Diablo Mountains (sta. 2764).

Description: Shell large, wider than long, growth irregular. Pedicle valve rather high but flat. Cardinal area 2 to 2.6 times as wide as high, lying at nearly right angles to the margin, flat transversely and somewhat concave longitudinally. In one distorted specimen from D3 the cardinal area is bent about 60° by a transverse angulation due to more rapid growth of the pedicle valve on one side; the part of the area in front of this geniculation lies nearly parallel to the plane of the margin on that side of the beak, while the other side is normal. Deltidium about 0.25 as wide at its base as the length of the hinge-line, divided into three parts, of which the median one is strongly convex but with a longitudinal groove, and the lateral ones nearly on a level with the rest of the area. Hinge-line equal in length to 0.7 to 0.9 the width of the shell. Brachial valve evenly convex.

Interior of the pedicle valve with a long, high median septum, at the apex meeting the deltidium, along the inside of which a low ridge continues from the septum to the hinge margin. Delthyrium bordered on the inside by low ridges which converge toward the septum at the apex. Muscle scars deeply impressed. Cardinal process of the brachial valve very large and massive, with strongly diverging apophyses, which receive between them the septum of the pedicle valve, curving upward to become nearly parallel with the plane of the shell margin.

Surface marked by rather thin and high radial lirae separated by striae of nearly equal size; they increase by intercalation and to a slight extent are alternating. The lirae number 10 to 14 in the space of 5 mm., varying on different specimens. Interruptions in growth are marked by strong concentric undulations.

Dimensions in mm. of several specimens:

	1 (loc. 39)	2 (loc. D3)	3 (loc. D3)
Length of pedicle valve	50	51	23
Width	80	57	24
Height of cardinal area	44	47	22
Length of hinge-line	17	16	11
Width of deltidium	—	10	5

Observations: This species is easily recognizable by its large size, the fineness of its ornamentation, the large undulations of growth, and the dimensions of its cardinal area. Of the foreign Derbyas, *D. grandis* Waagen is nearest to this species, resembling it closely in size, ornamentation, irregularity of growth, and shape and size of the cardinal process but differing from *D. nasuta* in having the hinge about as long as the greatest width of the shell and a narrower deltidium.

Distribution: Hess formation (Glass Mountains) at 4?, 8?, and 98?. Leonard formation (Glass Mountains) at 38?, 39, T41?, 119?, 123?, 124, 128, 174, T226?, and D3. Word formation (Glass Mountains) at 46, 47, 55?, 144, 145, 192, and T239. Leonard formation, transition beds (Shafter) at Th. Hess formation (Sierra Diablo) at 476. Bone Canyon member (Sierra Diablo) at 485. Limestone of Pichagüia (Las Delicias) at Cerro Pichaguïa?. The species is not common at any of these localities.

Family CHONETIDAE

Genus CHONETES Fischer von Waldheim

Diagnosis: Shell generally small, concavo-convex, subsemicircular in outline, wider than long, the greatest width being along the hinge-line. Pedicle valve convex, generally flattened on the ears, with a narrow cardinal area; delthyrium closed to the apex by the deltidium; lateral margins of the area sharply defined, bearing a single row of hollow, vertical or divergent spines which increase in length toward the cardinal extremities. Internally the muscle scars are generally faint, the surface outside the scars is strongly papillose, the papillae appearing in internal molds as pits. Brachial valve concave, with a cardinal area generally narrower than that of the other valve, and without marginal spines. Internally the shell is papillose just as the pedicle valve. External surface of both valves marked by fine radial costae, by plications, or smooth.

Genotype: *Orthis striatella* Dalman.

Geologic range: Upper Ordovician to Permian.

CHONETES BIPLICATUS King, n. sp.

Pl. IX, Figs. 12–13

Description: Shell medium-sized, wider than long, the cardinal angles being right angles. Pedicle valve rather strongly convex; beak prominent and greatly incurved; cardinal area low, bordered by numerous spines. A narrow, rather shallow median sinus, arising near the beak, lies between two plications, which are bordered laterally by deep sinuses lying parallel to each other rather than radial to the beak. On each side of these sinuses the shell is slightly convex, flattening out toward the hinge. The anterior margin is notched backward at the middle because of the sinus.

Outer surface marked by 4.5 to 5 lirae in the space of 1 mm. They parallel the two median plications, and therefore in the median part of the shell do not increase greatly in number from the beak to the front, but in the sulci bordering these plications they spread out and new lirae are introduced. Dimensions in mm. of one specimen from loc. 476: length 10, width 15, convexity 6.

Observations: This shell is distinguishable from other species of *Chonetes* by its narrow, shallow sinus and two high lateral plications lying parallel to each other and separated from the rest of the shell surface by deep sulci. The specimen from loc. 193 is probably immature, though it does not show the biplicate character at a length of 7 mm.

Distribution: Upper Wolfcamp formation (Glass Mountains) at 193 and 195. Hess formation (Sierra Diablo) at 476 and 485.

CHONETES DELICIASENSIS King, n. sp.

Pl. IX, Figs. 17–20

Description: Shell medium-sized, plano-convex, wider than long, length of the hinge less than, or rarely slightly greater than the greatest width of the shell. Pedicle valve strongly convex, without a sinus. Cardinal area relatively narrow, lying generally at about 45° to the valve margin. Spines not well preserved, but probably numbering about 8 on each side of the beak, their bases inclined backward toward the beak at an angle of about 45°, then turning at right angles upon reaching the edge of the area. Muscular areas small and circular. Brachial valve quite flat or very slightly concave near the beak; its cardinal area slightly smaller than that of the other valve and sloping back so as to lie at 120° to 180° to the ventral area. Cardinal process quadrilobate. Surface marked by lirae, of which 3 to 4 occupy the space of 1 mm., increasing in number by bifurcation. The striae are defined by rows of coarse punctae, as in *C. granulifer*.

Dimensions in mm. of 3 specimens:

Length	10	14	16
Width	18	21	22

Observations: The only other American species having this plano-convex form is *C. platynotus* White, from New Mexico (probably from the Magdalena formation). That shell, however, is not coarsely punctate, a character which allies *C. deliciasensis* more closely with *C. granulifer;* moreover, the New Mexico species is much smaller. The only foreign species at all similar is *C. moelleri* Tschernyschew, but this is too imperfectly known for comparison, the brachial valve not having been found.

Distribution: Limestone of Cerro Caballo (Las Delicias) at section 2, beds 12 and 18; section 1, bed 11 (a ventral interior).

CHONETES GRANULIFER Owen

Pl. IX, Fig. 14

1855 *Chonetes granulifera.* Owen, Geol. Rept. Minn., Iowa, and Wis., p. 583, pl. 5, fig. 12.

1915 *Chonetes granulifer.* Girty, Fauna of the Wewoka Formation, U. S. Geol. Sur. Bull. 544, pp. 59–62, pl. 7, figs. 12–13b. (See for synonymy.)

Description: Shell small or medium-sized, semicircular, with its greatest breadth at the hinge-line, or slightly in front of it. Pedicle valve moderately convex, with a broad, shallow mesial depression (absent in a specimen from loc. T88); beak small, slightly arched and projecting. Cardinal area rather narrow, lying nearly parallel to or at a low angle to the plane of the valves. The cardinal margins bear 4 to 5 spines on each side of the beak. Brachial valve concave, following nearly the curve of the pedicle valve. Cardinal area well developed, being nearly as large as that of the other valve. Surface ornamented by fine lirae.

Dimensions in mm. of two specimens:

	1 (loc. 88)	2 (loc. 88)
Width	19	13
Length	11	8.5

Observations: This shell is distinguishable from *C. verneuilianus* by the absence of a strong mesial sinus. The large variety *C. granulifer meekianus*, which is characteristic of the Cisco, is evidently absent from the Permian of the Glass Mountains, where the specimens are more like the typical *C. granulifer.*

Distribution: Wolfcamp formation, *Uddenites* zone at 88, 88s, T88, 95, and 195. Wolfcamp formation (Glass Mountains) at 89 and 196.

CHONETES HESSENSIS King, n. sp.

Pl. IX, Figs. 21–22

Description: Shell small, wider than long, subquadrate, concavo-convex, with only a faint trace of a sinus near the margin. Ventral beak high; ears somewhat flattened, but not very sharply defined. Ventral cardinal area slightly larger than the dorsal one, its margin marked by 5 spines on each side of the beak. Cardinal process quadrilobate, the two lateral lobes being much larger than the two inner ones, which are merely narrow ridges lying side by side.

Surface marked by coarse lirae, increasing by bifurcation, about 3 being present in the space of 1 mm. Striae are as broad as or broader than the lirae, marked by irregularly arranged punctae. Concentric growth lines present on some shells.

Length of one shell from loc. 107, 7 mm., width 9 mm.

Observations: This species is easily distinguishable by the coarseness of its lirae, which are not, however, so coarse as to place it in the group of the grandicostae, which evidently is not represented in this fauna. The nearest related species is *C. molengraaffi* Broili. The only difference is in the somewhat larger size and coarser liration of the Asiatic specimens. *C. strophomenoides* also is very similar, but has a lower ventral beak and fewer spines along the margin of the area relative to the size of the shell.

Distribution: Upper Hess formation (Glass Mountains) at 107.

CHONETES HILLANUS Girty

Pl. IX, Fig. 6

1859 *Chonetes Flemingi.* Shumard (non Norwood and Pratten), Trans. Acad. Sci. St. Louis, vol. 1, p. 590 (date of volume, 1860) (?).

White (Permian) limestone: Guadalupe Mountains.

1908 *Chonetes hillanus.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, p. 228, pl. 11, figs. 8–10.

Middle Capitan, Capitan Peak (sta. 2926); dark, limestone, Pine Spring (sta. 2930).

Description: Pedicle valve medium-sized, very broad, subtriangular, strongly convex. Sinus distinct but narrow. Hinge-line long, ears sharply pointed, each defined by broad, obscure sulcus, which is more distinct toward the beak than toward the lateral margin. Cardinal area rather high, bordered by about 9 spines on each side of the beak. Median septum extending more than half the length of the shell, bordered on each side by elongated narrow adductor muscles and large, laterally extended diductors, which are strongly defined by encircling grooves. The rest of the internal surface is marked by large granules regularly ranged in radial lines. Length, 10 mm.; width, 22 mm.

Observations: This species is easily distinguishable by its convexity, its wide hinge-line, and its low, narrow sinus. *C. subliratus* is larger, less alate, less strongly convex, and has a broad sinus. The surface is probably also quite different.

Distribution: Word formation (Glass Mountains) at T144? and 248. Very rare.

CHONETES MOLENGRAAFFI Broili?

Pl. IX, Fig. 26

1916? *Chonetes Molengraaffi.* Broili, Paläontologie von Timor, Lief 7, no. 12, p. 142, pl. 4, figs. 6–7.

Permian: Bitauni, path between Soefa and Manoemea.

1925? *Chonetes Molengraafii.* Fredericks, Rec. Geol. Com. of the Russian Far East, no. 40, pp. 5–6; pl. 2, figs. 67–68.

Permian: Cape Kalouzin, Ussuriland.

1927? *Chonetes? Molengraaffi.* F. R. C. Reed, Palaeontologia Indica, n. s., vol. 10, mem. 1, pp. 130–131, pl. 14, fig. 16.

Permian: Yellowish mudstone at Ta-li shao, Yunnan.

Description: Shell medium-sized, wider than long, subquadrate, cardinal angles rectangular. Pedicle valve strongly convex, especially in the posterior part. Median part depressed. Surface marked by coarse bifurcating lirae, about 2 to 3 of which occur in the space of 1 mm. Striae about as broad as the lirae, marked by rows of pores. Cardinal margin marked by about 7 spines on each side of the beak. Length, 10 mm.; width, 14 mm.

Observations: This species differs from *C. hessensis* in its larger size, stronger convexity, and coarser liration. So far as the characters may be seen they agree perfectly with those figured and described for *C. molengraaffi*, but there are no perfect specimens in the collection from Texas, so that absolute identification cannot be made.

Distribution: Leonard formation (Finlay Mountains) at 512.

CHONETES OSTIOLATUS Girty

Pl. IX, Fig. 24

1910 *Chonetes ostiolatus.* Girty, Fauna of the Phosphate Beds of the Park City Formation, U. S. Geol. Sur. Bull. 436, pp. 25–26, pl. 1, figs. 12–14.
Phosphate beds of the Park City formation; Thomas Fork, Wyoming; Montpelier, Idaho; Preuss Range, Idaho.

1927 *Chonetes ostiolatus.* Girty, in Geol., etc. of Part of Southeastern Idaho, U. S. Geol. Sur. Prof. Paper 152, p. 80, pl. 28, figs. 23–25.
Phosphoria formation: southeastern Idaho.

Description: Shell large, semicircular, widest at the hinge-line, the cardinal angle being about 80°. Pedicle valve slightly convex, with poorly defined low ears and a low median depression. Beak small and inconspicuous. There is a very shallow median depression. Surface smooth except for fine concentric striae or wrinkles, which are strong on the ears and less distinct over the rest of the surface. The shell is pierced by radially elongate, rather large pores, spaced about 2 mm. apart in the posterior part of the shell but more scattered in the anterior part. Through the outer shell layer fine lirae may be seen. The inside of the pedicle valve is finely papillose. Width 31 mm., length 18 mm.

Observations: But one specimen of this species is present in the collections here studied. Its characters fall easily within the limits of *C. ostiolatus* as described by Girty, though it is somewhat more extended at the hinge than in Girty's figured specimen, and in the presence of a median depression it is closer to the variety *impressus*. The distinction of the variety may be of doubtful value, as the distinguishing characters cited by Girty are rather variable. This species is very close to *C. capitolinus* Toula, but figures of that species do not show pores in the shell.

Distribution: Word? formation (Shafter) at Tn (no. 16005).

CHONETES PERMIANUS Shumard

Pl. IX, Figs. 1–4

185? *Chonetes Permiana.* Shumard, Trans. Acad. Sci. St. Louis, vol. 1, p. 390 (date of volume, 1860).
Permian: conglomerate at mouth of Delaware Creek.

1908 *Chonetes permianus.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 226–227, pl. 20, figs. 1–3a; pl. 29, figs. 1–2.
Dark limestone, Pine Spring (sta. 2930) and east of Guadalupe Point (sta. 3762b). Delaware Mountain formation, southern Delaware Mountains (stas. 2936 and 2969).

1908 *Chonetes* sp. Girty, *idem*, pp. 229–230.
Delaware Mountain formation (stas. 2903 and 2931); basal black limestone, Guadalupe Point (sta. 2920).

Description: Shell small to medium-sized, subsemicircular; hinge-line varying from slightly shorter to slightly greater than the greatest width of the shell; the cardinal angle being generally a right angle. Pedicle valve moderately convex, without a mesial sinus or with a faint depression; beak somewhat higher than the adjoining parts of the shell. Ears slightly deprest, but not well-defined. Cardinal margin with 6 spines on each side of the beak. Hinge-teeth small but distinct, not supported by dental plates. The median septum extends about half the length of the valve. Diductor muscle scars long and oval, lying beside the median septum. The rest of the interior surface is covered by coarse granulations.

Brachial valve flat in the posterior part but concave near the anterior margin. Cardinal process quadrilobate, being divided in the middle by a deep, narrow groove, and on each side by broader furrows. Crural plates short, diverging at about 45° from the hinge, giving rise to two linear brachial ridges, diverging at 60° from the hinge. Muscular area divided by a short, sharp median septum. Each antero-lateral part of the interior is raised into a curved ridge. Internal surface marked by large papillae, directed toward the lateral margins.

Surface smooth except for fine striae of growth. The inner shell layer is finely striated and punctate as in *C. subliratus*.

Dimensions in mm. of several specimens:

	1 (loc. 6)	2 (loc. 26s)	3 (loc. 8-14)	4 (loc. 31)	5 (loc. 128)
Width	14	20	20	12	13
Length	8	12	12	7	9

Observations: According to Girty, *C. permianus* Shumard has 3 rather than 6 spines on each side of the beak. Girty distinguished the type having a greater number of spines as *Chonetes* sp., but this feature is not here regarded as important enough to warrant distinguishing that type. Girty supposed that Shumard in his original description implied that there were 5 or 6 spines on the entire cardinal margin, but the fact that an odd number (5) is mentioned would rather suggest that Shumard meant 5 or 6 on each side. If so, Shumard's description fits best the specimens with the greater number of spines.

C. geinitzianus Waagen of the Pennsylvanian is broader than this species and has a well-marked sinus. *C. ostiolatus* Girty differs in its large size, low convexity, and the presence of pores piercing the shell. *C. ambiensis* Waagen, of the lower Productus limestone, appears to differ from *C. permianus* in having a higher ventral cardinal area, resulting in a greater angle between the cardinal margins on opposite sides of the beak. *C. obtusa* Schellwien is very similar but has a slight sinus. *C.* cf. *geinitzianus* Reed, from the Permian of Yun-nan, appears to be close to *C. permianus*, for it evidently has no mesial sinus in the pedicle valve. It appears, however, to be marked by stronger concentric growth lines. The description of *C. laevis* Davidson from Kashmir shows no point of difference from this species, but until it is better known any comparison would be unsatisfactory. *C. alatus* Stuckenberg has a much longer hinge. *C. rotundata* Toula has large punctures like those of *C. ostiolatus*. *C. amazonicus* Derby is of this type but has a nearly flat pedicle valve.

Distribution: Hess formation (Glass Mountains) at 207?. Leonard formation (Glass Mountains) at 8-14, D13, 15, T15, 26s, 31, 128, and 301. Word formation

(Glass Mountains) at 6, T144, 148, and T251. Upper Wolfcamp formation (Sierra Diablo) at 456?. Bone Canyon member (Sierra Diablo) at 483 and 484. Bone Canyon member (Delaware Mountains) at 490. Victorio Peak member (Sierra Diablo) at 495. Leonard formation (Baylor Mountains) at 495. Not abundant at any locality.

CHONETES QUADRATUS King, n. sp.*

Pl. IX, Figs. 7–11

Description: Shell small, subquadrate, slightly wider than long; cardinal angles approximately 90° in most specimens, but in some a little less. Sinus shallow and rounded, but narrow. Visceral slopes very steep, defining sharply the low ears. Spines probably about 6 in number on each side of the beak. Surface smooth, with tubules piercing it as in *C. subliratus;* inner shell layer finely striated.

Dimensions in mm. of several specimens:

	1 (loc.145-type)	2 (loc.246)	3 (loc.247)
Length	12	10	9
Width	14	12	12

There is much variation shown by some shells assigned to this species. One from loc. 246 has no fold or sinus. One from loc. 256 has a narrow and deep sinus.

Observations: This species probably is identical with a group of shells from the Kaibab limestone, probably the same as the ones referred to by Girty as *C. hillanus,* in Kaibab fossil lists. The Kaibab type is characterized, like the Glass Mountain species, by having quadrate ears and a narrow, shallow sinus. *C. quadratus* is closely related to *C. subliratus.* It differs in having a smaller size, quadrate outline, sharply defined ears, and a shallower ventral sinus. *C. hillanus* has, among other differences, much more extended cardinal extremities.

Distribution: Upper Word formation (Glass Mountains) at 145, T148, 192, 246, 247, and 256. Kaibab limestone of the Grand Canyon region.

CHONETES SPINOLIRATUS King, n. sp.*

Pl. IX, Figs. 15–16

Description: Shell very small, wider than long, ears quadrate. Pedicle valve strongly convex, beak prominent and incurved. Median sinus narrow and shallow. Ears small and not well-defined. Cardinal area fairly large, but smaller than that of the brachial valve. Cardinal margin with 3 spines on each side of the beak. Brachial valve concave, but with a very faint median ridge. Cardinal process quadrified, with two median lobes almost united. Surface of both valves ornamented with moderately strong lirae, numbering 5 to 6 in the space of 1 mm.; each lira divides once between the beak and the margin. The lirae of both valves appear to be hollow and open out at regular intervals in forward-projecting spine bases about 1 mm. or less apart. Dimensions in mm. of the type specimen: length 5, width 6, convexity 2.

Observations: The small size, narrow median sinus, strong lirae, and the possession of spines on the lirae serve to distinguish this species from all the others in this fauna. The specimen from loc. 92 has somewhat stronger lirae than the type, and spines cannot be seen on the lirae. There is, however, no other apparent difference, and the absence of spines is probably due to difference in the preservation.

Distribution: Wolfcamp formation (Glass Mountains) at 91a (type), 92, and 175a.

*This species may be identical with *C. quadratus* Girty, Jour. Wash. Acad. Sci., Vol. 19, 1929, p. 707.

*Probably a synonym of *C. victoriensis* Girty, Jour. Wash. Acad. Sci. Vol. 19, 1929, p. 410.

CHONETES SPINOLIRATUS DIABLOENSIS King, n. var.

Pl. IX, Fig. 23

Description: This variety differs from typical *C. spinoliratus* in having much stronger lirae, their number being 4 or less in the space of 1 mm. The spines arising from them are larger and fewer. It is also somewhat more strongly convex. Length 4.5 mm.; width, 6.5 mm.; convexity, 2 mm.

Distribution: Hess formation (Sierra Diablo) at 476 and 479. Rare.

CHONETES SUBLIRATUS Girty

Pl. IX, Fig. 25; Pl. X, Figs. 1–7

1908 *Chonetes subliratus.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 228–229, pl. 20, figs. 4–7.

Dark limestone, Pine Spring (sta. 2930); Delaware Mountain formation, Guadalupe Point (sta. 2919); ?Basal Capitan, hill southwest of Guadalupe Point (sta. 2906).

Description: Shell of medium to large size, wider than long, alate, strongly concavo-convex. Sinus of the pedicle valve strong, the shell rising in two humps on each side of the sinus and descending abruptly toward the wings, which are depressed and convex. Cardinal area broad, lying nearly in the plane of the valve margin. Spines about 7 in number on each side of the beak, their bases inclined backward toward the beak at an angle of about 45°, then turning at right angles upon reaching the edge of the area so that the spines extend back away from the beak. Delthyrium (as shown in a specimen from loc. 46) bordered by strong hinge-teeth, which are not supported by septa. Median septum low at the posterior end, but extending into a high, irregular, pustulose ridge which reaches three-fourths the length of the valve. Muscle scars irregularly striated. Lateral interior part of the shell marked by coarse granules arranged in distinct radial rows.

Brachial valve corresponding closely with the pedicle valve in curvature. Dorsal area about half as high as the ventral. Cardinal process quadrilobate on the posterior face, uniting forward with crural plates. Muscle scars separated by a median ridge, enlarging forward, and by two lateral ridges lying at a low angle to the septum, and each ending in a low protuberance. Anterior part of the inside of the valve raised into a marginal ridge, which is undeveloped along the median line. Interior surface of both valves strongly papillose.

Where perfectly preserved, the surface is essentially smooth, being marked only by very fine growth lines and by regularly spaced round holes that run obliquely out through the shell and may represent the bases of hollow spines. Where the outer shell layer has been removed by weathering, as is the case in most of the specimens from the Leonard and all of those studied by Girty, the underlying layer with radial striae is exposed; these striae are defined by rows of punctae, about 6 of which are present in the space of 1 mm. Only about a fourth of the specimens from loc. 123 show the outer smooth layer, while practically all those from the Word do. In some shells the outer layer has been partly worn through or partly destroyed during silicification, so that the striae may be seen through it.

Dimensions in mm. of several specimens:

	1 (loc. 250)	2 (loc. 123)	3 (loc. 123)	4 (loc. 144)	5 (loc. 253)
Length	15	10	15	33	22
Width	26	14	26	20	14

Observations: The only apparent differences between these specimens and *C. hillanus* Girty, from the Capitan, are that these are more strongly convex, more subquadrate, and probably have a stronger sinus. If the surface of *C. hillanus* as described were perfectly preserved, then this shell differs also in having a smooth outer layer pierced by pores; as indicated above, however, it is doubtful if Girty had perfect specimens on which to base his species.

C. subliratus is related to *C. ostiolatus* but there is a well developed sinus, while there is none in *C. ostiolatus*. *C. subliratus* may be confused with large specimens of *C. verneuilianus* if the outer layer has been destroyed, so that the punctate and striate interior is exposed, but the earlier species has a deeper and narrower sinus, and its punctae are not arranged in lines along the striae as in *C. subliratus*. It is also a much smaller shell than the Permian species.

The Salt Range species *C. morahensis*, *C. avicula*, *C. trapezoidalis*, and *C. bipartita* are much like *C. subliratus*, but do not have at all the same configuration of the sinus as the American species. They do, however, show traces of a similar perforation of the smooth shell by pores. *C. obtusa* Schellwien, from the Auernig formation, differs from *C. subliratus* in being less convex and having a much weaker sinus.

Distribution: Hess? formation (Glass Mountains) at 207. Leonard formation (Glass Mountains) at 3, T9, 12, T15a, 16, 20, 31, T119, 129, 123 (extremely abundant), 124, 227, 231?, D7, and D1. Leonard? formation (Glass Mountains) at 78, 82, T82a, and 83. Word formation (Glass Mountains) at 44, 46, 54?, 139, T140, T141, 144, 145, T148, Tx148, 238, T238, 239, T239, 241, 243, 250, 253, 265, and Tx. Vidrio member (Glass Mountains) at 49. Lower Hess formation (Sierra Diablo) at 471. Hess formation (Sierra Diablo) at 476 and 479. Bone Canyon member (Sierra Diablo) at 484. Victorio Peak member ((Sierra Diablo) at 499. Leonard formation (Finlay Mountains) at 512 and 513.

CHONETES VERNEUILIANUS Norwood and Pratten?*

Pl. IX, Fig. 5

1854 *Chonetes verneuilianus*. Norwood and Pratten, Jour. Acad. Nat. Sci. Phila., vol. 3, p. 26, pl. 2, figs. 6–6c.

Description: Shell small, wider than long, widest at the hinge-line. Pedicle valve convex, with a deep rounded median sinus, originating near the beak and widening slightly toward the anterior margin; ears more or less angular, flattened; beak rather prominent and incurved. Cardinal areas moderately developed, largest on the pedicle valve. Cardinal margin with 4 or 5 oblique spines on each side of the beak. Brachial valve rather deeply concave. Surface of both valves ornamented by fine lirae.

Dimensions in mm. of three specimens:

	1 (loc. 94s)	2 (loc. 75)	3 (loc. 94)
Length	9	10	7
Width	14	16	10

The specimen from loc. 94 is exceptional in having a shorter hinge-line than the greatest width of the shell.

Observations: This species is distinguishable by its convex pedicle valve and its deep median sinus. The specimens from loc. 94s* were identified by Schuchert as *Chonetes subliratus*. That species is very similar to *C. verneuilianus*, but is in general less strongly bilobate, larger, and has an outer smooth layer perforated by pores.

A bilobate Chonetes that may belong to this species was collected from section 1, bed 11, near Las Delicias, Coahuila. It has a narrower and deeper sinus than the Wolfcamp specimens assigned to this species.

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) T88, 94, and 94s. Wolfcamp formation (Glass Mountains) at 75, 87?, and 195.

Genus ISOGRAMMA Meek and Worthen

Diagnosis: Shells short, transversely elongate, hinge-line straight, generally making the greatest width of the shell. Pedicle valve slightly convex, with traces of a broad, obscure median sinus; brachial valve flat. Shell very thin and fragile, with a coarsely prismatic cellular structure. Surface covered with numerous regular and continuous concentric rounded ridges which are separated by furrows of equal width. In the pedicle valve there is no cardinal area, teeth exceedingly small. A pair of divergent, elevated ridges originate within the apex of the valve and extend for a third or even half the length of the shell, inclosing a thickened area or platform which terminates abruptly in a transverse anterior margin. This platform bears the adductor and diductor muscles, and probably rests on the bottom of the valve and is not vaulted. In the brachial valve there is a prominent cardinal process, from the base of which diverge two lateral ridges or socket-walls, lying just within the hinge-line; behind them are linear depressions or dental sockets.

*See *C. consanguineus* Girty, Jour. Wash. Acad. Sci., Vol. 19, 1929, p. 409.

*See Am. Jour. Sci., vol. 14, 1927, p. 392.

There is a low median ridge extending from the base of the cardinal process into the pallial region.

Genotype: *Chonetes? millepunctata* Meek and Worthen.

Geologic range: Pennsylvanian and lower Permian.

ISOGRAMMA MILLEPUNCTATA (Meek and Worthen)

Pl. X, Fig. 8

1870 *Chonetes? millepunctatus.* Meek and Worthen, Proc. Acad. Nat. Sci. Phil., p. 35.

1873 *Isogramma millepunctata.* Meek and Worthen, Geol. Surv. Ill., vol. 5, p. 568.

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at 203. Upper Wolfcamp formation (Sierra Diablo) at 456.

Family PRODUCTIDAE

In the present paper an attempt is made to classify the species of this family according to the work of Thomas, Chao, Fredericks, and Muir-Wood.* As there is a great deal of conflict in the ideas of these different writers, it has been necessary to correlate their work. The classification of Chao is accepted in the main, and the following artificial key to the genera of Productidae is taken from his second work, but with some additions and changes. Genera recognized in the species described in the present paper are starred.

I Cardinal area present.

- A Ventral median septum absent.
  - 1 Shell small; costae discontinuous, nodose; cardinal teeth present. . . . *Productella* Hall.
  - 2 Shell large, broad; striate, cardinal teeth absent. . . . *Kansuella* Chao.
  - 3 Shell semireticulate. . . . *Sinuatella* Muir-Wood.
- B Well-developed ventral median septum present.
  - 1 Shell pustulose, cardinal area low, ventral beak incurved. . . . *Tschernyschewia* Stoyano.
  - 2 Shell pustulose, cardinal area very high, ventral beak erect. . . . *Scacchinella* Gemmellaro.*

II Cardinal area absent.

- A Visceral region of the interior of the brachial valve not defined by marginal elevations.
  - 1 Surface pustulose.
    - a Surface with well-marked wrinkles bearing one or more rows of pustules. Brachial ridges diverge from the median ridge of the brachial valve some distance anterior to the cardinal process. . . . *Pustula* Thomas.*
    - b Surface with well-marked wrinkles bearing a row of pustules. Brachial ridges diverge from the base of the cardinal process, each pair of ridges having the shape of a ladle. . . . *Overtonia* Thomas.*
    - c Surface with elongate pustules in early stages, replaced in later stages by concentric bands bearing pustules of two sizes (as in *P. nebraskensis*). . . . *Juresania* Fredericks
    - d Surface with quincunxially arranged pustules. . . . *Waagenoconcha* Chao.*
  - 2 Surface pustulo-plicate.
    - a Surface marked by tubercles in the early stages, giving rise to plications in later stages. . . . *Avonia* Thomas.*
    - b Surface marked by elongate pustules arranged in lines to form costae. . . *Buxtonia* Thomas.*
  - 3 Surface plicate and generally semireticulate. . . . *Productus* Sowerby.*
  - 4 Surface lirate.
    - a Hinge-line wide, visceral cavity deep.
      - (1) Anterior margin evenly convex. . . . *Linoproductus* Chao.*
      - (2) Anterior margin of the pedicle valve elongated into a narrow proboscis. . . . *Proboscidella* Oehlert.
    - b Hinge-line short, visceral cavity narrow. . . . *Striatifera* Chao.*
  - 5 Surface smooth.
    - a Wrinkled in early stages. . . . *Plicatifera* Chao.
    - b Unwrinkled. . . . *Horridonia* Chao.
- B Visceral region of the interior of the brachial valve defined by marginal elevations.
  - 1 Inner surface of the brachial valve outgrown at its geniculation to form a raised platform. . . . *Diaphragmus* Girty.
  - 2 Inner surface of the visceral area of the brachial valve surrounded by a marginal ridge. . . . *Marginifera* Waagen.

Genus PRODUCTUS Sowerby

Diagnosis: Shells varying in size from small to very large, deeply concavo-convex in form, brachial valve geniculate, the anterior part of the shell being produced in a

*Thomas, Ivor: The British Carboniferous Producti. I.—Genera ***Pustula*** and *Overtonia.* Mem. Geol. Sur. of Great Britain, Palaeontology, vol. 1, pt. 4, pp. 197–366. 1914.

Chao, Y. T.: Productidae of China. Part I: Producti. Pal. Sinica, ser. B, vol. 5, fasc. 2. 1927.

Chao, Y. T.: Productidae of China. Part II: Chonetinae, Productinae and Richthofeninae. Pal. Sinica, ser. B, vol. 5, fasc. 3. 1928.

Fredericks, Georges: Communication for the Classification of the Genus Productus. Bull. du Com. Géol. (Russia). t. 46. no. 7. pp. 773–792. 1928.

Muir-Wood, Helen M.: The British Carboniferous Producti. II.—*Productus (sensu stricto)*; *semireticulatus* and *longispinus* groups. Mem. Geol. Sur. of Great Britain, Palaeontology, vol. 3. pt. 1. pp. 1–217. 1928.

long, narrow trail. Hinge-line straight, equaling the greatest width of the shell; ears generally extended. Pedicle valve without cardinal area or hinge-teeth, the two valves being held together at the cardinal margin by the strongly incurved beak of the pedicle valve. Cardinal area, dental sockets, and socket plates absent or very rudimentary, the cardinal process large and strong, extending far beyond the hinge-line. Visceral region of the brachial valve not defined by marginal ridges. Surface of both valves marked by radiating costae, and, in typical forms of the genus, by strong concentric wrinkles in the visceral region. The *P. guadalupensis* group is unwrinkled. Hollow spines are present over the shell surface, generally most conspicuously developed on the ears.

Genotype: Here regarded as *Anomites semireticulatus* Martin.

Geologic range: Mississippian to Permian.

Observations: While it is known that the true genotype of *Productus, Anomites productus* Martin, is actually a *Diaphragmus*, it is preferred to use the name here in the old sense, as if *A. semireticulatus* were the type.*

PRODUCTUS ARCTICUS Whitfield

Pl. X, Figs. 16–17

1878 *Productus semireticulatus.* Etheridge, Quart. Jour. Geol. Soc., vol. 34, pp. 629–630.
Fielden Isthmus, Ellesmere Island.

1908 *Productus semireticulatus arctica.* Whitfield, Bull. Amer. Mus. Nat. His., vol. 24, pp. 54–55, pl. 1, no. 2, pl. 2, figs. 8–10.
Cape Sheridan, Ellesmere Island.

1916 *Productus inflatus.* Tschernyschew and Stepanow, Rept. of Second Norw. Arctic Exp. in "Fram," vol. 34, pp. 30–32, pl. 5.
Store Björnekap, Ellesmere Island; Svarte Veg, Heiberg Island.

?1917 *Productus inflatus.* Grönwall, Marine Carboniferous of Northeast Greenland, Medd. om. Grønland, vol. 43, pp. 578–579, pl. 29, figs. 17–19.
Cape Jungerson and Eskimo Naze, Northeast Greenland.

Description: Shell rather large, with the hinge-line equaling the greatest width of the shell. Pedicle valve strongly convex longitudinally and abruptly geniculate at about two-fifths the length from the beak to the anterior margin, the curvature in front of and behind the geniculation being relatively low, though the beak is strongly incurved. Visceral region narrow and pointed, the umbonal angle being about 75°; lateral slopes of this region steep, setting off the ears sharply. Median sinus narrow but distinct, originating near the beak and maintaining about the same size from there to the front margin. Brachial valve nearly flat in the posterior half, then sharply geniculated. Interior of the pedicle valve strongly pustulose, especially in the anterior and lateral parts. Diductor muscle scars small but deeply impressed, and coarsely and irregularly striate. The adductor scars lie on the ridge between the diductors, and are divided by a groove.

Surface marked by medium-sized, even ribs, numbering 7 to 9 in the space of 10 mm., which remain of practically constant number in the median part but divide by bifurcation on the lateral slopes. Posterior to the geniculation the surface is crossed by low wrinkles, which are fine and strong on the wings. The part of the shell anterior to the reticulate region bears unevenly distributed spine bases, which are very small for so large a shell. Two rows of spines lie along the lateral slopes of the visceral region.

Dimensions in mm. of several specimens:

	1 (loc. 247)	2 (loc. 246)
Length	36	36
Width	35	37
Thickness	20	21

Observations: This species is distinguished by the geniculation and the low convexity in front of and behind it, by the incurved beak, by the pointed visceral region, by the narrow median sinus, by the low wrinkling of the posterior part, and by the small spines distributed over its surface. The Texas specimens agree perfectly with the figures and brief description of Whitfield. Tschernyschew and Stepanow figure as *P. inflatus* specimens that are quite like *P. arcticus*, but seemingly differ in several respects from the "*P. inflatus*" of the Uralian.

Distribution: Upper Word formation (Glass Mountains) at 143, 152, 246 (common), and 247 (common).

PRODUCTUS CAPITANENSIS Girty

Pl. X, Fig. 15

1858 *Productus semireticulatus.* Shumard, Trans. Acad. Sci. St. Louis, vol. 1, p. 292 (date of volume, 1860).
White (Permian) limestone: Guadalupe Mountains.

1859 *Productus semireticulatus* var. *antiquatus.* Shumard, *idem*, p. 389.
White (Permian) limestone: Guadalupe Mountains.

1908 *Productus semireticulatus* var. *capitanensis.* Girty, The Guadalupian Fauna, U. S. G. S. Prof. Paper 58, pp. 254–255, pl. 12, figs. 1–3b; pl. 20, figs. 8–8a(?).
Top of Capitan, Capitan Peak (sta. 3762); middle Capitan, Capitan Peak (sta. 2926); basal Capitan, hill southwest of Guadalupe Point (sta. 2906); (?) dark limestone, Pino Spring (sta. 2930).

Description: Shell large. Pedicle valve strongly convex, beak low. Sinus strong, narrow, extending nearly to the beak. Surface marked by fine costae, about 5 in number in 5 mm., and in the posterior part by concentric wrinkles, which produce nodes where they cross the ribs. Width, 37 mm.; length, 27 mm. plus.

Observations: This species is distinguished by its fine costae and strong narrow sinus. The specimens from the upper dark limestone of the Delaware Mountain formation identified by Girty as *P. capitanensis* are more coarsely costate, in which respect they are more similar to *P. arcticus*, which occurs at the equivalent horizon in the Glass Mountains.

*Editor's footnote: Miss Muir-Wood has recently proposed the name *Dictyclostus* for the "semireticulatus" group. Ann. and Mag. Nat. Hist., Vol. V, 1930, p. 103.

Distribution: Gilliam member (Glass Mountains) at 179 (one incomplete specimen).

PRODUCTUS COMANCHEANUS Girty

Pl. XI, Fig. 1

1908 *Productus guadalupensis* var. *comancheanus.* Girty, The Guadalupian Fauna, U. S. G. S. Prof. Paper 58, pp. 261–262, pl. 31, figs. 5–5b.
Delaware Mountain formation, "Comanche Canyon," Glass Mountains.

Description: Shell medium-sized, very wide in proportion to length. Pedicle valve strongly convex. Beak rather prominent. Ears long and depressed. Sinus deep and narrow, giving the shell a bilobate form. Surface marked by coarse ribs, numbering 4 or less in the space of 5 mm. No concentric wrinkling is visible. Length, 13 mm.; width, 32 mm. Length of Girty's type, 16 mm., width 38 mm.

Observations: In both Girty's collection and my own there is but a single specimen of this species. Girty considered it to be very close to *P. guadalupensis*, but it appears to me to be quite distinct, being much shorter in proportion to width, and having larger ribs which probably are not at all crossed by concentric undulations.

Distribution: Word formation (Glass Mountains) at 144.

PRODUCTUS DARTONI King, n. sp.

Pl. X, Figs. 12–13

Description: Shell small, transversely subquadrate, with the greatest width at the hinge. Pedicle valve strongly convex, geniculated at about two-fifths the length from beak to front. Umbonal region highly inflated; beak incurved over the cardinal margin. Ears very sharply defined, the lateral slopes of the visceral area being very steep. Sinus broad and shallow. Brachial valve flattened in the visceral area, then abruptly geniculated.

Surface of the pedicle valve marked by low, rounded costae, numbering about 6 in the space of 5 mm., separated by much narrower striae. The visceral area is crossed by low concentric wrinkles (hardly distinguishable in the specimen from loc. 460). Small spines are unevenly distributed over the surface, and an oblique row of prominent spines lies along the inner side of each wing.

Dimensions in mm. of several specimens:

	1 (loc. 460)	2 (loc. 399)	3 (loc. 385)
Length	19	22	19
Width	23	26	25
Convexity	13	12	11

Observations: This species is distinguished from other similar ones in the fauna by its low, fine even ribs, well-marked sinus, geniculated profile, and prominent ventral umbo. The specimens from the Victorio Peak member have a short snout-like emargination of the anterior margin, a fact suggesting relation to "*Proboscidella*" *genuina* Kutorga, which is externally somewhat similar. However, as Fredericks has pointed out, the presence of this anterior median extension is probably not of great significance.

Distribution: Lower Gym formation (Hueco Mountains) at 377b, 385, and 399. Upper Gym formation (Hueco Mountains) at 440. Upper Wolfcamp formation (Sierra Diablo) at 459 and 460 (type). Hess formation (Sierra Diablo) at 479.

PRODUCTUS DARTONI SULLIVANENSIS King, n. var.

Pl. X, Fig. 14

Description: This variety differs from typical *P. dartoni* in having a low, small beak instead of an inflated umbonal region, and somewhat coarser costae. Dimensions of a specimen from loc. 46: length 22 mm., width 25 mm.

Distribution: Word formation (Glass Mountains) at 46, 132, and T239. Word formation?, thin-bedded zone (Shafter) at Tj. Victorio Peak member (Sierra Diablo) at 493.

PRODUCTUS GUADALUPENSIS Girty

Pl. X, Figs. 9–11

1908 *Productus guadalupensis.* Girty, The Guadalupian Fauna, U. S. G. S. Prof. Paper 58, p. 261, pl. 22, figs. 1–2.
Delaware Mountain formation, Guadalupe Point (stas. 2919 and 2931).

Description: Shell medium-sized, inflated, wider than long. Pedicle valve so enrolled that its profile is semicircular. Beak low, bluntly pointed, not extending beyond the hinge-line; umbonal region depressed, showing in profile a very low convexity. Ears low, convex, greatly extended. Median sinus strong, narrow, originating near the beak. On one shell from loc. 247 the sinus is broad and deep, and the shell as a result is strongly bilobed. Brachial valve deeply concave, with a low median fold. Surface marked by radial lirae, numbering 6 to 8 in the space of 5 mm., and by a few widely scattered large spines in the marginal region. There are no concentric ribs in the umbonal region, but a few faint undulations of growth are present on some specimens in the mid-part of the shell.

Dimensions in mm. of several specimens:

	1 (loc. 247)	2 (loc. 247)	3 (loc. 247)	4 (loc. 246)
Length	19	22	18	21
Width	36+	44+	27	40

Observations: This species is distinguishable from related forms by its rather fine costae, absence of wrinkles, few but large spines, prominent sinus, low umbonal region, and extended ears. The specimens from the Glass Mountains have coarser ornamentation and a flatter ventral umbonal region than Girty's types. The differences give the type an aspect close to that of *P. schucherti*, but the latter species has very significant differences—pronounced wrinkling of the posterior part, large spines on the ears, and generally larger costae, and, moreover, it occurs at a lower stratigraphic level. *P. guadalupensis* differs from *P. multistriatus* in having smaller size, coarser costae, and stronger enrollment. It resembles *P. geniculatus* Girty and *P. mammatus* Keyserling in many respects, but is larger and has a deeper sinus and longer ears.

Distribution: Word formation (Glass Mountains) at 148, T148, Tx148, 155, 246 (common), 247 (abundant), and Tc.

PRODUCTUS HESSENSIS King, n. sp.

Pl. XI, Figs. 3–6

Description: Shell rather large, transversely subquadrate. Pedicle valve slightly convex in the posterior third, the beak overarching the hinge-line but little; somewhat posterior to mid-length there is generally more or less of an increase in curvature, and the curvature decreases gradually to the front margin. Ears broad, rather flat, and not sharply defined. Median region deprest to form a deep, narrow sinus. Brachial valve strongly geniculate, being nearly flat in the visceral region and having a long trail; along the median line there is a low elevation corresponding to the ventral sinus. Visceral regions of both valves marked by fine concentric wrinkles. Radial costae even and very fine, numbering 8 to 11 in 10 mm. Spines rather fine and on most specimens rather widely spaced, but some well-preserved specimens (loc. 510 and Tzz, aa) show rather thickly spaced spines. Spines on the ears not large or abundant.

Dimensions in mm. of several specimens:

	1 (loc. 106)	2 (loc. Tzz, aa)	3 (loc. Tzz, aa)
Length	34	42	36
Width	45	46	34
Convexity	16	25	19

Observations: This species differs from the common Pennsylvanian types designated as *P. semireticulatus* in having a low beak, more or less geniculation, narrow median sinus, and fine costation. *P. capitanensis* is somewhat similar, but has a narrower median sinus and a more strongly geniculate profile. The specimens of *P. hessensis* from northern Trans-Pecos Texas shows less geniculation and less distinct median sinus than those from the Glass Mountains.

Distribution: Upper Hess formation (Glass Mountains) at 106 (type), 107, T107, and 222. Lower Gym formation (Wylie Mountains) at 507 and Tzz, aa. Lower Gym formation (Carrizo Mountains) at 510. Lower Gym formation (Hueco Mountains) at 405 and 408.

PRODUCTUS HUECOENSIS King, n. sp.

Pl. XI, Figs. 7–8

Description: Shell large, very strongly convex, transversely subquadrate. Pedicle valve evenly convex (though the specimen from loc. 382 is geniculated at about mid-length), the longitudinal curvature decreasing gradually forward. Median region flattened or depressed to form a broad, shallow sinus. Ears well-defined, broad, and depressed. Brachial valve concave in its posterior two-thirds, then very strongly geniculate. Surface ornamented with radial ribs to the number of about 10 in the space of 10 mm., of rather even constant size except immediately anterior to a bifurcation. The visceral region is crossed by low or indistinct wrinkles, which are stronger on the lateral slopes and the ears. The part of the shell anterior to the wrinkled region has many relatively small spines rather evenly distributed. A row of large spines lies in an oblique row between each ear and the umbonal slope. On the type specimen the spines either lie at the point of bifurcation of a costa, or give rise to a single large costa in place of several smaller ones, on the anterior slope.

There is considerable variation in the specimens referred to this species. That from loc. 382 has a strong geniculation, broad visceral region, broader, deeper sinus, and coarser costae than the type. The specimens from loc. 193 are small and more inflated in the visceral region.

Dimensions in mm. of several specimens:

	1 (loc.	2 (loc. 380 —crushed)	3 (loc. 380 —type)	4 (loc. 193)
Length	38	45?	40	33
Width	53	70	58	50
Convexity	29	—	23	19

Observations: This form is distinguished from *P. hessensis* and *P. capitanensis* by being broader, with an indistinct sinus, and by the presence of a row of spines along the visceral shoulders. From *P. wolfcampensis* it differs in being much broader.

Distribution: Lower Gym formation (Hueco Mountains) at 380 (type), 382?, and 385. Upper Wolfcamp formation (Glass Mountains) at 193.

PRODUCTUS INCA d'Orbigny

Pl. XI, Fig. 2; Pl. XIII, Figs. 4–5

1842 *Productus inca.* d'Orbigny, Voy. dans l'Amér. mérid., pt. 4, vol. 3, p. 52, pl. 4, figs. 1–3.

1909 *Productus leei.* Girty, Manzano Group of Rio Grande Valley, U. S. Geol. Sur. Bull. 389, pp. 56–57, pl. 7, fig. 1.
San Andres formation; Engle, Caballos Mountains, Nogal Creek, and San Andres.

1914 *Productus semireticulatus* var. *Inca.* Kozlowski, Ann. de Pal., vol. 9, pp. 30–33, text fig. 5, pl. 3, figs. 1–7; pl. 4, fig. 18. See for synonymy.

1914 *Productus semireticulatus.* Douglas, Geological sections through the Andes, Quart. Jour. Geol. Soc., vol. 70, pp. 34–35, pl. 8, fig. 6.

Description: Shell medium-sized, subquadrate (or subtriangular if, as is commonly the case, only the visceral part is preserved), generally somewhat wider than long, with right cardinal angles. Pedicle valve strongly convex, geniculate. Beak low, projecting slightly over the cardinal line. Sides of the visceral area rounded but fairly steep, sharply set off from the ears, which are small, low, and flattened. About 10 mm. anterior to the beak there originates a narrow, shallow sinus. Brachial valve slightly concave in the visceral region, the margins of which are sharply geniculate, with a long trail anterior to the geniculation. In the median part there is an elevation corresponding to the sinus of the other valve. Brachial ridges similar to those of *P. ivesi.*

Surface of the pedicle valve marked by rather strong radial costae, crossed in the visceral part by concentric wrinkles of about the same size as the costae. Costae fairly regular and rounded, separated by rounded striae; about 6 to 7 occur in the space of 10 mm. Each costa bears, in the anterior part of the shell, several spine bases, which are unevenly distributed over the surface. A row of small spine bases lies along the cardinal margin on each side of the beak. Surface of the brachial valve similarly ornamented.

Dimensions in mm. of several specimens:

	1 (loc. 421)	2 (loc. 424)	3 (loc. 424)	4 (loc. 414)	5 (*P. leei*)
Length	28	35	28	32	24
Width	32	44	32	39	31
Convexity	13	19	16	17	13

Observations: This species was imperfectly known previous to the work of Kozlowski; the name *P. leei* was therefore applied to it by Girty in 1909. There can be little doubt that the Texas specimens are conspecific both with those from New Mexico and those from Bolivia. *P. inca* is distinguished by its low beak, coarse costae, strong wrinkles, and rather abundant spines. It somewhat resembles *P. magnicostatus*, but has a less incurved beak, smaller and more regular costae, and smaller spines. It is more coarsely costate and has a much less incurved beak than *P. semireticulatus hermosanus.*

Distribution: Middle Gym formation (Hueco Mountains) at 414, 415, 417, 418, 419, 421?, 424, 428, 439, and 434. Upper Gym formation (Hueco Mountains) at 436, 439, 449a, 444, and 449. Upper Gym formation (Wylie Mountains) at 508?. Chupadera formation (Salt Basin) at 420 (common).

PRODUCTUS IVESI Newberry

Pl. XII, Figs. 1–6

1861 *Productus ivesi.* Newberry, Rept. upon Col. River of the West Exp. by Lieut. Ives, p. 122, pl. 2, figs. 1–8.

Middle Carboniferous (Kaibab) limestone: banks of the Colorado near mouth of Diamond River.

1877 *Productus semireticulatus* (pars). White, U. S. Geol. Surv. W. 100th Mer., vol. 4, p. 111, pl. 8, figs. 1a–b (not 1c). (The legend of the plate refers to the figures as *P. semireticulatus* var. *ivesii.)*

Carboniferous: Near Bear Spring, Camp Wingate, and near Santa Fe, New Mexico; Camp Cottonwood, Old Mormon road, Lincoln County, and top of Grass Mountain, Ely range, 35 miles north of Pioche, Nevada; head of Patridge Creek; near Bill William's Mountain; Tenney's Ranch; Kaibab Plateau; head of Dry Fork and Kanab Canyon ("Aubrey" limestone), Arizona; crest of Hurricane Hill, near Toquerville, and Meadow Creek, south of Fillmore, Utah. (Some of these localities, such as that near Santa Fe, New Mexico, are probably Pennsylvanian and are not *P. ivesi.)*

1909 *Productus ivesi.* Girty, Manzano Group, U. S. G. S. Bull. 389, p. 65.

San Andres limestone, Nogal Creek, Mesa del Yeso, and San Andreas; Yeso formation, Mesa del Yeso.*

Description: Shell large, attaining a great length in proportion to width when mature, strongly convex, with extended, well-defined, strongly arched ears. Pedicle valve regularly convex, the curvature becoming gradually less toward the front. After a curvature of about 90°, or about 15 mm. in front of the beak, a slight flattening appears in the median part of the valve, and develops into a shallow but rather narrow median sinus. At the same stage the sides begin to slope more abruptly, and the low, broad ears become sharply defined from the steep lateral slopes. The entire curvature of the pedicle valve is about 180°. Brachial valve gently concave, the deepest concavity being near the beak, in front of which the surface flattens out.

Surface marked by strong radial costae, which are rather small in the umbonal region but attain a constant size over the main part of the shell, a few additional ones being introduced there by intercalation. On the pedicle valve the posterior part is crossed by concentric wrinkles, which are asymmetrical, the steepest sides being toward the beak; they are slightly more prominent and more widely spaced than the costae, and give rise to nodes where they cross the costae. Some of the nodes are the bases of large hollow spines, which are most abundant near the hinge, along which there are many large, irregularly placed spines. The ears are strongly wrinkled at right angles to the costae, and from these wrinkles there arise large laterally projecting spines. Over the median and anterior parts of the shell spines are less numerous, but still relatively abundant, occurring at intervals of 4 or 5 mm. on each costa. Their bases are hollow, and about 0.75 mm. across. The costae are somewhat variable in size, the intercalated ones being generally smaller for some distance anterior to their point of origin. In some shells the sinus pinches together forward, and the costae run into each other anteriorly along the sinus. The distance between centers of adjoining ribs is 1.5 to 2 mm., the costae and sulci being of equal dimensions. On the brachial valve the posterior part is wrinkled, but over a larger proportion of the surface than on the other valve; where radial ribs and concentric wrinkles intersect there are pits, equivalent in position to the spines of the pedicle valve. Surface marked also by fine, irregular, closely crowded undulating growth lines.

Shell of the pedicle valve very thick in large individuals; one shell is 12 mm. thick in the median part, and 7 mm. at the side, but most shells are considerably thinner. The interior of the pedicle valve bears large, deeply impressed muscle scars. The diductor scars are deeply incised, coarsely and irregularly striated, largest at about a third the length of the shell, and tapering toward the posterior end. The adductor muscle scars lie on the raised platform between the diductors, are multilobate, and are separated by a low ridge.

The interior of the brachial valve has a large trifid cardinal process, which extends beyond the hinge-line; the three branches are of about equal size, and the median one is divided by a small groove. From the process two blunt lateral ridges extend, one on each side, along the hinge-line. In the middle the process is joined by a broad median ridge, which extends forward between the muscle scars as a narrow, slightly elevated septum. The brachial ridges arise from the septum, extending first backward at angles of about 30° to the septum, then curve evenly around until parallel with the septum, and still further until they are directed backward, this end being high and straight and lying nearly parallel to the septum. Within each brachial loop there is a short elevated ridge connected with the brachial ridges, lying at an angle of 45° to the

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*The "*Productus* (undet. sp.) compare *P. ivesii*" of Meek (1877), also named by him *Productus longus* is a *Buxtonia* and occurs in the Pennsylvanian.

septum and directed toward the beak. A faint ridge connects the end of the loop again with the median septum. Inner median surface of the valve marked by short forward-projecting spines shingled over one another; the surface between the spines is strongly punctate. In front of the spinose region the surface is longitudinally roughly striated.

Dimensions in mm. of several shells:

	1(loc. 123)	2(loc. 107)	3(loc. 174)	4(loc. 174)
Length	50	50	70	51
Width	69	55	60	49
Convexity	27	28	40	28

Number 3 gives the typical dimensions of an old elongate shell. Number 4 is an unusually narrow specimen, and numbers 1 and 2 are relatively short.

If the brachial valve is somewhat caved in the valves pull apart and there is a strong appearance of a cardinal area.

Observations: This common Kaibab-San Andres species is very abundant in the Leonard and in the upper Hess of the Glass Mountains, and their equivalents in Sierra Diablo. Four badly preserved shells or parts of shells that apparently belong to *P. ivesi* were collected from beds of supposed Word age in the northeastern Glass Mountains and Sierra Madera. At localities 256 and 257 they are associated with fossils that are probably Word. The uncertainty of differentiation of Leonard and Word in this region makes the Word age of these fossils, however, doubtful, especially since *P. ivesi* has not been found in the Word in its normal phase in the western Glass Mountains. *P. ivesi* was referred to by Böse as "very large Producti of the group of *Productus sino-indicus* Frech."*

From *P. semireticulatus* and its varieties, *P. ivesi* differs in being much larger, narrower in proportion to length, and in having coarser costae and more numerous spines. Typical examples of the two cannot be confused. It differs from *P. inca* mainly in its much larger size and far more abundant spines. *P. uralicus* Tschernyschew differs in having fewer spines and probably also in some details of general form. *P. spiralis* Waagen has much larger costae and fewer spines (although, as Diener has pointed out, the specimens figured by Waagen have abnormally large costae). *P. sino-indicus* Frech is not well enough figured for satisfactory comparison. It appears to be narrower than *P. ivesi*, but is similar in other respects. No other foreign species appears to be closely similar.

Distribution: Hess formation (Glass Mountains) at 4, 7, 17, 102, 105, 106, 107, T108, 113, 128, 206, 211, 222, and 223. Leonard formation (Glass Mountains) at 9, T9, 15, T15, 21, 22, 24?, 31, 37, 38, 39, T41, 83?, 104, 119, T119, 120, 121, 123 (common and well-preserved), 124, 126, T128, 174 (extremely abundant), T233, T240, 301, D1, D4, D11, and Tb. Word formation? (Glass Mountains) at 256, 257, and 262. Hess formation (Sierra Diablo) at 141, 470, 471, 472, 476, 477, 479, and 481. Bone Canyon member (Sierra Diablo) at 484 (one of these specimens has exceptionally coarse costae and large spines), and 489. Victorio Peak member (Sierra Diablo) at 493, 495, 499, 500, and 503. Victorio Peak member (Brackett Draw) at Taa. Leonard formation (Baylor Mountains) at 503. Leonard formation (Shafter) at Tk, Tm?, 516, and 518. Leonard formation (Finlay Mountains) at 511 and 513. Gym formation (Wylie Mountains) at 508?. Limestone of Puertacitas at Puertacitas (Las Delicias) (a more finely costate individual than typical *P. ivesi).*

*U. of Texas Bull. 1762, p. 24.

PRODUCTUS LEONARDENSIS King, n. sp.

Pl. XIV, Figs. 4–9

Description: Shell medium-sized, subquadrate, with the hinge-line equal to or only slightly less than its greatest width. In most shells the hinge-line is straight, but in some the parts on opposite sides of the beak lie at an angle to each other of about 140° rather than 180°.

Pedicle valve strongly geniculated, being relatively flat in profile in the posterior and anterior halves but with the front part lying at a right angle to the visceral region, the only curvature being near the belt of geniculation. Region near the hinge nearly flat, with a low but abrupt elevation at the beak. Visceral angle relatively very narrow. Beak pointed, very low, ending essentially within the same line as the hinge margin. Ears broad and flattened, set off from the triangular, raised marginal part of the shell by well-defined sinuses. Median sinus narrow and subangular, extending from nearly the point of the beak, giving the shell a bilobed appearance. It becomes broader toward the front, but is deepest just behind the geniculation.

Brachial valve slightly concave near the beak but nearly flat near the cardinal margin, marked by a low fold corresponding to the sinus of the other valve. The brachial valve is geniculated toward the front, but less strongly than the pedicle valve.

Surface of the flattened posterior region marked by radial lirae and concentric wrinkles of the same strength, which are not asymmetric. The wrinkles converge near the hinge and become stronger; some of them give rise, about 1 to 2 mm. in front of the hinge margin, to spines which are arranged in two parallel rows on each side of the beak and are directed backward over the hinge-line. The concentric wrinkling extends as far forward as the beginning of the region of geniculation. The radial lirae number 7 to 10 in the space of 5 mm., increasing by bifurcation, the new lirae coming in in the direction of the lateral margins, while the lirae near the sinus are, except near the beak, parallel and simple.

Dimensions in mm. of several specimens:

	1(loc. 120)	2(loc. 82)	3(loc. 120)	4(loc. 120)
Width	24	28	27	28
Length	20	38	28	24

The differences in proportion of length to width are due largely to the length of the posterior geniculated part of the shell, for the width does not increase much after the reticulate posterior part of the shell has been formed. Mature specimens show evidence of lateral growth simultaneous with the forward growth of the geniculated front margin. In these the hinge-line bends forward at about 45° at the same stage of growth at which geniculation starts in the central part of the shell. These laterally extended parts of the wings turn sharply upward, forming a flange of the upturned brachial valve along the lateral margins, which may be several mm. wide. The flange lies at about a right angle to the rest of the brachial valve; toward the front it merges into the anterior extension of the shell, which is not turned back.

Observations: This species resembles the species of *Linoproductus* in the relative fineness of its radial ornamentation and in the presence of a double row of spines along the hinge, but it is clearly a true Productus. Several Russian species, especially *P. gruenewaldti* Krotow and *P. moelleri* Stuckenberg, are very similar to this species in ornamentation, but the configuration of the shells is quite different. The strong geniculation of *P. leonardensis*, the depth of its sinus, the presence of a flange along the lateral margins, and the fine sculpture distinguish it easily from all other described species of similar general nature.

Distribution: Hess formation (Glass Mountains) at 8. Leonard formation (Glass Mountains) at 4, 7, 9, 10, 11, 12, 13, 15, 21, 31, 37, 82, 83, 102, 104, 119, 120 (types), T120, 123, 231, 232, and Tb. Word formation (Glass Mountains) at 48 (single specimen). Bone Canyon member (Delaware Mountains) at 491. It is a very abundant and widespread Leonard fossil.

PRODUCTUS GRATIOSUS OCCIDENTALIS Schellwien

Pl. XIV, Figs. 1-3

1892 *Productus gratiosus* Waagen var. *occidentalis*. Schellwien, Die Fauna des karnischen Fusulinenkalks, Palaeontographica 39, pp. 24-25, pl. 3, figs. 6–9; pl. 8, fig. 25.

1927 *Productus gratiosus* var. *occidentalis*. Chao, Productidae of China, Pal. Sinica, vol. 5, fasc. 2, pp. 44-47, pl. 4, figs. 6–10.

Description: Shell small, transversely subquadrate, with the hinge-line equaling the greatest width. Pedicle valve flattened posteriorly, then broadly geniculated beyond the reticulated region, in front of which the curvature is slight and even. Beak pointed, only slightly incurved over the hinge. Ears flattened, set off from the rest of the shell by a concavity. Median sinus originating near the beak, narrow and moderately deep, of constant size throughout its length. Brachial valve slightly and regularly concave in the visceral region and sharply geniculated toward the front. Median fold low and distinct.

Surface of both valves marked by many high, rounded, relatively coarse costae, separated by deep sulci, which are much narrower than the costae. The costae in the median sinus of the pedicle valve are smaller than those on each side, and they converge toward the center, where they unite or become small and disappear. Posterior region marked by many fine regular concentric ridges, giving the surface a delicate reticulation. They are somewhat smaller than the costae. There is a flange-like lateral ridge on each visceral slope, which originates as a faint elevation slightly behind the geniculation, and extends at first oblique to the radial costae. After passing over the geniculation it joins several costae and develops into a large thickened ridge, bearing a row of several spines. There are many forward-directed spines that arise from the reticulated surface, and each costa bears several spines between the anterior end of the reticulate region and the front margin.

Dimensions in mm. of several specimens:

	1 (loc. 93)	2 (loc. 93)	3 (loc. 93)	4 (loc. Sd)
Length	14	16	17	20
Width	20	22	22	26

Observations: These specimens agree perfectly in all details with Chao's description and figures, detailed comparison with Schellwien's rather inadequate figures being difficult. This species is distinguished from all others in the Glass Mountains fauna by the strong reticulation of the posterior part, the large, rounded costae separated by very narrow sulci, and the large number of spines on the costae. The variety is distinguished from typical *P. gratiosus* Waagen by the presence of the thickened spine-bearing rib on each side of the visceral area.

Distribution: Gaptank formation (Marathon basin) at Sd (bed 3 of the Gap Tank section). Wolfcamp formation (Glass Mountains) at T91 and 93.

PRODUCTUS MULTISTRIATUS Meek

Pl. XIII, Figs. 1–3

1860 *Productus multistriata*. Meek, Proc. Acad. Nat. Sci. Philadelphia, vol. 12, p. 309.
Upper Carboniferous?: East side of Long Valley, lat. 39°57′; long. 115°10′.

1876 *Productus multistriatus*. Meek, Simpson's Rept. Expl. across the Great Basin of Utah, p. 350, pl. 1, figs. 8a–b.
Yellow ls. (Upper Carboniferous?): Long Valley.

1876 *Productus multistriatus*. White, Powell's Rep. Geol. Uinta Mts., p. 90.
Lower Aubrey group: Confluence of Grand and Green rivers, Utah.

1877 *Productus multistriatus*. Meek, King's U. S. Geol. Expl. 40th Parallel, vol. 4, pp. 76–78, pl. 8, figs. 3–3e.
Carboniferous ls.: Near center of the eastern margin of Nevada; Ruby Group and Mahogany Peak, Eagan Range.

1920 *Productus multistriatus*. Girty, U. S. G. S. Prof. Paper 111, pl. 56, figs. 7–7a.
Permian: Utah.

Description: Shell rather large, wider than long, with extended ears, which are broad and not sharply defined from the rest of the shell. The greater width than length stated for the present specimens may not actually be the case for the species if the anterial trail were completely preserved. Profile of the pedicle valve of very low convexity in the posterior part, then sharply geniculated. Beak low and bluntly pointed. Median sinus originating near the beak, but only slightly developed posterior to the geniculation, in front of which it is deep and narrow. Surface marked by fine radial lirae, 8 to 12 of which occur in the space of 5 mm. Only very faint concentric undulations are present. Spines are arranged in a row along the hinge, and are inclined strongly outward; the other spines are scattered sparsely and irregularly.

Dimensions in mm. of several specimens:

	1 (loc. 144)	2 (loc. 144)	3 (loc. 6)	Las Delicias	Meek's type
Length	24	23	18+	20	25
Width	40	42	35	21	44

Observations: This species is characterized by the flat visceral region of its pedicle valve, the strong geniculation at mid-length, and the fine liration. The specimens from Las Delicias are much smaller than those from the Glass Mountains. The forms identified by Tschernyschew as *P. multistriatus* var. have much coarser costae than the American form, and no prominent geniculation. *P. weyprechti* Toula is probably the most similar foreign species. It has coarser ornamentation and is less strongly arcuate.

Distribution: Word formation (Glass Mountains) at 6, 144, and T240. Limestone of Cerro Caballo (Las Delicias, section 1, bed 14, west of the Noria de Malascachas.

PRODUCTUS INDICUS Waagen

Pl. XIII, Figs. 6–9

1882 *Productus indicus.* Waagen, Productus-limestone Fossils, Pal. Indica, ser. 13, vol. 1, pt. 4, pp. 687–690, pl. 70, pl. 71, fig. 1. (See for further synonymy.)

"The commonest species of the Salt-range. It is restricted to the middle and upper divisions of the Productus-limestone."

1915 *Productus indicus.* Diener, Anthracol. Faunae of Kashmir, Kanaur, and Spiti, Pal. Indica, n. s., vol. 5, mem. 2, pp. 66–67, pl. 6, fig. 15.

Zewan beds, Kashmir.

Description: Pedicle valve strongly convex, showing in profile a regular curve; beak greatly incurved over the hinge-line. Wings very large, arcuate, and sharply set off from the rest of the shell. Hinge-line straight, wide, making the greatest width of the shell. Median sinus deep but fairly broad, originating near the beak and maintaining a nearly uniform width and depth from a place about 20 mm. in front of the beak to the anterior margin. Brachial valve concave in the visceral region and strongly geniculated at the outer border of that region.

Shell marked by very large, very unequal costae, some of which bifurcate and some unite with an adjacent costa. The strength of the costae varies from one specimen to another. In the sinus some costae may converge and disappear. Rather small, subequal wrinkles cover the visceral region and extend more or less upon the wings. A double row of heavy spines is borne on the posterior slope of the ears and the rest of the shell is marked by much smaller spines borne at intervals of 5 or 6 mm. along the costae.

Dimensions in mm. of several specimens:

	1 (loc. 46)	2 (loc. 46)	3 (loc. T251)
Length	37	44	30
Width	52	74	48

Observations: The Texas specimens show no characters that are not included within the range of variations of the specimens figured by Waagen. *P. indicus* is distinguishable from *P. ivesi* by its coarser costation, smaller size, and less prominent reticulation, and from *P. occidentalis* by its larger size, much greater breadth, and larger ears.

Distribution: Leonard formation (Glass Mountains) at Tb. Word formation (Glass Mountains) at 46 (abundant), 58, 141, and T251. Upper Hess formation (Sierra Diablo) at 480?. Leonard formation (Shafter) at 518. Word? formation—thin-bedded zone (Shafter) at Tk.

PRODUCTUS OCCIDENTALIS Newberry

Pl. XIV, Figs. 10–14

1858 *Productus costatus.* Marcou, Geol. of N. A., p. 46, pl. 5, fig. 5 (?).

Carboniferous: Cedar Creek, Mogollon Mountains, tributary of Gila River, sources of Colorado Chiquito.

1861 *Productus occidentalis.* Newberry, Rept. upon Col. R. of the West Exp. by Lieut. Ives, p. 122, pl. 2, figs. 9–10.

Cherty limestone near top of Carboniferous (Kaibab): banks of Cascade River near junction of Great and Little Colorado.

1908 *Productus occidentalis.* Girty, The Guadalupian Fauna, U. S. G. S. Prof. Paper 58, pp. 262–263, pl. 12, figs. 4–4c.

Middle Capitan, Capitan Peak (sta. 2926); dark limestone, Pine Spring (sta. 2930).

Description: Shell medium-sized, relatively very narrow, with the hinge-line forming the greatest width of the shell. Pedicle valve strongly inflated in the umbonal region, its curvature decreasing toward the anterior margin. The median sinus originates about 1 cm. in front of the beak and becomes broad and fairly deep. Ears broad, separated from the rest of the shell by deep sinuses. Costae uneven, large, from 2 to 3 mm. across and 20 to 26 in number. In some specimens the costae bordering the sinus are particularly large, while those in the sinus are much smaller and, in shells becoming laterally compressed toward the front, uniting toward the anterior margin. Other shells, however, are quite regular and the costae in the sinus are only slightly smaller than those of the rest of the shell. On the anterior part of the shell a few sparsely distributed large spines arise from the costae. Posterior and alar region marked by a few very faint concentric wrinkles, which give a somewhat nodose appearance. Some of the nodes give rise to spines, one of which, arising from an ear, is more than 2 cm. long.

Brachial valve gently concave, the deepest concavity being near the beak.

Pedicle valve with deeply incised, irregularly striated diductor muscle scars; adductor muscle scars multilobate, marking the raised platform between the diductors. Interior of the brachial valve having a large cardinal process, from the anterior end of which extends a low median ridge, and on each side a lateral ridge which extends along the hinge-line. Muscle scars small, oval, and elevated, bordered at the front by the brachial ridges, which arise from the median septum and extend laterally half way to the shell margin, curving continually forward, then reversing to produce a hook-like form, the ends pointing back toward the point of origin but not quite meeting the septum. The rest of the interior surface of the valve marked by fine granules.

Dimensions in mm. of several specimens:

	1 (loc. 128)	2 (loc. 123)	3 (loc. 174)	Kaibab, Grand Canyon
Length	36	27	40	35
Width	25	26	37	32
Convexity	20	14	26	18

Some of the Grand Canyon specimens are relatively slightly broader than the typical ratios given above.

Observations: This shell is easily distinguishable by its coarse costae, narrow outline, and prominent sinus, and by the limited area of reticulation and the sparseness of spines. The specimens described by Girty from the Delaware Mountain and Capitan, as well as those from the Word of the Glass Mountains, cannot be distinguished from the typical Kaibab form and its variations. However, it is very rare in the Word, and may be said to be common only in the Leonard and its equivalent.

P. occidentalis is distinguishable from *P. costatus* and *P. magnicostatus* by its stronger costation. The closest similarity among foreign species of *Productus* is shown by *P. grandicostatus* Chao, a form so much like this that it shows no marked difference. Since the Chinese species is based on but one specimen, it is rather difficult to make satisfactory comparison. There are several large-ribbed species of *Productus* in the Salt Range fauna, but all are much wider in proportion to length.

Distribution: Leonard formation (Glass Mountains) at 7, T119, T120, 123, 128, 174 (abundant), 232, and D3. Word formation (Glass Mountains) at 144, T148, Tx148, and 241. Bone Canyon member (Delaware Mountains) at 491. Victorio Peak member (Brackett Draw) at Taa. Gym formation (Diablo Plateau) at 446.

PRODUCTUS SCHUCHERTI King, n. sp.

Pl. XV, Figs. 1–5

1908 *Productus* sp. c. Girty, The Guadalupian Fauna, U. S. G. S. Prof. Paper 58, pp. 256–257.
Delaware Mountain formation, "Comanche Canyon," Glass Mountains.

Description: Shell medium-sized, strongly inflated, wider than long. Pedicle valve strongly arcuate longitudinally, somewhat geniculate. Beak small and pointed, strongly incurved. Ears well-defined, strongly convex, and very much extended. Sinus deep and rather narrow. Brachial valve deeply concave, with a low median fold; beak concave and pointed; cardinal area entirely wanting. Surface marked by low, rounded costae, numbering about 5 in the space of 5 mm.; they may be obsolescent near the anterior margin. Posterior part of most specimens not crossed by well marked concentric wrinkles, but having an obscurely nodose appearance; distinct wrinkles are, however, present on the ears of both valves. The ears bear two rows of rather small spines, set well back from the cardinal margin and inclined strongly outward toward the cardinal extremities. The rest of the shell bears somewhat coarser, sparsely scattered spines.

Dimensions in mm. of several specimens:

	1 (loc. 120)	2 (loc. 120)	3 (loc. 120)	4 (loc. 128)	5 (loc. 124)
Length	22	22+	26	27	22
Width	44	32	40+	34	40

Observations: This species is distinguishable by its low, medium-sized ribs, faintness of the wrinkling of the posterior part, prominent sinus, and extended ears. It belongs to the group of *P. boliviensis* d'Orbigny, and can hardly be distinguished from the specimens identified by Tschernyschew as *P. boliviensis* and *P. gruenewaldti*, except that it has a deeper sinus. *P. guadalupensis* Girty is somewhat similar, but is more strongly enrolled and has no concentric wrinkles and much finer costae. Girty's figures of *P. guadalupensis*, however, show great similarity to *P. schucherti*, (figures 1 and 1a, plate 22), having costae almost as coarse as those of the latter species.

Distribution: Hess? formation (Glass Mountains) at T205. Leonard formation (Glass Mountains) at 9, 12, 13, 31, 38, T82, 119, T119, 120 (abundant; types), T120, 123, 124, 128, 174, 232, Tb, Tba, D1, D4, D5, D8. Word? formation (Glass Mountains) at T240 and 265. Word? formation thin-bedded zone (Shafter) at Tq. Limestone of Cerro Caballo (Las Delicias) section 1, bed 14. Bone Canyon member (Sierra Diablo) at 484. Victorio Peak member (Sierra Diablo) at 494. Leonard formation (Baylor Mountains) at 503.

PRODUCTUS SEMIRETICULATUS HERMOSANUS Girty?

Pl. XIV, Figs. 15–17

1903 *Productus semireticulatus* var. *hermosanus*. Girty, U. S. G. S. Prof. Paper 16, pp. 358–359, pl. 2, figs. 1–4.

?1915 *Productus inflatus* var. *coloradoensis*. Girty, U. S. G. S. Bull. 544, pp. 64–65, pl. 8, figs. 1–2.

?1921 *Productus inflatus coloradoensis*. Plummer and Moore, U. of Tex. Bull. 2132, pl. 13, fig. 24. Not *P. semireticulatus hermosanus* Plummer and Moore, pl. 20, fig. 23; pl. 25, figs. 1–2.

Description: Shell medium-sized to large (up to 60 mm. across), marked by a very shallow median sinus. The costae average 6 to 8 in 10 mm. Concentric wrinkles form strong nodes in the posterior region. Spines are rather sparsely distributed, being generally not closer than 10 mm. from each other on the non-reticulate part of the shell.

Observations: The shells referred to this variety are mostly very fragmentary. It may be seen, however, that they agree with *P. semireticulatus hermosanus* in the strength of their costae and arrangement of spines. Because of the imperfect nature of the Wolfcamp material, as well as the great confusion which has attended the identification of this variety by other authors, exact identification is not possible. Girty, in his original description, mentioned as points of difference from *P. semireticulatus* the small size, more inflated and incurved form, fewer and larger spines, and more extended and enrolled ears. Since their original description, the identification of *P. hermosanus* and of *P. inflatus (coloradoensis)* appear to have been reversed. Girty originally pointed out emphatically that the only important distinguishing character between them was the finer lirae of *P. inflatus (coloradoensis)*. In the report on the Wewoka fauna, however, he figured and described a coarsely costate form under that name. The specimens identified by Plummer and Moore as *P. semireticulatus* var. cf. *hermosanus* (U. of Tex. Bull. 2132, pl. 25, figs. 1–2) agree almost exactly with Girty's original figures of *P. inflatus (coloradoensis)*, while those identified by them as *P. inflatus coloradoensis* are very similar to the original figures of *P. hermosanus.*

Distribution: Wolfcamp formation, *U d d e n i t e s* zone (Glass Mountains) at 88, 88s, T88, 94, 94s, 107, 175, and 201. Middle and Upper Wolfcamp formation (Glass Mountains) at 87 low, 87 high, 89, 91, T91, 92, 93, T93, and 195.

PRODUCTUS SEMISTRIATUS Meek

Pl. XV, Figs. 6–11

1860 *Productus semistriatus.* Meek, Proc. Acad. Nat. Sci. Phila., vol. 12, p. 309.
"Coal Measures": Timpanogos Canyon, lat. 40°22′, long. 111°38′.

1876 *Productus semistriatus.* Meek, Simpson's Rept. Expl. across the Great Basin of Utah, p. 347, pl. 1, figs. 7a–b.
"Coal Measures": Timpanogos Canyon.

1877 *Productus semistriatus.* Meek, Rept. of the Geol. Expl. of the 40th Parallel, pp. 74–75, pl. 7, figs. 8–8a.
Black bituminous limestone: southeast of Great Salt Lake, lat. 40°22′n, long. 111°38′w.

1920 *Productus semistriatus.* Girty, U. S. G. S. Prof. Paper 111, pl. 53 and p. 651.
Upper Mississippian: Utah.

Description: Shell medium-sized, transversely subquadrate. Pedicle valve highly inflated, somewhat geniculated at about a third of the length and gently and evenly convex in front of and behind the geniculation. Beak small, projecting somewhat beyond the hinge. Ears short, not well-defined, the umbonal region being relatively low; the hinge-line equals the greatest width of the shell. Median sinus broad and indistinct; in some specimens it is quite absent, there being only a flattening in the median region. Brachial valve evenly concave.

Visceral region of the pedicle valve covered by moderately distinct low, rounded costae, about 6 of which occur in the space of 5 mm.; they become obsolete over the anterior part of the shell. There is a single row of rather slender spines along the hinge-line, which apparently were directed outward away from the beak. Scattered spines are rather abundant over the body of the shell, being small on the visceral region and increasing in size toward the front margin. On the anterior slope, where the costae are obsolescent, the shell may bear several low broad, ribs, each of which arises in front of a stout spine base. The outer shell layer in this smooth anterior part is marked by many and closely spaced fine punctae. Where the surface is broken away, it is seen that posterior to the smooth region the sulci between the costae are marked by rows of large pores, just as the striae of *Chonetes granulifer* are marked by rows of punctae. The rest of the inner surface is even more finely punctate than the outer smooth surface.

Dimensions in mm. of several specimens:

	1 (loc. 92)	2 (loc. 193)	3 (SW of Hueco T.)
Length	22	23	22
Width	33	38	30
Convexity	13	16	14

A specimen from loc. 93 which probably belongs to this species shows on the inside of the brachial valve a low papillose arcuate ridge, suggesting *Marginifera* structure, but not as distinct as in *Marginifera.* The specimen from loc. 90 is not geniculate like the typical ones, and has fine costae, and the ones from 94 and 88s have extended ears, which are marked on each side of the beak by a row of laterally directed spines.

Observations: This species is distinguishable by its geniculate profile, very shallow sinus, faintness of the reticulation of the posterior part, the merging of the costate posterior part into the smooth anterior part of the surface, the few large spines in the anterior smooth region, and the punctate shell. In 1920 Girty figured *P. semistriatus* on a plate of Upper Mississippian fossils from Utah. In 1927*, however, he does not list it as a Brazer fossil, but cites *Prod.* aff. *semistriatus* from the Pennylvanian Wells formation. As no further discussion is given, it cannot be told whether the first listing was later found to be incorrect, or how closely similar the Wells form is to the *Productus semistriatus* of Texas.

Productus semistriatus is very similar to *P. chandlessi* Derby, the only apparent difference being that *P. semistriatus* has more or less of a median sinus, while the Brazilian species has none at all. *P. schucherti* differs in being much broader in proportion to length, in not having a smooth anterior region, and in its more extended ears.

Distribution: Wolfcamp formation (Glass Mountains) at 88s, T88, 90, 92, 93?, 93s, 94, and 196?. Lower Gym group (Hueco Mountains) at 376, 381, 382, 384, 388, 390, and Baker collection 4 miles southwest of Hueco Tanks. Upper Gym group (Hueco Mountains) at 438 and 440a. Upper Wolfcamp formation (Sierra Diablo) at 456 and 460.

PRODUCTUS WOLFCAMPENSIS King, n. sp.

Pl. XVI, Figs. 1–5

Description: Shell medium-sized, subquadrate, longer than wide. Pedicle valve highly inflated, the longitudinal profile showing a progressive decrease in convexity from beak to anterior margin, but without distinct geniculation. Beak small and pointed. The median region is slightly convex in transverse profile, or somewhat flattened, there being no distinct sinus. Ears small but well defined. Brachial valve evenly concave.

Surface marked by rather fine costae, which toward the anterior part become very uneven in size, some of them tending even to coalesce. The posterior one-third or one-fourth of the surface is crossed by low and rather fine concentric wrinkles. Small spines are rather abundantly distributed over the anterior two-thirds of the surface and on the ears. Very small spines seem to be abundant over

*U. S. G. Sur. Prof. Paper 152, p. 73.

the visceral region, but are shown only on very well-preserved specimens.

Dimensions in mm. of several specimens:

	1 (loc. Tmm)	2 (loc. 460)	3 (loc. 198)
Length	34	41	30
Width	38	44	31
Convexity	22	23	15

Observations: This species is distinguished by the greater length than width, the absence of a distinct sinus on the pedicle valve, regular convexity, and fine costae, which are uneven on the anterior part of the shell. The most nearly related species is *P. huecoensis,* which is, however, larger, much broader in proportion to length, and bears a row of spines along the visceral slope. The two species occur together rather abundantly at loc. 456.

Distribution: Upper Wolfcamp formation (Glass Mountains) at 2?, 83s?, 195?, 196, and 198. Upper Wolfcamp formation (Sierra Diablo) at 456 (common) and 460. Lower Gym formation (Hueco Mountains) at Tmm (type) and 383?.

PRODUCTUS sp.

Several specimens of *Productus* from the Hess and Leonard formations cannot be placed in any of the above species, but are too dissimilar among themselves to be described collectively. Some of them are similar to *P. inca,* but are smaller and more strongly enrolled.

Distribution: Hess formation (Glass Mountains) at Tt. Leonard formation (Glass Mountains) at 9, T9, 11a, 13?, 26, 37, 129, and 174. Bone Canyon member (Delaware Mountains) at 491. Leonard formation (Shafter), Cieneguita beds at Tg (2279), transition beds at Th (15978), and 518. Leonard formation (Finlay Mountains) at 512.

Genus LINOPRODUCTUS Chao

Diagnosis: Shell productoid; pedicle valve strongly convex, brachial valve flattened to slightly concave in the visceral part, strongly geniculated toward the front, resulting in the formation of an anteriorly produced long trail. Surface marked by numerous fine radiating lirae and indistinct concentric wrinkles. A double row of spines is invariably present along the margin of the hinge-line.

Genotype: *Productus cora* d'Orbigny.

Geologic range: Mississippian to Permian.

Observations: In 1928, the year following the publication of Chao's name of this genus, Fredericks introduced the name *Cora* for approximately the same group. Fredericks, however, excluded the *P. cancrini* group, because of its abundant thin spines, placing it in his genus *Cancrinella;* on the other hand he included the typical form of *Striatifera,* believing that the concavity of the brachial valve was not a generic character.

LINOPRODUCTUS CORA (d'Orbigny)

Pl. XVI, Figs. 6–7

1842 *Productus cora.* D'Orbigny, Voyage dans l'Amérique Méridional, t. 3, pt. 4, p. 55, pl. 5, figs. 8–9.

1909 *Productus cora.* Girty, The Manzano Group of the Rio Grande Valley, U. S. Geol. Sur. Bull. 389, pp. 58–61. Abo sandstone: Mesa del Yeso, Abo Canyon, and Sandia Mountains.

1915 *Productus cora.* Girty, Fauna of the Wewoka Formation, U. S. Geol. Sur. Bull. 544, pp. 68–72, pl. 8, figs. 4–6. (See for American synonymy.)

1916 *Productus cora.* Broili, Permischen Brachiopoden von Timor, Pal. von Timor, lief. 7, 13, pp. 19–22. (See for Eurasian synonymy. The inclusion in the synonymy of *P. lineatus* Waagen may be questioned.)

1927 *Linoproductus cora.* Chao, Productidae of China, pt. 1, Pal. Sinica, ser. B, vol. 5, fas. 2, pp. 132–134, pl. 13, figs. 17–18, pl. 14, figs. 1–4.

Observations: There has been some controversy as to the limits of this species, centering particularly about the distinction of *L. lineatus* (Waagen) from *L. cora.* Waagen, Tschernyschew, and Chao have insisted on separating the two types, the distinction being that Waagen's species has a median sinus and a rectangular rather than a triangular form. Kozlowski has shown* that though the type specimen is non-sinuate, specimens from the type locality are either sinuate or non-sinuate, and he therefore concludes that Waagen's distinction is not significant. The quadrate form of *L. lineatus,* however, remains as a distinguishing feature. Chao believes a still more minute division is possible, but this hardly seems practicable, in view of the great variation shown by the species. In the Gaptank and Wolfcamp formations sinuate and non-sinuate forms occur together, and it seems useless to attempt a distinction. None of the sinuate varieties, however, has the rectangular form of *L. lineatus. L. cora* is here, therefore, regarded as a shell of triangular outline, except for the ears, and with or without a shallow sinus.

The Glass Mountains specimens of *L. cora* are identical in every detail with the types from Bolivia as figured by Tschernyschew and Kozlowski, except for the single specimen from loc. 90, which has extremely fine lirae, 10 of them occurring in the space of 5 mm.

In this connection it is well to mention *Productus delawarii* Marcou*, which I think should be placed in synonymy with *L. cora.* The specimen figured appears to be a brachial valve, although Marcou seems to have regarded it as a pedicle valve. The beak is no more pointed, and the hinge no shorter than in most brachial valves of *L. cora,* but these characters were said to distinguish the species. The locality from which it was collected is "a siliceous limestone at the western foot of Delaware Mount on the bank of an affluent of Topofki Creek, Texas. This fossil is very common but never well preserved . . . In company with *P. delawarii* a true *Orthis* is found . . ." This locality is probably somewhere in northern Trans-Pecos Texas.

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at 88s, 93, 93s, T93, 175, 175a, 201, and 203. Wolfcamp formation (Glass Mountains) at 2?, 75, 87?, 90, T90, 92, 195a, 196, and 198. Upper Wolfcamp formation (Sierra Diablo) at 456, 459, and 460. Lower Hess formation (Sierra Diablo) at 471. Lower Gym forma-

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*Ann. de Paléontologie, t. 9 (1914), pp. 50–51.

*Marcou: Geol. of North America, p. 45, pl. 5, fig. 3. 1858.

tion (Hueco Mountains) at 383, 389, and 401. Middle Gym formation (Hueco Mountains) at 414, 416, 425, and 434.

LINOPRODUCTUS CORA ANGUSTUS King, n. var.

Pl. XVI, Figs. 8–9

Description: Shell medium-sized to large, with a roughly rectangular outline; hinge-line somewhat less than the greatest width of the shell. Posterior part of the pedicle valve very strongly inflated; the anterior half of low convexity in large shells. Beak pointed, but not much incurved over the hinge; the sides of the visceral cavity diverge from it at angles of 85° to 90°. Ears small and flattened, sharply demarked. Median sinus absent, though some specimens show a faint median flattening.

Surface marked by fine lirae, about 9 to 11 of which occupy the space of 5 mm.; they are rounded and separated by striae of varying width, some of which are broader than the lirae. Spines very few in number and inconspicuous. Concentric folds are present on the ears and on the posterior part of the brachial valve, but not on the convex part of the pedicle valve. There is a row of small spines along the hinge-margin.

Dimensions in mm. of several specimens:

	1 (loc. 105)	2 (loc. 105)	3 (loc. 15)	4 (loc. 219)	5 (loc. 222)
Width	40	30	35	21	24
Length	43	34	49	26	22

Specimens assigned to this variety agree in being elongate, with subparallel margins, but otherwise are rather variable. The typical form is that from locs. 105, 107, and 222. The large specimen from loc. 15 is similar in size to that from 105, but is much narrower in proportion to length, and is less strongly convex.

Observations: This variety differs from typical *L. cora* in its narrowness and rectangular outline. It is similar to *L. lineatus,* but has no sinus. *L. tenuistriatus* (Verneuil) is smaller, and has a regular curvature instead of a flattening in the anterior part.

Distribution: Hess formation (Glass Mountains) at 1, 98?, 105 (type), 107, T107, 113?, 120, and 222. Hess or Leonard formations (Glass Mountains) at 15 and Tba. Leonard formation (Baylor Mountains) at 503. Leonard formation (Finlay dome) at 512 and 513.

LINOPRODUCTUS GIRTYI King, n. sp.

Pl. XVII, Figs. 3–5

Description: Shell very small, transversely elliptical. Pedicle valve gently convex. Hinge-line shorter than the greatest width of the shell, the cardinal angles being obtuse. Ears broad and flattened, ill-defined. Median sinus absent, although the specimen from loc. 23–24 shows near the anterior margin a very slight insinuation. Surface marked by strong, rounded radial lirae, numbering about 8 in the space of 5 mm., and increasing in number by intercalation. The lirae tend to expand and contract irregularly, giving the shell a rough and somewhat crenulated appearance. They are separated by flat striae of equal width. Concentric growth lines, spaced at irregular intervals, cross the lirae.

Dimensions in mm. of three specimens:

	1 (loc. 23–24)	2 (loc. 13)	3 (loc. Ax)
Length	9	8	11
Width	14	14	14

Observations: *L. girtyi* differs from other species of *Linoproductus* of this fauna by its low convexity, small flat ears, short hinge-line, rounded, crenulated lirae with broad, flat striae, and well-marked concentric growth lines.

Distribution: Leonard formation (Glass Mountains) at 13, 16?, 23–24, 37, and Ax (type). Word formation (Glass Mountains) at 54 and T240.

LINOPRODUCTUS NASUTUS King, n. sp.

Pl. XVII, Figs. 8–9

Description: Shell rather small, elongate oval in outline, the hinge-line forming the greatest width of the shell. Pedicle valve strongly inflated, beak enrolled and projecting slightly beyond the hinge-line, ascending at first steeply, and then decreasing in curvature gradually to about mid-length, beyond which the curvature is slight. Transverse curvature very strong, the lateral slopes being steep and the wings flattened. There is a slight undefined median sinus in the visceral area, which dies out to give way to a median fold on the anterior slope. In mature specimens this fold appears as a spout-like projection of the anterior margin. Ears marked by about 5 strong concentric wrinkles, which become obsolete on the edge of the visceral convexity. Brachial valve slightly concave; marked near the hinge by concentric wrinkles like those of the wings of the other valve.

Surface marked by fine radiating lirae, of which from 6 to 12 occupy the space of 5 mm. In places they are small and crowded closely together. Spines rare over most of the surface, but concentrated into a row on the wings.

Dimensions in mm. of several specimens:

	1 (loc. 246)	2 (loc. 247)	3 (loc. 247)	4 (loc. 248)
Length	28	25	25	21
Width	20	28	23+	21+
Convexity	10	10	10?	10?

Observations: This species is characterized by the long hinge, posterior transverse median concavity and anterior convexity of the pedicle valve, sparseness of spines, and slight development of concentric wrinkling. Its closest American relative is *L. insinuatus* (Girty), which is much larger and broader, and lacks the sinus in the posterior region; moreover, *L. insinuatus* has a deep notch in its front margin. It is very close to *L. simensis* (Tschernyschew), but is easily distinguishable by its long hinge, more sharply demarked wings, and more strongly enrolled beak. *L. tenuistriatus* (Verneuil) and *L. schrenki* (Stuckenberg) also belong to the same group, but the former lacks a median fold on the pedicle valve, and the latter is much broader than *L. nasutus.*

Distribution: Leonard formation (Glass Mountains) at T119. Word formation (Glass Mountains) at 138, T144, 145, T148, 240, 241, 246 (common; types), 247 (common), and 248.

LINOPRODUCTUS WAAGENIANUS (Girty)

Pl. XVII, Figs. 10–15

1899 *Productus Cora.* Diener (ex parte), Anthracolithic Fossils of Kashmir, Pal. Ind., ser. 15, vol. 1, pt. 2, pp. 22–23, pl. 1, figs. 12a–c.

1899 *Strophomena analoga.* Diener, *idem*, p. 51, pl. 2, fig. 17.

1908 *Productus waagenianus.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 253–254, pl. 12, figs. 6–7a.
Middle Capitan, Capitan Peak (sta. 2926).

1908 *Productus waagenianus* var. Girty, *ibid.*, p. 254.
Delaware Mountain formation, Guadalupe Point (stas. 2903 and 2919).

1910 *Productus eucharis.* Girty, Fauna of Park City Formation, U. S. Geol. Sur. Bull. 436, pp. 28–29, pl. 2, figs. 3–4.
Phosphate beds, Montpelier, Idaho.

1915 *Productus waagenianus.* Diener, Anthracolithic Faunae of Kashmir, Kanaur and Spiti, Pal. Ind., new. ser., vol. 5, mem. 2, pp. 71–73, pl. 6, figs. 18–19; pl. 7, fig. 6.
Zewan beds, Kashmir.

1927 *Marginifera? eucharis.* Girty, in Geol., etc. of Part of Southeastern Idaho, U. S. Geol. Sur. Prof. Paper 152, p. 80, pl. 28, figs. 23–25.
Phosphoria formation, southeastern Idaho.

Description: Shell small to medium-sized; very wide, with an extended hinge. Ears pointed, in some shells projecting so far that the rest of the shell is wrapped around them. Pedicle valve strongly convex and much enrolled. Beak inflated, pointed, strongly incurved, slightly projecting. Sinus absent, though some individuals show a slight median flattening. Brachial valve concave, with a narrow geniculated part around the front and sides.

Surface marked by radiating lirae, of which from 7 to 14 occupy the space of 5 mm.; they are low and rounded, and separated by striae as wide as or wider than themselves, and they increase in number by intercalation. On some shells they are irregular in arrangement, probably as a result of interruption of normal growth. The lirae give rise to a few scattered spines; both lirae and striae are crossed by extremely fine concentric lines, about 10 of which are present in the space of 1 mm. The hinge is set with a row of large spines on each side of the beak. On the pedicle valve concentric wrinkles are present on the lateral margins, especially near the ears. Visceral area of the brachial valve marked as far as the geniculation by strong, sharp, regular, rather distantly separated wrinkles, of which the anterior slope is so much steeper than the posterior that in some specimens they appear lamellose. It was this character of the brachial valve that led Diener to identify a specimen from Kashmir as *Leptaena analoga.*

Dimensions in mm. of several specimens:

	1 (loc. 46)	2 (loc. 120)	3 (loc. 120)	Type of *L. waag.*	Kashmir (Diener)
Length	12	13	11	14	18.5
Width	34	19+	32	20+	32

Observations: The great variability of the size of the lirae in this species shows that Girty's distinction of the coarsely lirate form as a variety is not justified. Although Girty failed to compare *L. eucharis*, from the Phosphoria, with *L. waagenianus*, Diener has indicated their apparent identity. There is not a single important detail in which the descriptions and figures of the two differ. In his second figuring of these species, Girty says that *P. eucharis* may be identical with *P. aagardi*, "which probably is a *Marginifera*." The reason for assigning *L. aagardi* to *Marginifera* is not stated, and it seems to me to be hardly conceivable that it is not a *Linoproductus*. *L. aagardi* (Toula) appears to differ from *L. waagenianus* in being larger, having a shorter hinge-line, and bearing a median depression in the pedicle valve. According to Tschernyschew* the only distinction between "*P. waageni*" and *L. aagardi* is the finer lirae of the type specimens of the former, a character which he regards as unimportant, since many of the specimens of *L. aagardi* from the Urals and Spitsbergen have just as fine lirae as typical *L. waagenianus.* As here defined, *L. waagenianus* would agree perfectly with L. *aagardi* in the nature of its liration. The great length of the hinge of the Texas specimens is, however, an important difference.

Distribution: Hess formation (Glass Mountains) at 8, 17a, T205, and Tt. Leonard formation (Glass Mountains) at 12, 25, 37, 39?, 83, 120, T120, 123, 125, 232, D1, D11, D12b, and Tb. Word formation (Glass Mountains) at 45?, 46, 54, 144?, Tx148, 232, 240, T240, and 241. Bone Canyon member (Delaware Mountains) at 490. Delaware Mountain formation (Sierra Diablo) at 504. Leonard formation (Shafter) at 518. Limestone of Cerro Caballo (Las Delicias) at section 1, beds 11 and 14.

LINOPRODUCTUS (CANCRINELLA) PHOSPHATICUS (Girty)

Pl. XVII, Figs. 6–7

1910 *Linoproductus phosphaticus.* Girty, Fauna of the Phosphate beds of the Park City Formation, U. S. Geol. Sur. Bull. 436, pp. 29–30, pl. 2, figs. 7–9.
Phosphate beds of the Park City formation near Montpelier, Idaho.

Description: Most of the specimens in the present collection are so distorted that the actual configuration is not apparent. The following is taken from Girty's description: Shell "broad, slightly transverse or slightly elongate in different specimens. Hinge-line about as wide as the width below. The cardinal angles subquadrate. Ventral valve strongly convex, with small depressed ears. Beak inflated and much incurved. Dorsal valve similar to the ventral, but with lower convexity and smaller and less projecting beak. Surface marked by fine radiating lirae, 8 to 10 in 5 mm. The whole surface of both valves is crossed by moderately strong, subequal but more or less irregular transverse wrinkles, which are stronger and coarser on the ears. There are also small spines, which appear to be rather numerous and regularly distributed. The development of a spine may be accompanied by an elevation of the rib from which it springs, beginning some distance above the point of appearance. In such cases the presence of spines is a conspicuous feature, but otherwise

*Rept. 2nd Norw. Arc. Exp. in the "Fram." vol. 4, no. 34, pp. 37–38. 1916.

not, since they are of about the same size as the costae and do not produce very considerable enlargements."

Dimensions in mm. of several crushed specimens:

	1 (loc. 247)	2 (loc. 247)	3 (loc. 246)
Length	27	26	23
Width	20	26	20

Observations: The most closely related American species are *L. villiersi* and *L. pertenuis,* which have finer lirae, wrinkles, and spines. *L. phosphaticus* is very similar to *L. cancriniformis* (Tschernyschew), a widespread Artinsk species, and may actually prove to be identical with it. The Glass Mountains specimens, in fact, though somewhat crushed, appear to agree somewhat more closely in convexity with the Russian than with the American specimens. If the name *Cancrinella,* introduced by Fredericks for the group of *L. cancrini,* is to be used, this species and *L. villiersi* would be so designated.

Distribution: Leonard formation (Glass Mountains) at T119. Word formation (Glass Mountains) at 46, 246, and 247. Leonard formation (Shafter) at 512.

LINOPRODUCTUS (CANCRINELLA) VILLIERSI (d'Orbigny)

Pl. XVII, Figs. 1–2

1842 *Productus villiersi.* D'Orbigny, Voy. dans l'Amér. mérid., part 4, vol. 3, p. 53, pl. 4, figs. 12–13.

1914 *Productus villiersi.* Kozlowski, Ann. de Pal., vol. 9, pp. 42–44, text fig. 12, pl. 2, figs. 39–60. See for synonymy.

Description: Shell small, strongly convex, hemispherical. Hinge-line slightly shorter than the greatest width of the shell. Surface of both valves marked by fine radial lirae, which number about 15 in the space of 5 mm., by fine, more or less irregular wrinkles on both valves, and by numerous spines, which spring from elongated bases.

Dimensions in mm. of three specimens doubtfully identified:

	1 (loc. 3)	2 (loc. 26s)	3 (loc. 26s)
Length	14	11	13
Width	12	12	15

The specimen from loc. 3 is very narrow in proportion to length.

Observations: It is very likely that this species should include also *L. pertenuis* (Meek) and *L. clarkianus* (Derby). The only difference that can be made out between *L. villiersi* and the former is that in the first the spines are nearly prostrate, while in *L. pertenuis* they are more erect.

Distribution: Wolfcamp formation *Uddenites* zone (Glass Mountains) at 88. Wolfcamp formation (Glass Mountains) at 75, 193?, and 195. Middle Gym formation (Hueco Mountains) at 414 and 424.

Genus STRIATIFERA Chao

Diagnosis: Shell productoid, generally relatively narrow, with the hinge-line shorter than the greatest width of the shell. Pedicle valve strongly to slightly convex, brachial valve concave and following the curve of the opposite valve, forming a thin but uniform visceral cavity between them through the whole length of the shell. Surface marked by fine radiating lirae and generally also by concentric wrinkles.

Genotype: *Mytilus striatus* Fischer de Waldheim.

Geologic range: Mississippian to Permian.

Observations: As originally defined, this genus included also the *Productus giganteus* group, but Chao later separated that group as *Kansuella,* which is characterized by its thick shells of large size and transverse outline. Fredericks included *Striatifera* in his genus *Cora* (the other member of that genus being *Linoproductus).*

STRIATIFERA PINNIFORMIS (Girty)

Pl. XVII, Figs. 16–19

1908 *Productus pinniformis.* Girty, The Guadalupian Fauna, U. S. Geol. Surv. Prof. Paper 58, p. 272, pl. 12, figs. 5–5b.

Middle Capitan, Capitan Peak (sta. 2926).

Description: Shell medium-sized, spatulate. Postero-lateral margins more or less straight, diverging at an angle of 90° or less; greatest width at about mid-length. The lateral margins merge with the anterior in a broad curve. Beak of the pedicle valve pointed and prominent, bent down at the end. Hinge-line very short. Ears small, provided with several spine-bases near the margin. Pedicle valve longitudinally very slightly convex, except in some specimens in which either the anterior or the umbonal part has a greater convexity. Median sinus or flattening quite absent. Brachial valve concave and slightly wrinkled. Visceral cavity thin.

Surface marked by rather strong, irregular concentric wrinkles and very fine rounded radiating lirae, of which from 8 to 15 occur in the space of 2 mm. The latter are of varying size—on some specimens there are alternate large and small lirae, increasing in number by intercalation. They are larger near the anterior margin. The lirae are crossed at right angles by closely spaced finer concentric lines, which are distinguishable only on well preserved surfaces. The concentric wrinkles curve back toward the wings, where they become closely concentrated.

Dimensions in mm. of several specimens:

	1 (loc. 37)	2 (loc. 34)	3 (loc. 21)	I.s. of C. Cab.
Length	30	19?	28	30+
Width	24	20	28	37

The specimens from loc. 26s have conspicuous scattered spines on the surface.

Observations: The fact that this species occurs only in the Hess and Lower Leonard in the Glass Mountains, horizons much lower than that of typical *S. pinniformis,* suggests that they may be a different species, but no evidence of this could be seen in the present collection, in which most specimens of the species are rather incomplete.

The nearest relatives to this species are *S. compressa* (Waagen) and *S. mytiloides* (Waagen), which Chao regards as identical. It differs from them in being less elongate, in having the concentric wrinkles extending upon the wings, and in having fewer and less prominent spines on its wings. *S. compressa corniformis* Chao is still narrower, and has incurved sides.

Distribution: Hess formation (Glass Mountains) at 1 and 8. Leonard formation (Glass Mountains) at 16, 21, 26s?, 34, 37, 38, T41, 120, and Tb. Word formation (Glass Mountains at 137. Bone Canyon member (Delaware Mountains) at 491. Limestone of Cerro Caballo (Las Delicias) at section 1, beds 11 and 14. Girty's type was from the Capitan limestone.

Genus PUSTULA Thomas

Diagnosis: Shell productoid. Pedicle valve strongly convex, brachial valve flattish to slightly concave, generally upturned at the margins, so that there is a thick and uniform visceral cavity the entire length of the shell. Hinge-line less than the greatest width of the shell. Median sinus well-defined. Surface marked by conspicuous concentric bands or wrinkles, bearing one or more rows of spines.

Genotype: *Producta pustulosa* Phillips.

Geologic range: Mississippian to Permian.

Observations: Chao and Fredericks believe that the type of *P. punctata* should be distinguished as *Echinoconchus,* the distinction being that in the *P. pustulosus* group there are numerous, well marked wrinkles, each of which bears a single row of pustules on the crest, while in the *P. punctatus* group there are strong, well defined bands, each bearing several rows of small pustules. I can hardly agree to such minute splitting.

PUSTULA SEMIPUNCTATA (Shepard)

1915 *Pustula semipunctata.* Girty, Pennsylvanian Series in Missouri, Mo. Bur. of Geol. and Mines, vol. 13, ser. 2, pp. 349–350.

1928 *Productus punctatus* and *Pustula nebraskensis.* Schuchert, Am. Jour. Sci., ser. 5, vol. 14 (1927), p. 391.

Observations: A single imperfect specimen from the upper Hess formation cannot be distinguished from the common Pennsylvanian form in its visible characters. Like the American form *P. semipunctata* it is elongate and has a noticeable sinus. The lower Wolfcamp formation contains specimens unquestionably belonging to this species.

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at 88, 88s, and 175. Wolfcamp formation (Glass Mountains) at 93s, T93, and 169a. Hess formation (Glass Mountains) at 102.

Genus BUXTONIA Thomas

Diagnosis: Shell productoid, with a thick visceral cavity. Pedicle valve evenly convex, or rarely geniculated; brachial valve flattened or concave. Surface spinose, the spine bases being arranged to form more or less interrupted radiating costae, which may become obsolete in the gerontic stage, being replaced by concentric bands on which are numerous small spine-bases. Marginal ridges short. Median septum generally bifurcating about 5 mm. below the cardinal process, the two branches uniting with the two lobes of the process.

Genotype: *Anomites scabriculus* Martin.

Geologic range: Mississippian to Permian.

Observations: The diagnosis given above differs somewhat from those of Thomas, Muir-Wood, and Chao. The arrangement of the spine-bases as costae is here emphasized, rather than the pustulose bands in the gerontic stage, which have been observed only in the genotype. *Productus nebraskensis,* which has been regarded as either a *Pustula* or a *Buxtonia,* agrees best with *Juresania* Fredericks.

Fredericks in 1923* proposed the subgeneric name *Tschernyschewiella* for productids having a median septum or "euseptoid" in the pedicle valve. The type species was *Productus porrectus* Kutorga, which, according to Kozlowski, is synonymous with *P. peruvianus* d'Orbigny. Whether the presence of a low median septum is as important as believed by Fredericks is very doubtful, as many species have a more or less well developed median ridge. At any rate, the name *Tschernyschewiella* had been preoccupied by von Toll for a Siberian Cambrian trilobite, and its use for a brachiopod is incorrect. It seems logical to suppose that *P. porrectus* (or *P. peruvianus)* is a species of *Buxtonia* and deserves no separate designation.

BUXTONIA OCCIDENTALIS King, n. sp.

Pl. XVII, Figs. 20–21

1858 *Productus scabriculus* Marcou, Geol. of North America, p. 47, pl. 5, fig. 6.

1861 *Productus scabriculus.* Newberry, Ive's Rep. Colorado River of the West, p. 125.

1903 *Productus sp. a.* Girty, Carb. Formations and Faunas of Colorado, U. S. Geol. Sur. Prof. Paper 16, p. 372, pl. 5, fig. 3.
Middle and upper Hermosa formation, San Juan region.

1909 *Productus nebraskensis.* Girty, Manzano Group of Rio Grande Val., U. S. Geol. Sur. Bull. 389, pp. 62–64, pl. 7, figs. 5–6.
Abo sandstone: Abo Canyon, Mesa del Yeso, and Sandia Mountains. Yeso formation: Mesa del Yeso.

Description: Shell medium-sized, subtriangular in outline, hinge-line less than the greatest width, ears small and depressed. Pedicle valve strongly and regularly inflated in longitudinal profile. Beak pointed and somewhat incurved over the hinge-line. Median sinus broad and shallow, not well-marked. Surface of the pedicle valve marked by elongate spine bases, which are not connected end to end to form continuous costae, as typically in the species of this genus, but generally lie somewhat out of line with one another. The spine bases are so long and so closely set to one another that the shell appears to be costate when not carefully examined. There are several concentric undulations in the surface of some specimens, but they have no relation to the arrangement of the spines. Fine growth lirae may be distinguished in some specimens. Surface of the brachial valve marked by radially elongate pits and by faint concentric wrinkles.

Dimensions in mm. of several specimens:

	1 (loc. 75)	2 (loc. 75)	3 (loc. 323)
Length	21	25	38
Width	27	30	30
Convexity	10	13	12

Observations: This species appears to occupy an intermediate position between the Lower Carboniferous *Buxtonia*

*Rec. Geol. Com. Russian Far East, no. 28, pp. 20–21.

scabricula and *Juresania juresanensis*, having, unlike the former, interrupted rather than continuous costae, and, unlike the latter, no concentric arrangement of the spines, and but a single set of spines. The difference from *J. nebraskensis* is even greater, as the common mid-continent species has very strong concentric corrugations and many irregularly arranged spines of very diverse sizes.

Distribution: Gaptank formation (Marathon basin) at 75 (types), 272, 275, 284, Sa*, Sd, and Sh. Strawn group (Hueco Mountains) at 323 and 329. Wolfcamp formation (Glass Mountains) at 91a, T91, 93, and 203. A specimen from the basal Magdalena of the Sandia Mountains is identical with the Texas form, as well as specimens from the Pennsylvanian of Northern Arizona. The specimens identified as *P. scabriculus* by Newberry and Marcou were from near Santa Fe and from the Sandia Mountains, and there seems to be little room for doubt that they should actually be placed in *B. occidentalis*.

BUXTONIA PERUVIANA (d'Orbigny)

Pl. XVIII, Figs. 1–3

1842 *Productus Peruvianus*. D'Orbigny, Voy. dans l'Amér. mérid., p. 52, pl. 4, fig. 4.

1844 *Productus porrectus*. Kutorga, Zweiter Beitrag zur palaeont. Russlands, Verh. d. Russ. Kais. Mineral. Gesellsch., ser. 1, p. 26, pl. 10, fig. 3.

1914 *Productus peruvianus*. Kozlowski, Ann. de Pal., vol. 9, pp. 38–40, text fig. 7, pl. 5, figs. 1–4. (See for synonymy.)

1916 *Productus Porrectus*. Tschernyschew and Stepanow, Rept. Sec. Norw. Arctic Exped. in the "Fram," no. 34, p. 41, pl. 5; pl. 8, fig. 5.

1924 *Productus (Tschernyschewiella) porrecta*. Fredericks, Rec. Geol. Com. Russ Far East. no 28, p. 21.

Description: Shell large, triangular in outline. Pedicle valve strongly convex near the beak, but with gradually decreasing curvature toward the front. Beak greatly incurved over the hinge-line. Margins of the visceral area very steep. Ears small, slightly convex. Median region depressed in a broad sinus (which, however, is absent in one specimen from loc. Tmm). Brachial valve nearly flat or only slightly convex, with a low median fold; geniculate near the front. Surface marked by costae, which are continuous but consist of rows of elongate nodes, between which the costae become very faint. The nodes on the costae are the bases of small erect spines. Concentric wrinkles cross the pedicle valve of the specimen from loc. 472.

Dimensions in mm. of several specimens:

	1 (loc. 472)	2 (loc. Tmm)	3 (loc. 377b)
Length	50+	48	58
Width	52	54	55
Convexity	51	22	30

Observations: There is no apparent difference between these specimens and typical *B. peruviana* as described by Kozlowski.

Distribution: Lower Gym formation (Hueco Mountains) at 377b, 403, and Tmm. Hess formation (Sierra Diablo) at 472.

BUXTONIA VICTORIOENSIS King, n. sp.

Pl. XIX, Fig. 1

Description: Shell large, transversely subquadrate, visceral region subtriangular. Pedicle valve strongly and evenly convex, beak incurved over the cardinal area. Margins of the visceral area rather steep. Ears broad, convex, sharply set off. Median region depressed in a broad, shallow sinus. Surface marked by continuous radial costae, numbering about 9 in the space of 10 mm. They swell at intervals into small nodes, which are spine bases. Concentric wrinkles are absent.

Dimensions in mm. of the type specimen, from loc. 498: length, 50; width, 70; convexity, 25.

Observations: This species is distinguished from *B. peruviana* by being much broader, the greatest width being at the hinge-line, having broad, well-defined triangular ears, relatively finer costae and smaller nodes, and stronger convexity. It is much smaller and less strongly convex than *B. longa*.

Distribution: Victorio Peak member (Sierra Diablo) at 498 (type). Leonard formation (Glass Mountains) at 26s. Word formation (Glass Mountains) at 243? and 255?. Rare.

Genus WAAGENOCONCHA Chao

Diagnosis: Shell productoid, pedicle valve of low convexity, brachial valve nearly flat. Surface marked by quincuncially arranged tubular spines in the youthful and adult stages, which become smaller and closely packed together in old age. Wrinkles faint or absent.

Genotype: *Productus humboldti* d'Orbigny.

Geologic range: Uppermost Pennsylvanian and Permian.

Observations: In 1928, the year following the publication by Chao of his diagnosis of *Waagenoconcha*, Fredericks introduced the name *Ruthenia* for approximately the same group, the genotype being *P. irginae* Stuckenberg. Besides the *P. irginae* group, however, he included that of *P. tastubensis*, which is regarded by Chao as an *Avonia*. Other species classed as *Waagenoconcha* by Chao were placed by Fredericks in his genus *Krotovia*. The distinction by Fredericks between *Ruthenia* and *Krotovia* is that the former is ornamented with fimbriate tubes, and the latter with spines only. In each genus are placed shells having either plane or concave dorsal valve. To me the division by Chao seems the more natural, the shells in both of Fredericks' "genera" having a plane dorsal valve being placed in *Waagenoconcha*, while those having a concave dorsal valve are regarded as *Avonia* (or *Krotovia*, as defined by Chao).

WAAGENOCONCHA LEONARDENSIS King n. sp.

Pl. XIX, Figs. 2–4

Description: Shell large, subquadrate, with the hinge-line slightly less than the greatest width. Pedicle valve strongly inflated, especially near the beak, and flattening out in longitudinal profile toward the front. Lateral slopes very steep in early stages and somewhat less so later. Beak pointed, enrolled, and incurved over the hinge. Ears

*Identified by Schuchert (Am. Jour. Sci. ser. 5, vol. 14, 1927), as *Pustula nebraskensis*.

flattened, demarked from the rest of the shell by the concavity bordering the visceral area. Median sinus originating at the very point of the beak or slightly anterior to it, becoming strongest in the posterior median part of the shell, and becoming shallower toward the anterior margin. Surface marked by many large, elongated pustular spines, more or less arranged along two diagonal axes intersecting at a low angle.

Dimensions in mm. of several specimens:

	1(loc. 15)	2(loc. 120)	3(loc. 38)	4(loc. Tb)
Length	35	45	33	43
Width	43	50	35	42
Convexity	21	20	--	15

Observations: This species is easily distinguishable from *W. montpelierensis* by its greater convexity, its deep median sinus, and especially its large relative size and the irregularity in the arrangement of its spines. It differs from *W.? palliata* (Kayser) in having larger spines and a deeper sinus. *W. abichi* and *W. serialis* (Waagen) are similar to it in the size and arrangement of their spines, but are much smaller and have much shallower sinuses. *W. gangeticus* (Diener) also appears to be similar, but probably has smaller spines.

Distribution: Hess? formation (Glass Mountains) at 38 and Tv. Leonard formation (Glass Mountains) at 15, 22, 83, 120 (type), T233, and Tb.

WAAGENOCONCHA MONTPELIERENSIS (Girty)

Pl. XIX, Figs. 5–6

?1898 *Productus irginae.* Stuckenberg, Carte géol. de la Russie, f. 127, p. 220, pl. 2, fig. 16.

1910 *Productus montpelierensis.* Girty, Fauna of the Park City Formation, U. S. Geol. Sur. Bull. 436, p. 30, pl. 2, figs. 5–6.

?1914 *Productus humboldti* var. *irginae.* Kozlowski, Brachiopodes du Carb. super. de Bolivie, Ann. de Pal., t. 9, pp. 41–42, text fig. 10. pl. 7, figs. 1–6.

1927 *Productus montpelierensis.* Girty, in Geog., etc., of Southeastern Idaho, U. S. Geol. Sur. Prof. Paper 152, p. 80, pl. 28, figs. 12–13.

Phosphatic shale member of the Phosphoria formation, southeastern Idaho.

Description: Shell medium-sized to large, transversely oval in outline. Hinge-line shorter than the greatest width, cardinal angles rounded. Profile of the pedicle valve regularly convex. Visceral area triangular, with steep slopes, the umbonal angle being about 90°. Beak small, strongly incurved, rapidly expanding. Ears small and depressed. Median sinus shallow and regularly rounded, originating about 10 mm. in front of the beak and becoming less distinct toward the front, where it is hardly at all distinct. Brachial valve flat in the postero-central part. concave anteriorly and laterally, with a low undefined fold corresponding to the sinus of the other valve.

Surface of both valves ornamented with small, short, sharp, tubular spines, directed forward. On the pedicle valve these spines are arranged in intersecting diagonal lines, but in places, in irregular transverse lines bearing closely spaced spines. On the brachial valve the spines are arranged in very regular qunicunx. On the best specimen there is one faint growth varix near the anterior margin.

Internal characters are not determined.

Dimensions in mm. of specimen from loc. 146: length, 34; width, 43; convexity, 15.

Observations: *W. montpelierensis* shows no apparent difference from *P. humboldti irginae* as figured by Kozlowski, and only minor differences can be made out between it and *P. irginae* figured by Tschernyschew: a lower convexity and blunter and more strongly inflated beaks. Fredericks* entertains no doubt as to the actual identity of the Eurasian and American species. If *W. montpelierensis* is a different species from *W. irginae,* the question arises as to whether they differ according to time or according to place: are all the American forms *W. montpelierensis* and all the Eurasian forms *W. irginae,* or are the high Pennsylvanian and low Permian forms *W. irginae in Eurasia, Bolivia,* and the *Uddenites* zone of the Wolfcamp formation, and the middle Permian forms *W. montpelierensis* in the Phosphoria, the Leonard, and the Word? These questions cannot be settled now, because of the imperfect nature of the material from the Wolfcamp formation. All the specimens in the present collection will therefore be regarded as *W. montpelierensis,* although it is considered extremely likely that if that species is different from *W. irginae,* the form occurring in the *Uddenites* zone is *W. irginae. W. montpelierensis* appears to be a characteristic species of the North American Arctic Permian fauna. The *Pustula* aff. *P. humboldti* cited from the Alaskan Artinsk fauna is, as suggested by Girty*, possibly identical with *W. montpelierensis.* The specimens identified as *Pustula* aff. *P. irginae* and *Pustula* aff. *montpelierensis* by Girty* from the Kaibab in Arizona are almost certainly identical with this species. It is interesting to note that *W. irginae* is described by Tschernyschew and Stepanow as occurring abundantly in the lower Permian limestone of Store Björnekap, Ellesmere Island, in Arctic America. In Eurasia the species is restricted to Russia and Siberia, and does not occur in the faunas of the Tethyan region. From these facts it appears that *W. irginae* and *W. montpelierensis* are characteristically a northern type rather than a Tethyan one.

W. montpelierensis and *W. irginae* are easily distinguishable from other members of the genus by the extreme fineness and regularity of arrangement of their spines. Typical *W. humboldti,* for example, has long spines with much less regular quincuncial arrangement. Another closely related species is *W. waageni* (Rothpletz), from the East Indies, which has a deeper and narrower sinus, a more strongly enrolled beak, and concentric undulations of growth. It is certainly much closer to *W. irginae* than to *W. humboldti,* with which Broili compared it.

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at T88. Leonard formation (Glass Mountains) at 3, 13, T119, 120, 124, and 174. Word formation (Glass Mountains) at 146, T148, T240, and 247. Victorio Peak member (Sierra Diablo) at 496. Limestone of Cerro Caballo (Las Delicias) at section 1, bed 14.

*Mem. Com. Geol., n. s., liv. 193 (1915), p. 29.

*U. S. Geol. Sur. Prof. Paper 152, p. 79.

*In Darton, N. H.: Resumé of Arizona Geology, pp. 103-104.

Genus OVERTONIA Thomas

Diagnosis: Shell small, productoid. Surface of the pedicle valve marked by concentric elevated bands, each of which bears a single row of relatively large spine bases. Within the brachial valve the brachial ridges, instead of originating on each side of the muscular impression in a direction practically at right angles to the median septum, extend for almost the whole of their length at an angle of approximately 45° to the septum. The anterior ridge in each pair originates at the inner side and near the anterior end of the median septum and just in front of the roughly oval muscular area. It extends forward for a distance equal to half the length of the valve, and at its anterior limit it curves around in a postero-lateral direction, and then backward in a course nearly subparallel to the original direction, ending at the margin of the muscular area at about mid-length of the latter. The two branches of each pair of ridges become slightly nearer to each other at about the middle of their course, so that each pair of brachial ridges resembles a ladle with a short, broad handle.

Genotype: *Productus Simbriatus* J. Sowerby.

Geologic range: Mississippian to lower Permian.

Observations: Only two species have been recognized as belonging to this genus: *O. fimbriata* (Sowerby), the genotype, and *O. cristato-tuberculata* (Kozlowski). It is possible that *Pustula biseriata* (Hall), of the Mississippian Spergen formation, is an *Overtonia*, but this cannot be determined, for, though Weller has figured the interior of the brachial valve (Mississippian Brachiopoda, plate 17, fig. 15), the details of its structure cannot be seen in the figure, and none of the internal characters are described.

OVERTONIA CRISTATO-TUBERCULATA (Kozlowski)?
Pl. XX, Figs. 1–3

1914 *Productus cristato-tuberculatus.* Kozlowski, Brachiopodes du Carb. Supér. de Bolivie, Ann. de Pal., vol. 9, pp. 45–46, pl. 2, figs. 61–62.

Description: Shell small, ovoid, with the hinge-line slightly less than the greatest width of the shell. Pedicle valve regularly and strongly inflated. Beak pointed and incurved. Ears small and not very distinct. Median sinus absent. Surface marked by about 10 regular, obtusely angulated concentric ridges, steepest on the anterior sides, separated by broad, shallow depressions. These ridges are crowded together on the sides of the shell. Between the anterior face of each ridge and the crest of the next succeeding one there are long parallel spine-bases, evidently bearing forward-projecting spines. A few of the spine-bases are prolonged as costae marking the anterior faces of the ridges and connecting with the spine-bases of the next succeeding ridge. Brachial valve slightly and uniformly concave and marked as the pedicle valve. Length, 12 mm.; width, 12 mm.

Observations: These specimens differ from those figured by Kozlowski, so far as can be seen, only in a slightly greater size, the largest of those from Bolivia being 9 or 10 mm. long. Since in the Wolfcamp specimens the internal characters of the brachial valve cannot be determined, there is some doubt as to their generic reference. If they are, as appears, identical with the Bolivian species, then their generic reference is certain, for the internal characters of the brachial valve, as worked out by Kozlowski, are like those of *O. fimbriata*, the genotype.

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at 88, 94, 94s, and Tba. The species is present also in a collection from the Wayland shale member of the Cisco, 1.5 miles southeast of Gunsight, Texas.

Genus AVONIA Thomas

Diagnosis: Shell productoid, with concave brachial valve. Surface spinose in the first stages, developing costae later, through elongation of the spine bases. Marginal ridges short, diverging from the hinge-line. Cardinal process small. Median septum narrow. Adductor muscle-scars not dendritic.

Genotype: *Productus youngianus* Davidson.

Geologic range: Mississippian to Permian.

Observations: As here used, the name *Avonia* is applied to species with a variety of surface sculptures, some of them being marked exclusively by tubercles, and others having the tubercles give rise to a rather regular costation. This is the sense in which the name was used by Chao in part I of the "Productides of China." In part II of that work the greater part of the group was transferred to Fredericks' genus *Krotovia.* There is probably some justification in restricting the genus *Avonia* to species which, like the genotype, are spinose only in the visceral region and are evenly costate over the rest of the surface, but the differences between the typical form and such completely spinose species as *A. signata* seem to be more of degree than of kind. The species assigned to *Avonia* according to the present definition were grouped by Fredericks (1928) in *Ruthenia*, *Krotovia*, and *Thomasia*, the subdivision being on an entirely different basis than that of Chao.

AVONIA BOULEI (Kozlowski)
Pl. XX, Figs. 7–9

1914 *Productus boulei.* Kozlowski, Brachiopodes du Carb. Supér. de Bolivie, Ann. de Pal., vol. 9, pp, 47–48, text fig. 13, pl. 3, figs. 8–9.

1914 *Productus* aff. *spinulosus.* Douglas, Geological sections through the Andes, Quart. Jour. Geol. Soc., vol. 70, pp. 33–34.

Description: Shell small to medium-sized, outline subtriangular except for the ears; greatest width of the shell at the hinge-line. Pedicle valve strongly and evenly convex, beak incurved and projecting somewhat over the hinge-line. Borders of the visceral area diverge at about 90° from the beak, but become nearly parallel toward the front; they are very steep near the beak, and gradually decrease in slope forward. Ears well defined, slightly convex. Median region generally flattened, but not depressed into a sinus. Brachial valve deeply concave. Surface of the pedicle valve marked by large elongate spine bases, increasing in size from the beak toward the front. They are especially abundant on the slopes of the visceral area. Brachial valve marked by pits which are the reverse of the spine bases of the other valve.

Dimensions in mm. of several specimens:

	1 (loc. 193)	2 (loc. 193)	3 (loc. 95)	4 (loc. 389)
Length	20	14	26	18
Width	24	17	33	19
Convexity	11	7	15?	11

Observations: The Texas specimens resemble in every way those from Bolivia, except that some of them attain a greater size. The most similar American species is *A. subhorrida,* but this is distinguishable by the larger size, stronger convexity, greater length in proportion to width, and the presence of a median sinus. It is even more similar to *A. tuberculata* (Moeller), but differs therefrom in its smaller spines and the absence of a sinus. *A. wallaciana* (Derby) is similar, the only apparent difference being that the Brazilian species has smaller spines. It is quite likely that the specimens identified by Meyer* as *Productus wallacei* are actually *A. boulei,* for they were collected in Peru from a fauna like that of Bolivia in which the typical form of *A. boulei* was found.

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at 95. Wolfcamp formation (Glass Mountains) at 87 low, 93, 93s, and 193. Lower Gym formation (Hueco Mountains) at 377b, 389, 390, 392, and 4 miles southwest of Hueco Tanks (Baker coll.). Hess formation (Sierra Diablo) at 472.

AVONIA? INCURVATA King, n. sp.

Pl. XX, Fig. 6

Description: Shell small, subquadrate, greatest width at the hinge-line. Pedicle valve strongly arched, the umbo being greatly elevated. Beak large and very much incurved over the hinge-line. Ears extended and fairly well defined. Median region faintly depressed into a sinus. Brachial valve concave, ears flattened. Surface marked by broad, low, rounded costae, separated by shallow furrows; they arise some distance anterior to the beak, and bear scattered large erect spines. There are uneven concentric undae, some of which, near the front margin, are especially strong. It is possible that this species is a *Marginifera.*

Dimensions in mm. of the typical specimen: length, 16; width, 22; convexity, 9.

Observations: This species is distinguished by its triangular outline, strongly incurved beak, large ears, and extended hinge-line.

Distribution: Word formation (Glass Mountains) at 46 (rare).

AVONIA LATIDORSATA (Girty)?

1907 *Productus latidorsatus.* Girty, the Guadalupian Fauna, U. S. Geol. Surv. Prof. Paper 58, pp. 264-265, pl. 11, figs. 11–13b.

Description (after Girty): "Shell rather small, thin, transverse. Ventral valve moderately convex, the anterolateral curvature being stronger than the transverse. Beak small, incurved, not projecting far beyond the hinge-line. Ears small, depressed, somewhat arched, probably slightly projecting. Sinus shallow, ill defined. Dorsal valve moderately convex, with flattened visceral region. Beak inconspicuous. Ears small, depressed, somewhat arched, and slightly projecting.

"Surface nearly smoooth. Traces of ribs can be seen on most specimens, but they are usually faint. Equally or somewhat more indistinct concentric wrinkles also are found, and rather strong growth lines. Spines are numerous and small over the posterior portion of the shell, rather scarce and larger over the front, lateral portions, and ears. The ribs in many cases, especially where at all well marked, are more or less discontinuous, and originate severally at the bases of the larger spines."

Dimensions in mm. of the Word specimen: length, 13; width, 22; convexity, 9.

Observations: In the present collection there are but two specimens referable to this species, and since they are incomplete, the identification is not certain. The species is distinguished from related ones in this fauna by being short and broad, having a median sinus, and bearing few spines.

Distribution: Word formation (Glass Mountains) at 241.

AVONIA MEEKANA (Girty)

Pl. XX, Figs. 4-5

1908 *Productus meekanus.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, p. 263, pl. 30, figs. 13–13a.
Delaware Mountain formation, Guadalupe Point (sta. 2931); Delaware Mountain formation, Glass Mountains (sta. 3763).

Description: Shell small. Pedicle valve moderately convex. Beak small. Hinge-line shorter than the greatest width of the shell; ears small and not very sharply set off. Sinus absent, although one specimen has a median flattening of the posterior part of the shell. Surface marked by concentric wrinkles and spines. Wrinkles small and irregular, strong on the sides and ears but fainter and somewhat interrupted elsewhere. Spines medium-sized, numerous, and regularly arranged 1.5 to 2 mm. apart, projecting strongly downward and forward so that their bases are very elongate. Where the surface is worn, there appear radiating lirae, which are faint and interrupted by the spines; about 3 of them occupy the space of 1 mm.

Dimensions in mm. of one specimen: length, 15; width, 16; convexity, 8.

Observations: This species is very similar to the more common *A. signata,* but has much more closely arranged and smaller spines. The only foreign species to which it is closely similar is *A. pustulata* (Keyserling), which has similar ornamentation but a quite different configuration, being much wider and more convex.

Distribution: Word formation (Glass Mountains) at 144 and Tc (rare).

AVONIA SIGNATA (Girty)

Pl. XX, Figs. 16–24

1908 *Productus signatus.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 263–264, pl. 22, figs. 4–4b.

1908 *Productus signatus* var. Girty, *idem.,* p. 264.
Delaware Mountain formation, Guadalupe Point (sta. 2931).

*Meyer, H. L. F.: Carbonfaunen aus Bolivia und Perú. N. Jahrbuch, vol. 37, p. 632. 1914.

1908 *Productus* sp. c. Girty, *idem*, p. 266, pl. 22, figs. 5–5a. Delaware Mountain formation, Guadalupe Point (sta. 2920).

Description: Shell medium-sized, generally slightly longer than wide, rarely somewhat wider than long, with the hinge-line narrower than the greatest width of the shell. Pedicle valve moderately arched, the curvature near the beak amounting to 90° of a circle. The convex margins of the visceral area diverge from the beak at right angles or more toward the greatest width of the shell, in front of which place the lateral margins are parallel. Median part flattened, without a sinus, bordered laterally by an abrupt up-turning to the margin. Ears small, depressed, and rounded. Brachial valve regularly concave.

Surface marked by rather regularly arranged spines mounted on narrow elongate bases, which make up a sort of coarse, irregular, and discontinuous ribbing. The abundance of these spines is extremely variable; they are from 1.5 to 6 mm. apart, but generally about 2 mm. apart and evenly spaced at that interval on any one shell. There appear to be all gradations in amount of spacing from the more common fine type to the coarse type. Where the shell surface has been removed it is seen that the spines arising from these elongate bases originate deep within the shell wall and pass up through the bases. They reach a length of at least several millimeters. Surface marked also by fine concentric wrinkles, which are stronger and more closely spaced near the beaks of some specimens, but in others are only slightly developed. Near the anterior margin of some shells the spine bases are prolonged into costae of about the same width as the spine bases, but varying in size on different individuals. The spines on the ears are much larger than those on the body of the shell.

Shell thin. Adductor muscle scars finely labyrinthiform, not situated on a raised platform, but lying at the same level on the shell interior as the diductor muscle scars, which are coarsely striated longitudinally. An interior of a brachial valve doubtfully referable to this species, from loc. 246, has a low, thin median septum. Brachial ridges obscured by pustules, which mark the entire interior.

Dimensions in mm. of several specimens:

	1(loc. 247)	2(loc. 144)	3(loc. 144)	4(loc. 144)	5(loc. 253)
Length	21	24	23	18	22
Width	20	22	22	21	21

Observations: The average type of the shells referred to this species differ from Girty's type in being generally more elongate, but as certain Glass Mountains specimens agree with the original it cannot be doubted that the two are identical. It is probable that the lirae noted by Girty on an internal mold are merely the striations of the adductor muscle scars, rather than the reflection of surface lirae, for no true lirae are present on any of the specimens here examined. The differences noted by Girty between *A. signata, A. signata* var., and *A.* sp. c appear to come within the limits of this variable species as here defined. *A. signata* is very similar to *A. opuntia* (Waagen), differing from it, according to Girty, in the more elongated character of its spine bases. This feature, however, is variable, many specimens of *A. signata* actually having nearly as short spine bases as the Indian species.

Distribution: Word formation (Glass Mountains) at 138, 143?, 144 (abundant), T144, 146, 148, T148, Tx148, 150, 153, 154?, 162, 180, T239, T240, 243, 246, 247, 248, T241, 253, Tc, and Tx. Word? formation (Glass Mountains) at D8 and T91.* Delaware Mountain formation (Sierra Diablo) at 504.

AVONIA SUBHORRIDA (Meek)

Pl. XX, Figs. 10–11

1877 *Productus subhorridus.* Meek, King's U. S. Geol. Expl. 40th Par., vol. 4, pp. 75–76, pl. 7, figs. 3–3b.
Carboniferous limestone of Wasatch Mountains; Hamilton Butte, Ruby Group; Mahogany Peak, Egan Mountains, and north slope of Moleen Peak, Elko Range, west side of Long Valley, Ruby Group.

1920 *Pustula subhorrida.* Girty, in Ore Deposits of Utah, U. S. Geol. Sur. Prof. Paper 111, p. 655, pl. 56, figs. 1–2 (copied from Meek).
Permian, Utah.
Also cited by Girty (U. S. Geol. Sur. Prof. Paper 152, p. 79) as characteristic of the Phosphoria formation of Idaho, Wyoming, and Montana.

Description: Shell medium-sized, transversely ovate, hinge-line slightly less than the greatest width. Pedicle valve very strongly convex, especially in the umbonal region, with a shallow, broad median sinus (there is no sinus in the specimen from T239). Beak pointed and incurved, but not greatly overhanging the hinge-line. Lateral slopes of the visceral area very steep, ears small and sharply set off. Surface set with fairly evenly distributed large scattered spines, the bases of which are to some extent elongated longitudinally. Fine concentric lirae are present also. Brachial valve concave.

Dimensions in mm. of two specimens from loc. Tx148: No. 1, length 20, width 22, convexity, 10; No. 2, length 15, width 18, convexity 9.

Observations: The Texas specimens agree with those from the Phosphoria in every respect except that the sinus is not quite as deep in the former.

Distribution: Word formation (Glass Mountains) at Tx148 and T239.

AVONIA SUBHORRIDA RUGATULA (Girty)

Pl. XX, Figs. 12–15

1908 *Productus subhorridus* var. *rugatulus.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 267–268, pl. 30, figs. 11–12c.
Delaware Mountain formation, Guadalupe Point (sta. 2931?); Glass Mountains (stas. 3763 and 3840).

Description: Shell small, transversely subquadrate. Pedicle valve moderately convex. Beak low. Ears small and depressed, hinge-line equal to or less than the greatest

*Loc. T91 is presumably Wolfcamp. There appears to have been an error in the labeling of this specimen.

width of the shell. Median region depressed as a very shallow sinus. Brachial valve gently concave. Surface of the pedicle valve marked by fine, irregular concentric wrinkles, some of which are stronger and of the nature of growth lines. Spines large, long, and scattered; most of them are directed slightly forward or lie perpendicular to the surface. The spine bases give rise to faint costae, which extend forward a short distance, then die out. The interior of the brachial valve lacks marginal ridges, though one specimen shows ridges that lie in the posterior part of the shell, diverging from the base of the cardinal process, as in a *Marginifera* having the anterior part of the marginal ridge undeveloped.

Dimensions in mm. of several specimens:

	1 (loc. 137)	2 (loc. 50)	3 (loc. 123)	Girty's type
Length	13	15	13	12
Width	16	18	13	14
Convexity	8	9	8	7

Observations: This variety differs from typical *A. subhorrida* in being smaller, and in having the posterior part crossed by fine wrinkles. *A. boulei* is much larger, less strongly convex, and non-sinuate.

Distribution: Leonard formation (Glass Mountains) at 31 and 123. Word formation (Glass Mountains) at 44, 46, 50, 54, 137, 138, 150, 240, and 241. Upper Gym formation (Hueco Mountains) at 440a. Limestone of Cerro Cabello (Las Delicias) at section 1, bed 19.

AVONIA WALCOTTIANA (Girty)

Pl. XXI, Figs. 1–5

1908 *Productus walcottianus* (ex parte). Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 269–270, pl. 21, figs. 27–27b (not 28–28b). Delaware Mountain formation, Guadalupe Point (sta. 2903), and southern Delaware Mountains (sta. 2969?).

Description: Shell small, probably longer than wide when complete. Pedicle valve strongly convex, geniculate, with a small visceral region. Median region depressed into a rather strong sinus. Ears small and short. Posterior third of the pedicle valve spinose but not costate. Anterior to this region the spine bases are elongate, and give rise to costae, which are large near the spine base but decrease in height in front of it. Other spines tend to arise along the same line, so that discontinous costae are formed, which swell out near the spine bases and contract between them. Visceral region crossed by small but strong concentric wrinkles. One specimen from loc. 46, relatively broad and with a long hinge, has larger and fewer spines than the typical specimens.

Dimensions in mm. of several specimens:

	1 (loc. 240)	2 (loc. 241)	3 (Girty's type)
Length	15	—	16?
Width	16	16	20
Convexity	10	—	10

Observations: Girty tentatively referred his specimens illustrated on his plate 21, figs. 28–28b, to this species. Tschernyschew* expressed the view that it is distinct, and it is now embraced in the new variety *A. walcottiana costata.* The persistent nature of the costae which arise from the spine bases distinguishes *A. walcottiana* from the other species of *Avonia* here described.

Distribution: Word formation (Glass Mountains) at 46, 144, 239, T239, 240, T240a, 241, 248, and Tc.

AVONIA WALCOTTIANA COSTATA King, n. sp.

Pl. XXI, Figs. 8–13

1908 *Productus walcottianus* (pars). Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 269–270, pl. 21, figs. 28–28b (not 27–27b). Delaware Mountain formation, Guadalupe Point (sta. 2931).

Description: Shell small, narrow, longitudinally subquadrate. Pedicle valve strongly convex, with a very much incurved beak; greatest curvature at about a third the length from the beak to the front margin. Lateral slopes steep; umbonal angle about 90°. Ears small. Beak pointed. Umbonal disc marked by small erect spines and by sharp but fine concentric wrinkles; the long anterior slope covered by rather strong, even, rounded costae, from which small erect spines arise at frequent intervals.

Dimensions in mm. of several specimens:

	1 (loc. 241)	2 (loc. 55)	3 (Girty's fig. 28)
Length	21	13	22
Width	17	13	18
Convexity	12	8	10

Observations: These shells agree perfectly with the specimen from Girty's sta. 2931 assigned by him to *P. walcottianus.* Typical *A. walcottiana* is more strongly geniculate than this variety, as well as broader and shorter, and marked by interrupted spine bases rather than continuous costae.

Distribution: Word formation (Glass Mountains) at 55?, T240 (type), 241, and Tx. Limestone of Cerro Caballo (Las Delicias) at section 1, beds 12 (SW of the Noria) and 14.

Genus HORRIDONIA Chao

Diagnosis: Shell productoid, subtriangular in outline. In the pedicle valve there is a strong median sinus. Brachial valve slightly concave. Surface smooth except for a few scattered very stout hollow spines.

Genotype: *Productus horridus* Sowerby.

Geologic range: Upper Carboniferous (Eurasia) and Permian.

Observations: In 1928, the year following the publication of Chao's name of this genus, Fredericks introduced the name *Sowerbina* for the same group, but with *Productus timanicus* Stuckenberg as the type. Chao's name clearly has priority.

HORRIDONIA TEXANA King, n. sp.

Pl. XXI, Fig. 25

Description: In the present collection there is a single specimen of this species, a pedicle valve. It is subtriangular in outline, with the hinge-line straight and

*Rept. 2nd Nor. Arctic Exp. in the "Fram," vol. 4, no. 34, p. 34. 1916.

probably at least as long as the greatest width of the shell. Beak strongly incurved and projecting far beyond the hinge-line, its end being sharply pointed. A narrow, deep median sinus is present on the pedicle valve, starting at the tip of the beak and widening gradually anteriorly; at the anterior margin it is broad and flattened. Surface smooth. Spines not observed, but quite possibly obscured by silicification. Length, 40 mm.; width, 46 mm.; convexity, 21 mm.

Observations: This shell appears to belong to the genus *Horridonia*, the sinus and general form being of the characteristic type of *H. horrida*, *H. timanica*, and *H. granulifera*. From them all, however, it differs in having a deeper sinus and a triangular rather than a pentagonal outline.

Distribution: Middle Word formation (Glass Mountains) at 255.

Genus MARGINIFERA Waagen

Diagnosis: Shell small, productoid. Visceral cavity deep, brachial valve geniculate. Visceral area of the brachial valve chambered off from the anterior trail by a marginal ridge, which extends from each side of the cardinal process first laterally, then forward, and then around the anterior margin of the visceral area to meet the part of the ridge of the other side. The median anterior part of the ridge may be only imperfectly developed. In the pedicle valve a similar ridge is developed only within the wings. There are three types of surface ornamentation: those with a tuberculose ornamentation, such as *M. cristobalensis;* those with pustules and generally also with wrinkles in the early stages, changing to plicae in the later periods, such as *M. manzanica;* and, the typical form, those with semireticulate ornamentation and their phylogerontic derivatives, such as *M. lasallensis* and *M. typica.*

Genotype: *Marginifera typica* Waagen.

Distribution: Viséan to Permian.

Observations: The variety in the surface sculpture of these shells indicates that the genus is polyphyletic, but no attempt can here be made to split it along more natural lines. It is likely that the first two types of ornamentation noted above were derived from an *Avonia* ancestor, while the typical form of the genus derived its type of sculpture from a semireticulate *(Productus)* ancestor.

MARGINIFERA CAPACI (d'Orbigny)

Pl. XXI, Figs. 14–18

1842 *Productus capaci.* D'Orbigny, Voy. dans l'Amér. mérid., t. 3, pt. 4, p. 51; pl. 3, figs. 24–26.

1861 *Productus longispinus.* Salter, Fossils from the High Andes, Quart. Jour. Geol. Soc. of London, vol. 17, p. 64, pl. 3, fig. 2.

1903 *Marginifera haydenensis.* Girty, Carboniferous Formations and Faunas of Colorado, U. S. Geol. Sur. Prof. Paper 16, p. 389, pl. 5, figs. 9–11.

1914 *Productus capaci.* Kozlowski, Brachiopodes du Carb. super. de Bolivie, Ann. de Pal., t. 9, pp. 22–26, text figs. 1–2, pl. 2, figs. 1–15; pl. 5, fig. 12.

Description: Shell small, hinge-line forming the greatest width of the shell, sides nearly parallel. Pedicle valve strongly convex and geniculate, the visceral region being relatively short and the anterior slope at maturity about twice as long. Ears fairly large, quadrate, and sharply defined. There is a flattening or slight depression along the median line. Surface marked by faint or obscure irregular costae, and, in the posterior part, by low concentric wrinkles. Spines rather large, numbering 8 to 10 on the anterior slope. Average length, 14 mm.; width, 16 mm.; convexity, 8 mm.

Observations: This species is distinguished by its relatively great length, very much enrolled ventral umbo, shallow sinus, evanescent costae, and large spines. In his description of *M. haydenensis*, Girty stated that it could be distinguished from *M. capaci* by its finer costae. The subsequent publication by Kozlowski of figures and descriptions of typical shells from Bolivia has shown that the ornamentation of the two is quite similar, and that they must be synonymous. The Texas specimens are as a whole less deeply sinuate than the ones from Colorado and Bolivia, but they appear to be quite similar in other respects. The actual horizon of the Colorado specimens described by Girty is doubtful. They were collected by the Hayden survey and were not definitely labeled with respect to locality and stratigraphic position. *M. capaci* is very similar to *M. timanica* Tschernyschew, but the latter is even more strongly geniculated and bears no sinus at all.

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at 88, T88, 203, and 204? Wolfcamp formation (Glass Mountains) at T82, 91, 92, 93, 93s, 196, and Tba. Lower Gym formation (Hueco Mountains) at 376, 381, 383, 384, 387, 390, and 402. Upper Gym formation (Hueco Mountains) at 439.

MARGINIFERA CRISTOBALENSIS Girty

Pl. XXI, Figs. 19–21

1908 *Productus latidorsatus* var. Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 265–266.
Basal black limestone, Guadalupe Point (sta. 2920).

1909 *Marginifera? cristobalensis.* Girty, Fauna of the Manzano Group, U. S. Geol. Sur. Bull. 389, p. 65, pl. 7, fig. 2.
San Andres formation: Fra Cristobal and San Andres?.

Description: Shell very small, outline longitudinally ovoid. Pedicle valve strongly convex, somewhat flattened or even faintly sinuate along the median line. Length of the hinge-line equal to or slightly less than the greatest width of the shell. Ears very small and depressed. Surface near the beak crossed by very fine indistinct concentric wrinkles. Costae not present. Many fairly large spines are distributed over the surface; some of them have elongate bases, but many do not. Brachial valve regularly concave. Marginal ridge low but distinct.

Dimensions in mm. of several specimens:

	1 (loc. 120)	2 (loc. 123)	3 (loc. 104)	4 (Girty's type)
Length	14	14	12	11
Width	13	14	13	12

Observations: The shells referred to this species have less distinct concentric wrinkling and more prominent spines than Girty's figures of his type specimen show. The original description, however, agrees almost perfectly with the Texas specimens. *M. cristobalensis* is similar in form to *M. manzanica*, but differs markedly in not being costate. It has a great similarity in appearance to *Avonia subhorrida rugatula*, but is narrower and more globose, and has a fainter sinus. The Eurasian species *M. spinosocostata* (Abich) and *M. helica* (Abich) are extremely similar to *M. cristobalensis.*

Distribution: Hess formation (Glass Mountains) at 8, 35, 104, and 105. Leonard formation (Glass Mountains) at 3, 7, T9, 12, 13, 16, 21, 23, 26?, 31, 37, 82, 83, T119, 120 (very abundant), 123, 124, 125, 128, T226, 228, 232?, Ax, Tb, and D1. Middle Gym formation (Hueco Mountains) at 424?. Bone Canyon member (Sierra Diablo) at 484.

MARGINIFERA DUGOUTENSIS King, n. sp.

Pl. XXI, Figs. 6–7

Description: Shell small, much wider than long. Pedicle valve strongly convex, geniculated. Ears large and extended, sharply demarked from the visceral region by sinuses. Median sinus narrow but deep, originating nearly at the beak, giving the shell a bilobed appearance; its width varies, being in some specimens very narrow, but on all the shells it is sharply defined and subacute. Surface marked by low, rounded, irregular radial costae, each of which is about 1 mm. wide. Spines very sparsely distributed. The umbonal region and ears are crossed by faint concentric ridges.

Dimensions in mm. of two specimens:

	1 (loc. 193)	2 (loc. 193)
Length	10	9
Width	18	11
Convexity	5	4

Observations: This species is most nearly related to *M. wabashensis*, but differs in having a narrower and deeper sinus and longer ears.

Distribution: Upper Wolfcamp formation (Glass Mountains) at 193 (types). Wolfcamp formation, *Uddenites* zone (Glass Mountains) at 201?. Upper Wolfcamp formation (Sierra Diablo) at 456?.

MARGINIFERA LASALLENSIS (Worthen)

1873 *Productus lasallensis.* Worthen, Geol. Sur. Illinois, vol. 5, p. 569, pl. 25, fig. 9.

Observations: This species is not abundant at any locality, and since there are no complete specimens the identification may be rather uncertain. It is similar in its ornamentation to the shells from Bolivia identified by Kozlowski as *Productus inflatus*, which have well developed marginal ridges. Some of the specimens figured by Kozlowski are very large, while most are about the same size as *M. lasallensis*, and it is to be wondered if the large specimens may not be distinct, and be true *Productus*, the smaller ones being actually *M. lasallensis.*

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at 88, 88s, and 95.

MARGINIFERA MANZANICA Girty

Pl. XXI, Figs. 22–24

1909 *Marginifera? manzanica.* Girty, Fauna of the Manzano Group, U. S. Geol. Sur. Bul. 389, pp. 64–65, pl. 7, fig. 3.
San Andres formation: Fra Cristobal and San Andres?.

Description: Shell very small, outline transversely ovoid. Pedicle valve strongly convex, with a mesial flattening or very shallow depression in its anterior half. Hinge-line equal to or a little less than the greatest width of the shell. Ears small and depressed. Posterior part marked only by many fine wrinkles. A few millimeters in front of the beak ribs originate, first as nodes, then becoming persistent and strong and so continuing to the anterior margin; they number about 4 in the space of 5 mm., or 14 or more over the entire surface. The costae give rise to small spines, mostly near the anterior and lateral margins. Brachial valve gently concave in the visceral region and strongly curved around the margin, marked in the visceral region by fine, regular concentric wrinkles, beyond which, toward the margin, there are coarse, not very strong radial costae. At the place at which the wrinkles are succeeded by costae there is a low marginal ridge on the inside of the valve.

Dimensions in mm. of several specimens:

	1 (loc. 4)	2 (loc. 222)	3 (Girty's type)
Length	11	13	12
Width	13	13	12
Convexity	6	7	6

Observations: These specimens agree perfectly with Girty's description and figure, except that Girty states that the hinge forms the greatest width of the shell. This species has a great resemblance to *M. ingrata* and *M. carniolicus* Schellwien from the Trogkofel formation, but is distinguished from both by the greater strength of its costae. *M. lopingensis* (Kayser) from the Permian of China has similar ornamentation but is much larger. The most similar American species is *M. whitei*, which is larger and has a greater number of plications.

Distribution: Hess formation (Glass Mountains) at 35, 106, and 223. Leonard formation (Glass Mountains) at 4, 9, T9, 15, 20, 21, 24, 26s, 27, 37, 38, 104, T120, T233, Tb, and Tba. Hess formation (Sierra Diablo) at 465. Bone Canyon member (Sierra Diablo) at 484. Victorio Peak member (Sierra Diablo) at 494. Leonard formation (Baylor Mountains) at 502. Leonard formation, transition beds (Shafter) at Th (15979).

MARGINIFERA OPIMA (Girty)

Pl. XXII, Figs. 20–25

1859 *Productus Popei* (ex parte). Shumard, Trans. Acad. Sci. St. Louis, vol. 1, p. 389.
White (Permian) limestone, Guadalupe Mountains.

1908 *Productus popei* var. *opimus.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 258–259, pl. 20, figs. 12–14a.
Dark limestone, Pine Spring (sta. 2930).

Description: Shell medium-sized, wider than long. Pedicle valve flat in the visceral region, but geniculated so that the anterior part of the shell lies at a right angle to it. Beak not incurved, and projecting only slightly over the hinge-line. Ears small and depressed. Sinus generally broad and shallow. Costae strong but rounded, numbering from 24 to 28, or about 7 in the space of 10 mm. The costae on the median part of the shell originate at the beak, where they are fine, and increase in size to the geniculation, in front of which their size is constant; the costae on the sides of the visceral region and on the wings originate, both fan-like, by intercalation laterally of the costae arising from the beak, and by bifurcation of the costae in the median part of the shell. On the posterior part of the shell the costae have a somewhat wavy, irregular course. On one large specimen the anterior one-third of the shell is almost smooth, the costae becoming obsolete. Spines few and large, present mainly on the lateral parts of the shell near the ears, where there is a row of three or more of them along the concavity defining the ears.

Brachial valve deeply concave. Cardinal process broad. The brachial ridges arise from a median ridge which extends forward from the base of the process, and is rather high and sharp at its termination at about mid-length of the shell. From each side of the cardinal process there arises a ridge which extends about the margin of the visceral area, at first diverging but slightly from the hinge-line, then swinging forward and finally inward toward the median line, around the front of the visceral area. The anterior part of the marginal ridge is not high and sharp like the sides and the posterior part, being only a slightly elevated highly papillose band.

Dimensions in mm. of several specimens:

	1 (loc. 247)	2 (loc. 247)	3 (loc. 247)	4 (loc. 145)	5 (loc. 145)
Length	21	25	28	33	28
Width	29	36	36	32	42

Observations: This shell was originally mentioned by both Girty and Shumard as a variety of *Productus popei*, as the two occur together and have similar configuration and ornamentation. However, it seems to be so easily separable from *M. popei* that it is best to regard it as distinct. It is larger, with more costae, a broad, flat posterior face, strong geniculation, and a peculiar fan-like manner of increase of the costae on the sides of the visceral region. Some of the same characters are shown more or less in *M. popei*, but the posterior face of the latter is generally nearly smooth.

Distribution: Word formation (Glass Mountains) at 54, 143, 144, 145 (common), 148, T148, Tx148, 154?, 162, 239, T239, T240, 243, 246, 247 (abundant), 248, and 255. Altuda member (Glass Mountains) at 50. Delaware Mountain formation (Sierra Diablo) at 504.

MARGINIFERA POPEI (Shumard)

Pl. XXII, Figs. 16-19

1858 *Productus Popei.* Shumard, Trans. Acad. Sci. St. Louis, vol. 1, p. 290 (date of volume, 1860). (Permian, New Mexico and Texas.)

1859 *Productus Popei* (ex parte). Shumard, Trans. Acad. Sci. St. Louis, vol. 1, p. 389, pl. 11, figs. 8-8b. White (Permian) limestone, Guadalupe Mountains.

1908 *Productus popei.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 257-258, pl. 20, figs. 9-11b. Dark limestone, Pine Spring (stas. 2930 and 2924). Delaware Mountain formation, southern Delaware Mountains (sta. 2957).

Description: Shell small, subquadrate, wider than long, with the greatest width along the hinge. Pedicle valve evenly curved, its profile forming slightly more than a semicircle. Median sinus rather deep and narrow, starting near the beak, giving the shell a somewhat bilobed form. Ears small and rather sharply set off. Brachial valve concave, with a low median fold. Within, the median septum extends about two-thirds the distance to the marginal ridge, which is low but distinct. Surface of the pedicle valve marked by from 6 to 9 coarse, rounded costae on each side of the sinus, some of which bifurcate in the posterior half of the shell; the costae are strongest on the anterior two-thirds of the shell and faint or nearly obsolete on the posterior third. Spines scattered, most of them being on the sides of the visceral area.

Dimensions in mm. of several specimens:

	1 (loc. 247)	2 (loc. 247)	3 (loc. 246)	4 (loc. 248)	5 (loc. 141)
Length	20	12	11	20	15
Width	25	18	13	27	19

Observations: This species is distinguishable from the other productids in the fauna by the combination of its small size, bilobate form, strong costae, and by the absence of reticulation on the posterior part. It is somewhat similar to *P. occidentalis*, but is much smaller and has a stronger sinus. It resembles *M. typica* Waagen, but has larger costae than the Indian species and no reticulation near the beak.

Distribution: Word formation (Glass Mountains) at 6, 46, 54, 55, 143, 144, T144, 148, T148, Tx148 (abundant), 154, 162, 192, T239, T240a, T240, 242, 246, 247, 248, 261, Ta, and Tc. Very abundant at 246 and 247. Vidrio formation (Glass Mountains) at 43. Leonard formation (Glass Mountains) at 15, 38, and 124. Hess? formation (Glass Mountains) at 98.

MARGINIFERA POPEI MINOR King, n. var.

Pl. XXII, Figs. 1-2

Description: Shell small, its width averaging 16 mm., and its length 13 mm. (probably longer when complete). The pedicle valve is strongly geniculate. Costae low and indistinct, numbering 6 to 8 on each side of the sinus, which is narrow and rather deep.

Observations: This variety is distinguished from typical *M. popei* by its generally smaller size, narrower form, narrower sinus, and stronger geniculation. In none of these respects, however, is it very markedly different from *M. popei*, and it does not seem proper to regard it as a distinct species.

Distribution: Limestone of Cerro Caballo (Las Delicias) at section 1, bed 14 (west of the Noria), bed 11 (west of the Noria), bed 12, and bed 19.

MARGINIFERA RETICULATA King, n. sp.

Pl. XXII, Figs. 3–10

Description: Shell small, wider than long, subquadrate. Pedicle valve of low convexity, being depressed in the posterior part and then geniculated. A deep, narrow sinus is present in the anterior part of the shell; it originates back of the geniculation but in front of the beak. Brachial valve nearly flat posterior to the geniculation, with the beginnings of a sinus. Inside, at the line of geniculation there is a raised marginal ridge. Surface of the anterior part of the shell marked by 18 to 20 strong, sharp, irregular costae, separated by rounded sulci. Surface of the posterior part also marked by concentric folds of the same strength as the costae, forming a grid-like surface. There are also very fine concentric lines of growth. Spines are sparsely scattered over the surface, and a row of them lies along the cardinal slope.

Dimensions in mm. of several specimens:

	1 (loc. 26s)	2 (loc. 26s)	3 (loc. 3)	4 (loc. 3)	5 (loc. 232)
Length	15	14	14	18	14
Width	22	20	18	24	18

Observations: This species resembles *M. whitei,* with which it is associated, but differs in having a strong sinus, a geniculated rather than a regularly rounded profile, and strong reticulation of the umbonal region. The agreement in other details, however, is so strong as to indicate their near relationship. *M. reticulata* is very closely similar to *Productus gratiosus* Waagen, but differs from it in being strongly geniculated and having coarser costae and a more strongly nodose posterior part.

Distribution: Hess? formation (Glass Mountains) at T107 and Tv. Leonard formation (Glass Mountains) at 3, 4, T9, T15, T15a, 16, 24, 26s, 226, 227, 228, 232, T232, T233, Ax, Tb (types), D1, and D4. Leonard formation (Shafter) at Td.

MARGINIFERA RETICULATA ANGUSTA King, n. var.

Pl. XXII, Figs. 11–15

Description: This variety differs from typical *M. reticulata* in being much narrower in proportion to length and in having only a very shallow sinus. The costae average 15 in number, and are very uneven in size.

Dimensions in mm. of several specimens:

	1 (loc. 26s)	2 (loc. Tb)	3 (loc. 4)
Length	13	12	14
Width	17	16	17
Convexity	6	7	7

Observations: M. reticulata angusta is similar in some respects to *M. whitei,* but has much less regular costae, and generally has a shallow sinus. It is much smaller than *Productus mexicanus* of Shumard and of Girty, but otherwise quite similar.

Distribution: Upper Hess formation (Glass Mountains) at 207. Leonard formation (Glass Mountains) at 4, 12, 15, T15, T15a, 24, 26s (types), 38, 39, Tb, and Tba. Victorio Peak member (Sierra Diablo) at 494.

MARGINIFERA SUBLAEVIS King, n. sp.

Pl. XXXIII, Figs. 13–19

Description: Shell small, wider than long, subquadrate. Pedicle valve strongly inflated and geniculated. Ears small, the length of the hinge being equal to or less than the greatest width of the shell. Median sinus rather strong, extending from near the geniculation to the anterior margin. Brachial valve flattened near the beak, then geniculated, the anterior part bearing a median fold. The umbonal part of the shell is quite smooth, but faint radial lirae arise about at the geniculation and cover the anterior slope. The lirae are low and fine, 7 of them occupying a space of about 5 mm. Spines few but large.

Interior of the brachial valve papillose behind the geniculation. Median septum obsolescent. Adductor impressions indistinctly striated. The brachial ridges originate from the median line at the anterior margin of the adductor impressions, and extend forward and laterally nearly to the geniculation, then curve about nearly to meet the first part of the ridge. Strongly developed marginal ridges are present a little in front of the geniculation.

Dimensions in mm. of several specimens:

	1 (loc. 120)	2 (loc. 174)	3 (loc. 123)	4 (loc. 125)
Length	17	15	15	18
Width	23	24	20	21
Convexity	11	9	7	9

Observations: The combination of complete absence of reticulation on the posterior part of the shell with the faintness of the costae, the geniculation of the shell, and the presence of a strong median sinus distinguish this species. The most closely similar in appearance is *Avonia latidorsata* of the Delaware Mountain and Capitan. *A. latidorsata,* however, appears to have a fullness in the center of the visceral area so that the pedicle valve is subhemispheric, the faint and narrow sinus dying out both in front and behind. The sinus in *M. sublaevis,* on the other hand, is pronounced and broad, and the sides of the visceral region are inflated into lateral bumps.

Distribution: Hess formation (Glass Mountains) at 106. Leonard formation (Glass Mountains) at 4, T9, 12, T41, 82, 83, T119, 120 (types), T120, 123, 124, 125 (very abundant), 174, D9, D12, D13, D22, and Tb. Word formation (Glass Mountains) at T144a and 241?. Hess formation (Sierra Diablo) at 476, 478, and 479. Bone Canyon member (Sierra Diablo) at 485 and 491. Leonard formation (Baylor Mountains) at 503. Leonard formation (Finlay Dome) at 512 and 513. Leonard formation (Shafter) at 514.

MARGINIFERA? TEXANA (Girty)

Pl. XXIII, Figs. 5–7

1908 *Productus texanus.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 259–260, pl. 21, figs. 25–26b.

Delaware Mountain formation, Guadalupe Point (stas. 2903 and 2919).

Description: Shell small. Pedicle valve strongly arched, transversely subquadrate, with a distinct but shallow sinus and abruptly descending sides. Greatest width at the hinge-line. Ears large and convex but poorly defined. Brachial valve regularly and slightly concave. Surface marked by strong costae, numbering 4 to 5 in the space of 5 mm.; they are obscure in the posterior region, which is nearly smooth. Toward the front of the pedicle valve the costae become somewhat coarser as a result of the union of some of the older costae into one. The ears are faintly wrinkled, and bear a few spine bases. Internal characters not known.

Dimensions in mm. of several specimens:

	1 (loc. 247)	2 (loc. 247)	3 (loc. 247)	4 (Girty's type)
Length	18	18	13	19
Width	25	30	20	22
Convexity	12	8	6	11

Observations: The only noticeable point of difference between these specimens and Girty's type is the greater length of their ears. They agree in having a very faint sinus and moderately strong costae, which bear very few spines. The costae are finer and the sinus less pronounced than in *M. popei*, with which *M.? texana* is associated. *M.? texana* is much smaller than *M. opima*. As Girty has pointed out, there is great similarity to *M. capaci* (d'Orbigny), but the costae of that species are much finer and the surface is more spinose.

Distribution: Word formation (Glass Mountains) at T148, 246, and 247 (types).

MARGINIFERA WABASHENSIS (Norwood and Pratten)

Pl. XXIII, Fig. 4

1854 *Productus wabashensis.* Norwood and Pratten, Acad. Nat. Sci. Philadelphia, Jour., (2), vol. 3, p. 13, pl. 1, figs. 6a–d. (Date of whole volume, 1855.)

1903 *Marginifera wabashensis.* Girty, Carboniferous Formations and Faunas of Colorado, U. S. Geol. Sur. Prof. Paper 16, pp. 375–379, pl. 5, figs. 8–8a (see for synonymy).

Description (from Girty): Shell broad, highly arched, "with strong median sinus and slightly extended ears. The beak is small and transgresses the hinge-line but little. Concentric wrinkles are almost wanting; the striae are fine and obsolescent, and the surface supports a few comparatively large scattering spines."

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at 88s (abundant), 94, 95, and 201. Wolfcamp formation (Glass Mountains) at 75, 89, and 195. Leonard? formation (Glass Mountains) at T9 and 20.

MARGINIFERA? WHITEI King, n. sp.

Pl. XXIII, Figs. 1–3

1877 *Productus mexicanus?* White (non Shumard), U. S. Geog. Sur. W. 100 Mer., Rept., vol. 4, p. 120, pl. 8, figs. 6a–c.

Carboniferous: Camp Cottonwood, old Mormon road, Lincoln County, Nevada; near Salt Lake, New Mexico.

1883 *Productus mexicanus.* Kayser, Richthofen's China, vol. 4, p. 182, pl. 28, figs. 7a–b.

Permian: Lo-Ping, China.

1902 *Productus mexicanus.* Tschernyschew, Com. Geol. (St. Petersburg), Mem., vol. 16, no. 2, p. 264, pl. 52, fig. 10.

Schwagerina zone of the Urals.

1909 *Productus mexicanus?* Girty, Fauna of the Manzano Group, U. S. Geol. Sur. Bull. 389, pp. 57–58, pl. 7, fig. 4 (?).

Yeso formation: Mesa del Yeso; San Andres formation: Nogal Creek and San Andres.

Description: Shell small, subquadrate, hinge-line equal to or greater than the greatest width of the shell. Pedicle valve subhemispherical, rather strongly convex and regularly arched, but not inflated near the beak. Some of the shells show a faint sinus, but others are nearly evenly hemispherical. Ears small but well-defined. Surface marked by 14 to 18 coarse, rounded, unequal costae, some of which are twice as large as the others. Posterior part of the shell crossed by concentric folds, which give it a nodose aspect. The entire surface is covered with fine growth lines. Spines few and large, arising from the costae. Brachial valve flattened in the visceral region, then geniculated.

Dimensions in mm. of several specimens:

	1 (loc. 107)	2 (Girty—San Andres)	3 (White)
Length	12	22	14
Width	14	22	15
Convexity	6	13	—

Observations: This species is distinguishable from others in this fauna by its strong costae, general absence of a sinus, low beak, small ears, and nodose posterior part. It agrees perfectly with the specimens from Nevada and New Mexico identified by White as *Productus mexicanus*, yet it is certainly different from *P. mexicanus* Shumard, which is a large shell collected originally from the Capitan. The identity of *M. whitei* with *P. mexicanus* Girty from the Yeso and San Andres is doubtful, though they occur in a similar faunal association. The shells from New Mexico agree better with Shumard's species than do the Leonard specimens. No important difference can be seen between *M. whitei* and the specimens from China and Russia identified as *P. mexicanus* White. *M. manzanica* is also very similar, but is smaller, narrower, and has fewer plications.

Distribution: Hess formation (Glass Mountains) at 17a, 107, T107, 207, 208, and 222. Hess formation (Sierra Diablo) at 476, 479, and 485. Leonard formation (Glass Mountains) at T226. Leonard formation (Findlay Mountains) at 512. Upper Gym formation (Hueco Mountains) at 440?.

MARGINIFERA? WORDENSIS King, n. sp.

Pl. XXIII, Figs. 8–11

Description: Shell very small, slightly wider than long. Pedicle valve very convex, geniculated at mid-length, the posterior slope being gently convex and the anterior flattened. Ears broad and flat, so extended that the greatest width of the shell is at the hinge-line. Beak pointed and not incurved. Median part depressed into a faint sinus, or in some specimens convex. Surface marked by about 10 strong costae, each about 1.5 mm. wide, and each bearing several small spine bases. Brachial valve slightly concave. A distinct marginal ridge is not present, there being only a papillose band about the anterior part of the visceral area.

Dimensions in mm. of several specimens:

	1 (loc. 162)	2 (loc. 239)	3 (loc. T240)
Length	11	10+	11
Width	13	15	14
Convexity	7	4+	5

Observations: This species is distinguished by its small size, geniculated profile, and strong costae. It is similar to *M. manzanica* but has larger costae. It has stronger costae and stronger geniculation than *M.? whitei*, and is shorter in proportion to width.

Distribution: Word formation (Glass Mountains) at Tx148, 162, 239, T239, T240 (types), 265, and Tx.

Genus SCACCHINELLA Gemmellaro

Diagnosis: Shell irregular in growth, pedicle valve conical, brachial valve nearly flat. Hinge-line shorter than the greatest width of the shell. Ventral cardinal area very high, longitudinally striated, with an indistinct deltidium. Dorsal area very low or absent. Shell surface marked with many small tubular spines on the pedicle valve and similarly arranged pustules on the brachial valve. Inner shell layer pustulose. In the specimens having very high, conical pedicle valves, the inside of the valve is filled by irregularly arranged transverse partitions. Within the pedicle valve there is a high median septum and near the apex faint flabelliform muscular impressions lie on each side of the septum. In the brachial valve the cardinal process consists of two distinct long apophyses, each base of which continues forward as a ridge, straddling the septum of the pedicle valve.

Genotype: *Scacchinella variabilis* Gemmellaro.

Geologic range: Permian.

Observations: According to Gemmellaro, *Scacchinella* is in youth attached at the apex, later by one of the sides or by the anterior part of the pedicle valve. The evidence for this conclusion is not stated.

There is some disagreement as to the taxonomic relations of this genus. It is placed by Schuchert* in the Orthotetinae, and by Broili* in the Richthofenidae. It is more probably related to neither. Its spinose surface, indistinct deltidium, deeply bilobed cardinal process unsupported by crural plates show that it cannot be placed with the Orthotetinae. According to Likharew* the median septum is entirely differently constructed from that in the strophomenids. The broad cardinal area, absence of an enveloping layer, and the development of the median septum from the infolding of the inner side of the cardinal area rather than independent of the area as in *Richthofenia* prove that it is quite different from the Richthofenidae.

*In Zittel's Textbook of Palaeontology, second edition. 1913.

*In Zittel's Gründzuge der Paläontologie, fifth edition. 1921.

*Palaeontolog. Zeitsch., bd. 10 (1928), pp. 287–288.

The most clearly related genus to *Scacchinella* is *Tschernyschewia*, the important features of which are the spinose surface, low cardinal area, high median septum, and cardinal process consisting of two elongate apophyses, from the bases of which thickened ridges extend anterolaterally. All these features are like those of *Scacchinella*, except that the pedicle valve of the latter is much deeper, and the cardinal area much higher. A low dorsal median septum is present in *Tschernyschewia*, which has not been noted in *Scacchinella*.* The only argument against regarding *Tschernyschewia* as the ancestor of *Scacchinella* is the fact that the only known occurrences of the former are in the middle Permian (Lo-Ping) of China and the upper Permian near Djulfa, Armenia, while *Scacchinella* first occurs in the very lowest Permian. Otherwise the agreement is so nearly perfect that one cannot help but suspect that with more complete knowledge of Permian faunas *Tschernyschewia* may be found at a lower horizon. *Tschernyschewia* appears to have arisen from *Buxtonia*. *B. porrecta* (=*B. peruviana*) has a low ventral median septum, and for this reason was made the type of a new subgenus, *Tschernyschewiella*, by Fredericks (although the name proves to have been preoccupied). It appears likely that *Scacchinella* is a member of the subfamily Productinae, which arose from *Buxtonia* through *B. porrecta* and *Tschernyschewia*.

SCACCHINELLA GIGANTEA Schellwien

Pl. XXIII, Figs. 20–25; Pl. XXIV, Figs. 1–5;
Pl. XXV, Figs. 16–18

1898 *Scacchinella variabilis.* Schellwien, Sitzungsber, d. Akad. d. Wiss. Berlin, p. 697, no. 61; and Verhandl. d. k. k. geol. R.–A. Wien, no. 16, p. 360.

1900 *Scacchinella gigantea.* Schellwien, Fauna der Trogkofelschichten, Abh. der k. k. géol. Reichs-Anstalt, bd. 16, heft 1, pp. 35–37, pl. 4, figs. 1–3; pl. 5, figs. 1–8.

Description: Shell large, the pedicle valve being a high cone, with the posterior side flattened by the large cardinal area; the brachial valve operculiform. Apex of the pedicle valve bluntly pointed, the valve expanding gradually, with irregular concentric undulations. Hinge-line somewhat shorter than the greatest width of the shell. Cardinal area nearly flat, but in some specimens from loc. 35 bent backward about 20° at a transverse angulation near the middle of the area. The area is generally twisted to one side. Deltidium very narrow, linear, and poorly defined. Surface of the cardinal area vertically striated, and marked by transverse growth striae. Brachial valve very slightly convex, with an inconspicuous beak. Surface of both valves uneven; the outer layer of shell is not preserved in the specimens of the present collection, as they were broken from limestone, but it appears to have been like that of *Buxtonia*.

In the pedicle valve the median septum is very long and high, extending from the beak to the hinge-line, where its

*The relations of *Tschernyschewia*, *Scacchinella*, and *Richthofenia* have been discussed in detail by Stoyanow: On Some Permian Brachiopoda of Armenia, Mém. du Com. Géol. (Russie). n. s., liv. 111, pp. 55–74. Likharew (Palaeontolog. Zeitsch., bd. 10, pp. 274–288) has justly criticized Stoyanow's comparison of *Scacchinella* with *Richthofenia*.

dorsal edge lies parallel to the inside of the brachial valve and about 2 mm. from it. Its height is variable, equaling as little as a fourth and as much as three-fourths the diameter of the shell, but generally equaling about half the diameter. The septum consists of two parallel lamellae, which apparently represent greatly developed and closely appressed dental lamellae. The shell tends to cleave between these lamellae. Most of the inside of the pedicle valve is filled with transverse partitions or tabulae. These plates do not extend individually across the entire diameter of the shell, but join each other at low angles to form a very coarse vesicular structure. The shell breaks so easily along these partitions that entire specimens can rarely be removed from the rock. The cardinal process was deeply bilobed, consisting of two thin and very elongate lamellae which straddle the great septum of the pedicle valve.

Dimensions in mm. of several specimens:

	1 (loc. 208)	2 (loc. 208)	3 (loc. 208)	4 (loc. 208)	5 (Sch.)
Height of cardinal area	30+	70+	38	12	59
Length of hinge-line	21	34	30	12	46
Width of brachial valve	34	—	—	17	59
Length of brachial valve	33	—	37	13	55

The specimens from the Wolfcamp formation are very small (the largest one being 17 mm. wide) and it cannot therefore be told if they would be of large size and contain partitioning plates when mature. They agree perfectly, however, with small specimens of *S. gigantea* from the Hess. The specimen from loc. 71 has a width of 55 mm., but the complete length of the pedicle valve cannot be determined because only the anterior part is preserved. Traces of transverse partitions are present. It must have been a very large shell.

Observations: All the features shown by the Glass Mountains specimens strongly indicate their complete identity with those from the Karnic Alps. The internal characters of the brachial valve were not, however, fully determined in the specimens of the present collection. *S. gigantea* is distinguished from *S. variabilis* Gemm. by its much larger size, higher ventral median septum, the presence of partitions in the pedicle valve, and by the internal differences of the brachial valve.

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at 199. Wolfcamp formation (Glass Mountains) at 71. Hess formation (Glass Mountains) at 4?, 15, 17a, 35 (abundant), 106, 108, T108, 208 (abundant), 209, and 211.

Genus AULOSTEGES Helmersen

Diagnosis: Shells small to very large, pedicle valve convex, brachial valve flat or concave. Surface wrinkled and very spinose. Apex of the pedicle valve more or less deformed; ventral cardinal area large and nearly flat, bearing in the middle a narrow deltidium, provided, if well preserved, with small spines. Hinge-teeth rudimentary if present at all. Dorsal cardinal area linear, cardinal process large. Brachial ridges generally not well developed.

Genotype: *Aulosteges variabilis* Helmersen (=*Orthis wangenheimi* de Verneuil).

Geologic range: Permian.

Observations: There is a great deal of doubt as to the correctness of the name *Aulosteges* for the group of shells here assigned to it. This matter has been discussed at length by Girty and Chao.* The genotype of *Strophalosia*, *S. excavata*, may be a member of the group commonly designated as *Aulosteges*. If so, the name *Aulosteges* is a synonym, and a new name must be found for the shells commonly known as *Strophalosia*. The distinguishing characters of the two genera as recognized by Waagen are that in *Strophalosia* the umbo is deformed by attachment, the muscle scars of the brachial valve are raised and not dendritic, and the cardinal teeth are constantly present, while in *Aulosteges* the shell is free from umbonal attachment, the muscle scars are dendritic, and the cardinal teeth are either absent or extremely rudimentary. These cannot be used to distinguish the species in the present collection, however, for in *A. beedei* the muscle scars are raised and not dendritic, though the other characters are in agreement. More reliable features defining the two groups are the following: *Strophalosia* is small, with low, imperfectly developed cardinal area; it was either cemented to some larger organism or marked by a distinct scar of attachment. *Aulosteges* is large, generally with a high, well-developed cardinal area, and without evidence of attachment. There is a great deal of difference in the internal characters of the brachial valve in the various species assigned to *Aulosteges*, and it is possible that several genera may be distinguished in it on that basis.

AULOSTEGES BEEDEI King, n. sp.

Pl. XXV, Figs. 12-15

Description: Shell small to medium-sized, of low curvature and subquadrate outline. Pedicle valve of low convexity, upturned near the margin. Ventral beak very small and low; umbonal region only obscurely separated from the ears. Hinge-line about equal to the greatest width of the shell. Cardinal area high, very uneven in curvature, marked by strong longitudinal undulations and lirae, and by fine vertical lines. The area is divided by the delthyrium, which is covered in its posterior half by narrow, triangular, strongly convex deltidium. The half of the delthyrium near the hinge-line is occupied by the large cardinal process.

Brachial valve slightly concave or quite flat, with no cardinal area. Its posterior part appears to overgrow the edge of the cardinal area of the other valve. Cardinal process long and narrow, the posterior face lying at an acute angle to the plane of the shell margin, slanting toward the front. The posterior face has the form of a rounded ridge; the anterior face is deeply excavated by a groove. From each side of the base of the process extends a ridge, which expands forward and bears the adductor muscle scars; these are raised on elongate platforms, with a deep groove between. The internal characters are described from specimens from loc. Tx.

Surface of the pedicle valve marked by very strong concentric wrinkles, which extend from ear to ear, or, in the umbonal region, from one side of the beak to the other against the hinge-line. On the lateral slopes the growth

*Girty: U. S. Geol. Sur. Prof. Paper 58, pp. 274-275. 1908.
Chao: Pal. Sinica, ser. B, vol. 5, fasc. 3, pp. 69-71. 1928.

wrinkles pass into strong laminae, which converge toward the ears. Spaced at intervals of about 2 mm. are large spine-bases, from which there extend spines, lying against the shell surface and directed radially from the beak; they are 2 to 3 mm. in length. Radial lirae are absent. Brachial valve faintly wrinkled, but without spines.

Dimensions in mm. of several specimens from loc. 123:

	(1)	(2)	(3-brachial valve only)
Length	20	28	15
Width	19	23	18

Observations: This species is distinguished by its low, uneven convexity, elongate quadrate outline, strong concentric wrinkles, the absence of radial lirae, the abundance of prostrate, forward-directed spines, and the high, irregular cardinal area.

Distribution: Leonard formation (Glass Mountains) at 123 (types). Word formation (Glass Mountains) at 53 and Tx.

AULOSTEGES GUADALUPENSIS Shumard

Pl. XXV, Figs. 8–11

1858 *Aulosteges guadalupensis.* Shumard, Trans. Acad. Sci. St. Louis, vol. 1, p. 292 (date of volume, 1860).
White (Permian) limestone: Guadalupe Mountains, New Mexico and Texas.

1859 *Strophalosia (Aulosteges) Guadalupensis.* Shumard, *idem*, p. 390, pl. 11, figs. 5a–b.
White (Permian) limestone: Guadalupe Mountains.

1890 *Strophalosia? Guadalupensis.* Beecher, Am. Jour. Sci., ser. 3, vol. 40, p. 241.

1908 *Aulosteges guadalupensis.* Girty, The Guadalupian Fauna, U. S. Geol. Prof. Paper 58, pp. 277–278, pl. 20, figs. 22–22a.
Upper dark limestone, Pine Spring (sta. 2930).

Description: Shell medium-sized to large, outline subtriangular. Pedicle valve moderately and regularly convex. Umbonal region flattened; beak erect and sharply pointed. Hinge-line shorter than or equaling the greatest width of the shell. Ears small and rounded. Median sinus broad, shallow, but distinct, originating some distance in front of the beak and extending to the anterior margin. Cardinal area triangular and high, sharply demarked from the rest of the shell. Deltidium not distinguishable, but the delthyrium appears as a shallow notch in the mid-part of the area. Brachial valve flattened in the visceral region, then slightly geniculated in the marginal region. Surface of the pedicle valve covered with small tapering spines that incline strongly forward, separated by pits. On some shells the spine bases are arranged more or less quincuncially, while on others they show no definite arrangement, or seem to be borne on irregular longitudinal costae. Brachial valve pitted by inward-projecting spine bases.

Dimensions in mm. of several specimens:

	1(loc. 144)	2(loc. 58	3(loc. 248)
Length	23	18	35
Width	22	37	58

Observations: This species is easily distinguished from others in the fauna by its small, longitudinally elongate spine bases, which are thickly set over the entire surface.

Distribution: Lower Word formation (Glass Mountains) at 58 and 241. Middle and Upper Word formation (Glass Mountains) at 144 (abundant), T144a, 146, 148, T148, Tx148, 239?, T239, 240, T240, 243, 247, 248, 252, 265, and Tx. Word formation (Glass Mountains) at 167?. Delaware Mountain formation (Sierra Diablo) at 504.

AULOSTEGES MAGNICOSTATUS Girty

Pl. XXV, Figs. 1–4

1908 *Aulosteges magnicostatus.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 278–279, pl. 31, figs. 4–4b.
Delaware Mountain formation, Glass Mountains

Description: Shell small, wider than long, semicircular. Pedicle valve with an extended beak and a longitudinally flattened posterior part to about two-thirds the length from the beak to the front margin, where it is strongly geniculated. Cardinal area triangular, symmetrical or twisted, divided by a narrow but strongly convex deltidium. Brachial valve flattened in the visceral part and strongly curved up at the front and sides, its beak small.

Surface of both valves marked by very fine, irregular, sharp concentric wrinkles, which bear many spine bases. Toward the front and sides the wrinkles die out and are replaced by relatively coarse radial costae, which are faint at first but become strong. At the posterior end of each costa are one or more spine bases. The anterior margin of the pedicle valve is bordered by a raised band, which is smooth except for concentric striae. The costae extend under this band; just posterior to the band is a row of large spines, one on each costa. The brachial valve bears no band. Fine but sharp growth lines cover the entire surface.

Dimensions in mm. of several specimens:

	1(loc. 123)	2(loc. 228)	3(loc. 4)	4(Girty's type)
Length	11	10	12	9
Width	14	12	14	8
Ht. card. area	1.5	—	—	2

Observations: Some of the specimens in the present collection, particularly those from locs. 1, 104, and 128, are relatively broader than Girty's type. The presence of the marginal smooth band and the large costae of the geniculated part of the shell are the most striking characters of this species.

Distribution: Hess formation (Glass Mountains) at 1, 35, and 207. Leonard formation (Glass Mountains) at 4, 8?, T9, 26s, 31, 38, 25–29, T41, 104, T119, 120, 123, 128, 228, D5, and Tb. Word formation (Glass Mountains) at 2?7 and 245. Bone Canyon member (Sierra Diablo) at 484.

AULOSTEGES MEDLICOTTIANUS Waagen

Pl. XXVI, Figs. 7–11; Pl. XXVII, Figs. 8–9

1884 *Aulosteges medlicottianus.* Waagen, Salt Range Fossils; Pal. Ind., ser. 13, vol. 1, Productus Limestone Fossils, Pt. 4, pp. 663–666, pl. 62.
Amb group (lower Productus limestone): Salt Range.

?1914 *Aulosteges* aff. *medlicotti*. Tschernyschew, Fauna der Oberpal. Ablager. des Darwas, Mem. Com. Geol. (Russie), n. s., liv. 104, pp. 4, 66, pl. 10, fig. 4.

Artinsk: Darwas, Bokhara.

Description: Shell medium-sized, subquadrate (but generally appearing to be subtriangular because the ears are broken off), width equal to or slightly less than the length; sides subparallel. Pedicle valve of low curvature over the visceral region to about mid-length of the shell, then strongly curved up to the front margin. In transverse direction the surface is moderately convex, but with more or less of a median sinus. Ears flattened and sharply set off. Beak bluntly pointed and not prominent, extending slightly over the gently concave cardinal area. The small triangular delthyrium was probably covered by a deltidium, although that structure is not preserved. The anterior margin of the shell may turn back to form a narrow flange, as wide as 5 mm. Brachial valve concave, with a faint median fold. Cardinal process large, similar to that of *A. beedei*, but, because this valve is more concave it projects farther back.

Surface of the pedicle valve marked by wavy lirae of uneven size, which number about 15 in the space of 5 mm., they are generally obscured by silicification. The entire surface is crossed by strong concentric wrinkles and fine concentric growth lines. Large hollow spines are distributed over the surface at intervals of a few millimeters. Surface of the brachial valve lirate and wrinkled, marked by dimples rather than spines. Shell fibrous and strongly punctate.

Dimensions in mm. of several specimens:

	1 (loc. 38)	2 (loc. 222)	3 (loc. 108)	4 (loc. 124)	5 (loc. 124)
Length	34	30	30	37	36
Width	32	35	38	43	37

Observations: This species is distinguished from related forms in this fauna by its flattened posterior region, strong concentric wrinkles over the entire surface, fine, uneven lirae, and its large, rather abundant spine bases. It is somewhat smaller than typical *A. medlicottianus*. Waagen states that his species has fine radial wrinkles of the shell substance rather than external radial markings, and it may be that the lirae above described are of this nature. *A. medlicottianus* differs from *A. hispidus* Girty, a Phosphoria species, in being larger, having a subquadrate rather than a subtriangular form, and in having stronger concentric wrinkles and larger spines. *A. poyangensis* is somewhat similar, but has a very prominent ventral beak.

The specimen described by Girty under the name *Aulosteges medlicottianus* var. *americanus* appears to have no relation to the form now under discussion. Girty suggested that it might be a *Strophalosia* or a *Streptorhynchus*, but to me it seems even more to resemble *Rhipidomella*, the points of resemblance being the evenly lirated shell, oval outline, broad delthyrium, and the tubules piercing the lirae. The specimen described by Girty as *Aulosteges* sp. b is very probably *A. medlicottianus*.

Distribution: Upper Wolfcamp formation (Glass Mountains) at 70. Hess formation (Glass Mountains) at 1, 4, 107, T107, 108 (abundant), 222, and 91x?. Leonard formation (Glass Mountains) at T9, 15, 23?, 38 (abundant), T39, 120?, 121, 124, 226, T226, T233, Tb (abundant), Tba, Ax, and D3 (abundant). Word formation (Glass Mountains) at 44, 46, and 144.

AULOSTEGES SUBCOSTATUS King, n. sp.

Pl. XXV, Figs. 5–7

Description: Shell small, slightly wider than long, subtriangular in outline except for the ears. Pedicle valve strongly and evenly convex, with the greatest convexity near the beak, which is pointed and extends somewhat over the hinge-line. Visceral region triangular, with steeply descending sides, depressed into a broad, shallow, undefined sinus of variable prominence. Hinge-line straight, shorter than the greatest width of the shell, bearing a low cardinal area. Brachial valve slightly concave, with a well-defined cardinal area, which is slightly smaller than that of the other valve.

Shell very thick. In the pedicle valve the diductor muscles diverge radially from the beak in the form of deeply impressed grooves, separated by a broad platform bearing the unevenly striated adductor scars. Median septum absent.

Surface of the pedicle valve marked by fine concentric growth lines and by sparsely distributed spine bases, which are elongated so as to appear as low, interrupted costae. Just in front of the cardinal margin is a row of large laterally directed spines. Surface of the brachial valve nearly smooth. Shell fibrous and finely punctate.

Dimensions in mm. of several specimens, all from loc. 123:

Length	18	17	20?
Width	20	18	20
Convexity	9	9	12

Observations: This species is distinguished by the triangular form of its visceral region, its extended ears, its strong convexity, the presence of both valves of a low cardinal area, the absence of strong concentric wrinkles, and the few spines, whose bases are greatly elongate. It is similar in general appearance to *Strophalosia costata* Waagen, but there is no evidence of a scar of attachment as in that species.

Distribution: Leonard formation (Glass Mountains) at T119, 120, and 123 (types).

AULOSTEGES TRIAGONALIS King, n. sp.

Pl. XXVII, Figs. 1–3

Description: Shell small, generally longer than wide, outline triangular. Pedicle valve flattened longitudinally to about two-thirds its length from beak to front, where it is strongly geniculated. Median region depressed into a deep, wide, rounded sinus, which starts a short distance behind the geniculation. Beak extended and sharply pointed, with no ears, the hinge-line extending no farther than the edge of the visceral region. Cardinal area small and triangular, most of its area being taken up by the delthyrium, which is occupied by the cardinal process of the brachial valve. Brachial valve evenly concave.

Surface of both valves ornamented by strong, irregular concentric wrinkles bearing many spines on the pedicle valve. Radial ornamentation not present. Shell fibrous.

Dimensions in mm. of several specimens:

	1 (loc. 8)	2 (loc. 37)	3 (loc. 231)	4 (loc. 237)
Length	13	13	12	12
Width	14	12	13	12

Observations: This species is easily distinguishable by its small size, very short hinge, narrow cardinal area, median sinus, and absence of radial ornamentation.

Distribution: Hess formation (Glass Mountains) at 8. Leonard formation (Glass Mountains) at 9, 37, 83, 231 (type), 232, 233, D4, and D7. Word formation (Glass Mountains) at 237, 239, D239, and Tx. Leonard formation (Baylor Mountains) at 503. Bone Canyon member (Guadalupe Mountains) at 221?.

AULOSTEGES TUBERCULATUS King, n. sp.

Pl. XXVII, Figs. 4–7

Description: Shell subtriangular, width and length about equal. Pedicle valve low, geniculated near the front margin. Beak narrow, expanding gradually into the triangular visceral area, which is widest at the front, the umbonal angle being about 70°. The ears are nearly flat but large, so that the hinge-line about equals the greatest width of the shell. The entire pedicle valve is abundantly spinose, the ears bearing the largest spines, which are spaced 2 to 5 mm. apart and directed backward. The visceral part of the shell is marked by approximately quincuncially arranged large conical tubercles, which are the bases of spines. Fine concentric wrinkles, which are especially strong on the ears, cross the entire surface. On the marginal part of the shell the spines give rise to large subangular costae, each about 3 mm. wide. The beak of the valve may be nearly straight or considerably arched over the cardinal area, which is high and striated parallel to the hinge margin. Delthyrium narrow, the upper part covered by a small deltidium, and the lower a broad open notch.

Brachial valve nearly flat over most of its area, but with an undulating surface. Marginal part geniculated. Surface of the posterior part marked by dimples of about the same size and appearance as the tubercles of the other valve, the only difference being that they point inward rather than outward. The geniculated part is marked by costae like those of the other valve.

Dimensions in mm. of several specimens:

	1 (loc. 247)	2 (loc. 247 brachial)	3 (loc. 146)	4 (loc. T239)
Length	55	35	31	50
Width	60	40	34	42

Observations: This species is distinguished from other members of the genus by its coarse tuberculate-costate ornamentation and sprawling growth.

Distribution: Word formation (Glass Mountains) at 144 (abundant), 146, Tx148, 152, 239, T239 (types), T240, 241?, 243, and 247. Delaware Mountain formation (Sierra Diablo) at 504.

AULOSTEGES WOLFCAMPENSIS King, n. sp.

Pl. XXVI, Figs. 1–6

Description: Shell rather large, subtriangular, expanding from a bluntly pointed posterior to a broadly rounded anterior end, the outline being interrupted by the projection of small ears. Hinge-line slightly less than the greatest width of the shell. Pedicle valve rather strongly convex, but with flattened profile both in front of and behind a region of strong curvature which lies at about mid-length or in front of mid-length. Transversely the profile is flattened over the visceral cavity and descends steeply to the lateral margins. Median part depressed into a shallow, narrow, but distinct median sinus. Ears small and flattened. Cardinal area short and low, lying in about the plane of the shell margin.

Brachial valve regularly concave, but abruptly geniculate near the margin. The interior of a brachial valve from loc. 93, probably belonging to this species, has a large cardinal process, which is narrow on its posterior side near the hinge-line, and expands toward the anterior side, where it is divided at the end into three lobes. From the base of the process extend two strong lateral ridges, which lie parallel to the hinge margin, and a low median septum, which is bordered on each side by raised lobes bearing the muscular impressions. Brachial ridges indistinct.

Surface of both valves marked by strong rounded radial lirae, numbering about 9 in the space of 5 mm., crossed by very fine, regularly arranged concentric lirae. At intervals of 4 to 5 mm. on the pedicle valve there are large forward-directed spines, arranged more or less quincuncially, practically restricted to the posterior half of the valve; on the brachial valve there are corresponding depressions. Posterior part of the pedicle valve crossed by a few faint concentric wrinkles, but the entire brachial valve strongly wrinkled.

Dimensions in mm. of several specimens:

	1 (loc. 93)	2 (loc. 93s)	3 (loc. 143)	4 (loc. 196)
Length	35?	30	33	33
Width	40	36	40?	38
Convexity	14	15	16	15

Observations: This species is distinguished from others in this fauna by the triangular outline of the visceral cavity, faint wrinkling of the pedicle valve, strong radial lirae, and regularly arranged, sparsely distributed spines. The internal characters indicate a relation to the productids, as the cardinal process is more productid than that in such a specialized form as *A. beedei*. The appearance of the muscle scars in the brachial valve is, however, similar to that of *A. beedei*, though they are not as much elevated above the general level of the valve. It may be that this species forms a connecting link between the productids and *Aulosteges*. If so, it probably arose from a *Linoproductus*, judging from the surface ornamentation. *Aulosteges* is generally regarded as having arisen from the earlier *Strophalosia* stock, and is put in the same subfamily, but it is very likely that it arose independently from the productids at the beginning of the Permian. Unfortunately, no conclusions confirmatory or otherwise of this can be drawn from Tschernyschew's figures and descriptions of *Aulosteges dalhousii,* the first Eurasian species.*

Aulosteges medlicottianus is much more strongly wrinkled and spinose than *A. wolfcampensis,* and is not strongly lirate; its general form is, however, similar. *A. hispidus* Girty has a somewhat similar configuration, but its radial lirae are much fainter and the spines are most prominent near the anterior margin, rather than in the posterior half of the pedicle valve as in *A. wolfcampensis.*

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at 88, 88s, T88, 94, 201, and 203. Wolfcamp formation (Glass Mountains) at 71, 85, 86, 87 low?, 90, 92, 93 (types), 93s, 193, 196, 198, and Tba.

Genus STROPHALOSIA W. King

Diagnosis: Shells productoid, with a distinct scar of attachment at the ventral umbo, or attached by nearly the entire outer surface of the pedicle valve. Pedicle valve with a well defined cardinal area, the delthyrium closed by a deltidium; hinge-teeth prominent but not supported by lamellae. Brachial valve with a narrow cardinal area; cardinal process erect, bifid on its outer and trifid on its posterior face, supported laterally by socket plates and continued anteriorly into a median septum which extends half the length of the valve. Surface of the pedicle valve spinose, the spines near the beak commonly recurved and embracing some external object, and in some species all the spines assisting in the attachment of the shell. Brachial valve spinose, lamellose, or smooth externally.

Genotype: *Orthis excavata* Geinitz.

Geologic range: Middle Devonian to Permian.

Observations: As pointed out in the discussion of *Aulosteges,* the group of shells to which the name *Strophalosia* is generally applied may not be congeneric with the genotype of *Strophalosia,* in which case a new name must be found for the group.

STROPHALOSIA HYSTRICULA Girty

Pl. VII, Fig. 9; Pl. XXVII, Figs. 10–13

1908 *Strophalosia hystricula.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, p. 275, pl. 30, figs. 14–14a.

Delaware Mountain formation. "Comanche Canyon," Glass Mountains.

Description: Shell small, subcircular. Pedicle valve moderately convex, beak somewhat elevated. Hinge-line shorter than the greatest width of the shell. Ears small and undefined. Cardinal area linear. Surface covered by long, tubular, upwardly convex spines, directed forward so as to be tangent to the surface. On the ears there are very large laterally directed spines, each about 6 mm. long. Brachial valve slightly concave. Along the hinge-line are curved spines, directed toward the beak.

Dimensions in mm. of several specimens:

	1 (loc. 128)	2 (loc. 128)	3 (Girty's type)
Length	10	8	10
Width	13	9	11

Observations: As noted by Girty, this species is closely allied to *S. cornelliana* Derby, but is distinguished by its more distinct and elevated beak and larger and less numerous spines, fewer of which are reclining.

Distribution: Wolfcamp formation (Glass Mountains) at 87 low and 93s. Leonard formation (Glass Mountains) at 128 and D3. Word formation (Glass Mountains) at 144 and Tx. Hess formation (Sierra Diablo) at 479. Bone Canyon member? (Sierra Diablo) at 470.

Family RICHTHOFENIDAE

Genus TEGULIFERINA Schuchert and Le Vene (=TEGULIFERA Schellwien)

Diagnosis: Shell irregular in growth, the brachial valve being round and flat and the pedicle valve more or less high and distorted, and to a greater or less extent enveloping the margins or the entire surface of the brachial valve. Brachial valve produced posteriorly into a tongue which is articulated in a notch near or slightly to one side of the apex of the other valve. Cardinal area completely lacking. Some species of the genus have a rim of inwardly directed spines just within the aperture of the pedicle valve. The outside of the pedicle valve bears long spines serving to attach the shell.

Genotype: *Tegulifera deformis* Schellwien.

Geologic age: Middle Pennsylvanian to Upper Permian.

Observations: In the Texas Permian the highest occurrence of *Teguliferina* is in the Wolfcamp formation, in the Lower Permian. The only species occurring in an Upper Permian fauna is *T. transkaukasia* (Stoyanow), which differs considerably in appearance from most species of the genus. The form described by Ivanow* as *T. rossica* certainly cannot belong to this genus. It has a cardinal area, and Ivanow concluded that an area was present in other species of *Teguliferina* but had not been recognized before. There can hardly be any doubt that other described species of *Teguliferina* do not bear an area, and it seems most natural to conclude that Ivanow had either a *Richthofenia* or some other related genus.

TEGULIFERINA BÖSEI King, n. sp.

Pl. XXVII, Figs. 14–16

Description: Shell medium-sized, having the form of a more or less broad asymmetric cone, rounded at the apex. Growth very irregular. Pedicle valve large, completely overgrowing the flat brachial valve, which is attached on one side of the cone and lies subparallel to the dorsal side of the cone. Cardinal area not present, the brachial valve being articulated by a three-cornered extension which lies in a notch on the inside of the other valve. Cardinal process small, projecting from the end of the posterior extension of the brachial valve. Pedicle valve strongly wrinkled and bearing many long slender spines. It is asymmetric because the apex of the cone is twisted up on

*This species is reported from the *Omphalotrochus* and the *Schwagerina* horizons of the Uralian. Only specimens from the latter are figured. If the identification from the former horizon is accepted, the geologic range of the genus must be extended down to include the highest part of the Upper Carboniferous.

*Sur la systématique et la biologie du genre *Spirifer* et de quelques brachiopodes de CII et CIII du gouvernement de Moscou. Bull. Soc. Nat. Moscou, Sec. Géol. 3, 1926, p. 111, figs. 4–6.

the dorsal side. Around the anterior margin of the pedicle valve there are several lamellar outgrowths on all but the dorsal side, and the mouth of the shell is encircled within on the ventral side by a thickened band which bears large, irregular, inward-pointing spines, that are largest in the center of the ventral side and diminish in size laterally. Surface marked by fine concentric lirae, spines, and very faint radial lirae. Dimensions in mm. of a specimen from loc. 93: width, 22 mm.; height, 15 mm.

Observations: The specimens from the *Uddenites* zone placed with this species are positively identified generically but not specifically, none being complete enough to show the details of the structure. *T. bösei* is very close to *T. deformis* (Schellwien), the genotype, differing only in the much less elongate mature form of the Texas specimens and the presence of a ring of spines inside the pedicle valve.

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at 88, T88, 95, and 203. Wolfcamp formation (Glass Mountains) at 71, 85, 87 low, 90, 93* (types), T93, and 193.

Genus PRORICHTHOFENIA, novum

Diagnosis: Similar to *Richthofenia* but without a myophore chamber lying along the inside of the cardinal area. Pedicle valve irregularly conical, generally twisted to one side. Cross-section nearly circular or transversely ovate. Brachial valve operculiform, when closed lying across the aperture of the cone. *Prorichthofenia* commonly grows in colonial habit, a number of specimens being attached to each other by spines and diverging from a common axis.

Pedicle valve composed of three shell layers. External layer thin, strongly wrinkled, set with numerous long, hollow spines, which rise from the internal shell layer and pass through the median and outer layers. Internal layer homologous with the outer shell of other brachiopods (the external one being a secondary investment). Medial layer thick and cystose, occupying the space between the other layers; it is thickest near the apex, becoming very thin above the plane of articulation of the brachial valve, and again thickening in a ring about the aperture.

Internal shell irregularly conical, bearing on its posterior face a cardinal area, extending from the apex of the cone to the place of articulation of the brachial valve, divided into three subequal parts by the sharp elevation of the median part and marked by transverse growth striae. This cardinal area appears to be the trace on the shell formed by the growth upward along the posterior side of the pedicle valve of the short hinge line of the brachial valve. On each side of the cardinal area the shell folds inward, defining it sharply. The posterior prolongation of the brachial valve fits into the groove so formed.

In the apical part of the ventral cone there is a median thickening of the shell on the inner anterior side, which may form a fairly high median septum. On each side of this ridge, in the posterior apical part, there is a deep pit. The diductor muscles were attached on each side of the median ridge, while the adductor scars lie along the axis of the ridge.

A narrow shelf or flange, formed by a fold of the inner shell layer, encircles the interior of the front and sides of the shell at the level of articulation of the brachial valve; it apparently formed a support for the brachial valve when it was closed. Above this shelf the interior of the shell is covered with small spines, especially on the posterior side. In addition, a few large spines rise from the anterior side and are directed upward so as not to interfere with the movement of the brachial valve. The rim of the shell bears large spines on the anterior side, which are rooted in the medial shell layer and extend inward and upward. Posterior part of the rim formed of several lamellae directed outward and upward.

Brachial valve with a short hinge-line, in front of which there is a slight constriction and then an expansion into a subcircular form. Upper surface finely spinose; lower surface papillose, with spines on the anterior and lateral margins directed downward. These spines would interlock with the spines on the rim of the pedicle valve when the shell was open. The tongue-like projection of the posterior side of the brachial valve extends into the groove below the cardinal area; the median elevation of the area incloses the cardinal process, which is small, rounded, and bilobed. From the base of the cardinal process, extend two small parallel ridges, inclosing the dendritic adductor impressions, which are divided by a median groove. A low median septum may be present in the anterior part.*

Genotype: *Crania permiana* Shumard.

Geologic age: Permian.

Observations: This genus differs from *Richthofenia*, with which it has previously been identified, in having quite different internal structure. In *Richthofenia* the groove below the cardinal area is separated from the rest of the body chamber by a partition lying immediately below the cardinal area. The tube so formed is called a myophore tube. It is generally divided in two by a median septum, and crossed at right angles by small partitions.* The importance of the difference between *Prorichthofenia* and *Richthofenia* was first noted by Likharew, who proposed that the forms lacking a myophore chamber be placed in a new genus.* In *Prorichthofenia* the muscles are attached to the median ridge in the apical part of the living chamber, without a special tube for their reception.

The species belonging to *Prorichthofenia* are:

Prorichthofenia permiana (Shumard) of the Delaware Mountain and Capitan formations of Trans-Pecos Texas.

P. uddeni (Böse) of the Leonard formation of Trans-Pecos Texas.

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*This species was mentioned by Böse (U. of Tex. Bull. 55, p. 47) as "*Rickthofenia*" which "resemble somewhat *R. Uddeni*," and specimens from this locality were identified by Schuchert (Am. Jour. Sci., ser. 5, vol. 14, p. 391) as "*Richthofenia permiana* (small)."

*See also Böse, E.: Contributions to the Knowledge of Richthofenia in West Texas, U. of Texas Bull. 55, 1916.

*Di-Stefano, G.: Le Richthofenia dei calcari con Fusulina di Palazo Adriano nella valle del fiume Sosio. Palaeontographica Italica, vol. 20, 1914, pp. 1-27, pls. 1-3.

Stoyanow, A. A.: On Some Permian Brachiopoda of Armenia, Mém. Com. Geol. (Russie), n. s., liv. 111, 1915, pp. 59-63, pl. 3.

Likharew, Boris: Über einige seltene und neue Brachiopoden aus dem Unterperm des nördlichen Kaukasus. Palaeontologische Zeitschrift, Bd. 10, 1928, pp. 258-289.

*Idem, pp. 282-283, fig. 13.

P. likharewi King of the Hess and Leonard formations of Trans-Pecos Texas and the zone of *Waagenoceras* near Las Delicias, Coahuila.

P. teguliferoides King, a primitive type transitional between *Teguliferina* and *Richthofenia*, of the Hess formation of Trans-Pecos Texas.

The following probably also belong to the genus:

Prorichthofenia sp., from the lower Permian of the Caucasis, figured by Likharew (text fig. 13) as Genus nov. sp. nov., and described by him on pp. 282–283.

Prorichthofenia? rossica (Ivanow) from the Government of Moscow, originally described as a *Tegulifera.* Because of the presence of a cardinal area (unlike true *Teguliferina*), Likharew suggested that it might belong to the same group as *P. permiana.**

It has generally been supposed that the cardinal area of *Richthofenia*, *Prorichthofenia*, and *Gemmellaroia* is like that of other Protremata, with a median raised deltidium. That this cannot be true is indicated by several facts. The median raised third of the cardinal area is not defined from the lateral parts of the area by a different type of transverse striation, as is true in shells having a true raised deltidium. The outline of the brachial valve of *Richthofenia* is like that of *Teguliferina* and *Gemmellaroia:* there is a tongue-like extension of the posterior margin into a corresponding groove in the shell of the pedicle valve. In *Teguliferina* there is no cardinal area; the brachial valve merely fits into a depression on the inside of the pedicle valve, which is notched in the middle to inclose the cardinal process. If the brachial valve of a *Teguliferina* type had shifted its position along the posterior inner wall of the pedicle valve it would form a cardinal area on the inside of the inner layer, the extension of the cardinal process forming a median groove having the appearance of the inner side of a deltidium. This is the situation in *Richthofenia* and *Prorichthofenia.* The cardinal area is crossed by continuous growth lines indicating successive positions of the brachial valve. Similarly, in *Gemmellaroia* the growth lines on the cardinal area are continuous with the growth lines on the rest of the shell. Gemmellaro stated that in this genus there is a raised "pseudodeltidium" but that an area was lacking. The "pseudodeltidium" is actually homologous to the entire area of *Richthofenia* and *Prorichthofenia*,* there being no median elevation in *Gemmellaroia* formed by extension of the cardinal process into the posterior wall during upward growth of the brachial valve (as in the "deltidium" of Richthofenia).

The presence of a myophore chamber is taken by Likharew* to be the essential character of the family Richthofenidae. In view of the agreement of the other shell characters it seems quite unnatural to separate those forms having a well developed myophore chamber in another family from those without it. Moreover, as has been shown, it is hardly to be doubted that *Teguliferina* is the ancestral form of the family, yet because of its structure, a myophore chamber could not occur in that genus.

Stoyanow* regarded as the essential character of his subfamily Richthofenidae the presence of a ventral median septum. Likharew* has clearly shown that the median septum of *Scacchinella* is of quite different nature from that occurring in the myophore chamber of *Richthofenia*, *Gemmellaroia*, and *Tectarea.* To me it appears that the important characters uniting the related genera *Teguliferina*, *Prorichthofenia*, *Richthofenia*, *Gemmellaroia*, and *Tectarea* into the family Richthofenidae are the high, deformed pedicle valve, the posterior tongue-like projection of the brachial valve, which fits into a notch in the pedicle valve, the presence in all but *Teguliferina* of a cardinal area, and the long anchoring spines. *Teguliferina*, *Prorichthofenia*, and *Richthofenia* have an external shell layer which envelops the entire surface, while *Gemmellaroia* and *Tectarea* are only slightly enveloped. The arrangement of the adductor muscles of the brachial valve is somewhat different in *Gemmellaroia* than in *Richthofenia* and *Prorichthofenia;* in the former they are simple and enclosed by apophyses, rather than broad and dendritic. The most highly specialized internal characters are those of *Tectarea:* in it there is a very long massive cardinal process which extends far into the myophore chamber; from the base of the process extend two diverging ridges.

It seems likely that *Prorichthofenia*, *Richthofenia*, *Gemmellaroia*, and *Tectarea* evolved from the primitive form *Teguliferina*, which in turn probably arose from some member of the subfamily Strophalosiinae.

*Idem, p. 283, note.

*See also Likharew, *idem*, p. 279.

**Idem*, p. 282.

*Mém. du Com. Géol. Russ., n. s., liv. 111, p. 74.

Idem, pp. 281-288.

PRORICHTHOFENIA LIKHAREWI King, n. sp.

Pl. XXVIII, Fig. 1; Pl. XXIX, Figs. 1–5; Pl. XXX, Fig. 1

1915 *Richthofenia permiana.* Haack, Zeit. der Deutsch. geolog. Gesellsch., pp. 491–482, pl. 38, figs. 6a–b. Pichagua, near Las Delicias.

Description: Shell similar in external configuration to *P. permiana*, though generally smaller. The cystose filling of the apical part of the cone is, however, much thicker; it fills the lower part of the cone, in some instances, to a depth of more than 15 mm. There is a great thickening in the median part of the anterior wall, which is produced toward the posterior side into a high, sharp septum, directed toward the cardinal area. Unlike the situation in *P. uddeni* this septum does not reach the posterior side of the shell. In some specimens the septum extends upward along the anterior side of the shell nearly to the shelf on which rests the brachial valve, but in others it occurs only in the apical part of the living chamber, the rest of the anterior wall being regularly rounded. On each side of the septum in the apical part of the shell there is a deep pit. The muscles must have been attached on each side of the septum and in the pits on each side. The inner surface of the cardinal area lies exposed to the living chamber. The other characters are as in *P. permiana.* One large piece of a colony from loc. 128 consists of about 50 specimens of this species grown together and attached by spines; the apices of the shells are directed toward a common center, as in a colonial coral.

Dimensions in mm. of several specimens:

	1 (loc. 128)	2 (loc. 128)	3 (loc. 123)	4 (loc. 120)
Length of pedicle v.	41	30	31	31
Length of brachial v.	12	18	16	16
Width of brachial v.	21	17	22	11

Observations: This species appears to be ancestral to *P. permiana*, the main differences between them being the greater development of the cystose filling of the apex and the great thickening and extension into a septum of the anterior wall of the living chamber.

Distribution: Hess formation (Glass Mountains) at 1?, 4, 8, 17b, 35, 103, 106, 107, 117?, 211, 223, and 226. Leonard formation (Glass Mountains) at 3, 8, 11a, 11b, 7–14, 12, 13, 16, 23, 26s, 31, 34, 37, 38, 39, T41, 83, 102?, 104, T119, 120 (abundant), T120, 123 (abundant), 124 (abundant), 126, 128 (abundant; types), 228, 231, 232, Tb, Ax, D2, D3, D7, and D22. Hess formation (Sierra Diablo) at 469 and 479. Bone Canyon member (Sierra Diablo) at 491. Leonard formation (Baylor Mountains) at 502. Leonard formation, just above brecciated zone (Shafter) at Td. Limestone of Pichagüia (Las Delicias) at Cerro Pichagüia.

PRORICHTHOFENIA PERMIANA (Shumard)

Pl. XIX, Figs. 6–9; Pl. XXX, Figs. 8–13

1859 *Crania Permiana.* Shumard, Notice of fossils from the Permian strata of Texas and New Mexico, etc., Trans. Acad. Sci. St. Louis, vol. 1, p. 395 (date of volume, 1860).
White (Permian) limestone, Guadalupe Mountains.

1908 *Richthofenia permiana* (ex parte). Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 283–286, pl. 14, figs. 27–27d; pl. 20, fig. 23; pl. 22, figs. 6–6b; pl. 31, figs. 2–3.
Middle Capitan, Guadalupe Point (sta. 2926); dark limestone, Pine Spring (sta. 2930) and Guadalupe Point (stas. 3762b and 3762c); Delaware Mountain formation, Guadalupe Point (sta. 2931); Delaware Mountain formation, southern Delaware Mountains (stas. 2964 and 2969); and Delaware Mountain formation, "Comanche Canyon," Glass Mountains (sta. 3763). (Not from stas. 2920, 2967, and 3763 part.)

1916 *Richthofenia permiana* (ex parte). Böse, Contributions to the knowledge of Richthofenia in the Permian of West Texas, U. of Tex. Bull. 55, pp. 36–42, pl. 1, figs. 1–16; pl. 2, figs. 8, 15; pl. 3, figs. 1, 4–7.
Zone of *Medlicottia* n. sp. (Word), Gilliam Canyon, mountains north of Leonard Mountain, Hess Tank, Word Ranch, Mt. Ord Range. (Not from the zone of *Waagenoceras* n. sp. (Leonard).

Description: Pedicle valve long, narrow, and irregularly conical; transverse section elliptical, being longer in the lateral axis; longitudinal axis generally curved, being convex toward the anterior side. Surface covered by many long hollow spines, generally projecting downward away from the shell, which serve for attachment to other Richthofenids or other shells; where the individuals grow in groups one shell may lie against two or three others and bear spines only on the free surfaces. Outer layer strongly rugose and marked by concentric growth lines. The cystose filling of the lower part of the cone is thickest at the apex and along the median part of the anterior wall in the apical region, but even there is relatively thin, being not more than a few millimeters thick even in large shells. Along the posterior side is the long, narrow cardinal area, depressed in the median part in a long concavity. Living chamber generally equal in length to about .8 the length of the valve; it is bordered above by the shelf on which rests the brachial valve. The inner side of the cardinal area is exposed to the living chamber except near the apex, where it is more or less covered by the secondary cystose filling of the apical region. Opposite the apical part of the cardinal area there is considerable later deposit on the inner anterior wall. It rises along the median line to form a low, broad ridge, bearing the elongate scars of the adductor muscles along the top and of the diductor muscles on the sides. The inside of the living chamber is marked by scattered tubes which lie against the shell wall and open out in the direction of the aperture. Above the rim on which rests the brachial valve the inner wall of the pedicle valve is thickly set with upward-projecting spines, which are larger on the anterior side, and increase in size toward the aperture, which is bordered by a ring of long, longitudinally striated spines.

Brachial valve flat and round, with a posterior projection into the notch in which lies the cardinal area. The inner side of the valve bears many small spines in the anterior and lateral parts. Cardinal process small and bilobed, projecting into the groove in the middle of the cardinal area. In front of it lie the dendritic adductor muscle scars.

Dimensions in mm. of several specimens:

	1 (loc. 144)	2 (loc. 144)	3 (loc. 144)	4 (loc. 247)
Length of pedicle v.	39	34	48	43
Length of brachial v.	18	---	22	19
Width of brachial v.	22	18	28	23

Observations: This species differs from *P. likharewi* in having a low, broad median ridge rather than a high sharp septum, and in much less development of apical cystose tissue. It is distinguishable from *P. uddeni* by its more slender form and the absence of sharp median ridge.

Distribution: Word formation (Glass Mountains) at 44–46?, 46, 54, 55, 135, 136, 138, 139, 142, 144 (extremely abundant), T144a, T144, 145, 146, 148, T148, Tx148, 152, 153, 160, 171, 192, 232, T233, T238, T239, D239, T240, 241, 243, T243, 245, 247, 265, Tc, and Tx. Limestone of Cerro Caballo (Las Delicias) section 1, bed 12; section 2, bed 12, between El Tordillo and Cerro Caballo.*

PRORICHTHOFENIA TEGULIFEROIDES King n. sp.

Pl. XXX, Figs. 2–7

Description: Shell small. Pedicle valve having the form of a very asymmetric cone, with the apex twisted toward the posterior side. The anterior side is very long and convex outward, while the posterior side is about a third as long and concave outward. On the posterior side there

*The specific determination of these Las Delicias specimens is uncertain, as the apical parts are not preserved.

is a short cardinal area, at the top of which the flat brachial valve is attached; the posterior articulating extension of the brachial valve fits into the groove of the inside of the cardinal area. The brachial valve rests on a rim extending around the inside of the marginal part of the pedicle valve, its plane lying at about 45° to the main axis of the pedicle valve. There is no conspicuously developed apical callosity or internal septa. A row of spines lies about the aperture on the anterior side. The outside of the shell is covered by numerous round, prostrate anchoring spines. Cardinal process of the brachial valve extended back from the cardinal margin as a narrow ridge with two short lobes at the end. Dimensions of one specimen from loc. 479: length of anterior side, 18 mm.; of posterior side, 6? mm.; width of brachial valve, 15 mm.; length of brachial valve, 12 mm.

Observations: This species is intermediate in structure between *Teguliferina* and the more specialized forms of *Prorichthofenia.* The cardinal area is very short, a fact which indicates that the migration of the point of articulation of the brachial valve from the apex (as in *Teguliferina)* to a point high on the posterior side of the shell (as in *Prorichthofenia likharewi,* etc.) was only the beginning. Were it not for the presence of the small cardinal area, it would be placed in *Teguliferina,* for its general aspect is the same and there is no distinctly developed apical callosity or internal septa.

Distribution: Hess formation (Glass Mountains) at 105, 207, 208, and 222. Hess formation (Sierra Diablo) at 475, 476, 478, and 479 (abundant, types). Hess formation (Finlay Mountains) at 511.

PRORICHTHOFENIA UDDENI (Böse)

Pl. XXXI, Figs. 1–6

?1908 *Richthofenia permiana* (pars). Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 284–285, pl. 24, figs. 10–10a; pl. 31, figs. 1–1a. Basal black limestone, Guadalupe Point (Stas. 2920 and 2967). Delaware Mountain formation, "Comanche Canyon," Glass Mountains.

1916 *Richthofenia Uddeni.* Böse, Contributions to the knowledge of Richthofenia in the Permian of West Texas. U. of Texas Bull. 55, pp. 43–48, pl. 2, figs. 1–7, 9–14, 16; pl. 3, figs. 2–3. Zone of *Waagenoceras* n. sp. (Leonard); ? zone of *Medlicottia* n. sp. (Word).

Description: Pedicle valve broadly conical; apex pointed and turned toward the posterior side. Transverse section transversely oval. Outer surface rugose and marked by strong growth lines; it gives rise to many long hollow spines, projecting generally downward or laterally for attachment to a foreign body. Median layer thickest in the apical region, especially along the middle of the anterior side; it is not, however, more than a few millimeters thick even in large shells. Directly below the aperture there are several sharp flanges marking successive growth stages; at the aperture the shell flares out in a broad thin sheet. Living chamber generally equal in length to about two-thirds the depth of the valve; it is bordered above by the shelf on which rests the brachial valve. The inner side of the cardinal area is not exposed to the living chamber, being covered by a later deposit of the mantle. In the median apical part of the living chamber there is a broad, rounded elevation, extending from the posterior side across the bottom of the chamber and along the median anterior surface, where it gradually decreases in elevation but is distinguishable as far up as the shelf. The top of the ridge gives rise on the posterior side to a sharp median septum, which connects with the later deposit covering the inside of the cardinal area, and rises halfway up the posterior side of the shell toward the place of articulation of the brachial valve. On each side of the septum, directly within the fold of the inside of the cardinal area, there is a well-defined pit; these pits and the sides of the septum were evidently the places of attachment of the muscles. Several small, upwardly directed spines are present inside the living chamber. Immediately above the shelf on which rests the brachial valve, on the anterior and lateral inner surface of the shell, there are ridges which project upward, and at the aperture give rise to thick, bifurcating spines, which are directed upward and inward toward the axis of the shell.

Brachial valve flat, its outline corresponding to the cross-section of the upper part of the living chamber.

Dimensions in mm. of several specimens:

	1(loc. 128)	2(loc. 128)	3(loc. 120)	4(loc. 124)
Length of pedicle v.	27	22	27	45
Length of brachial v.	25	17	18	—
Width of brachial v.	25	20	23	28

Observations: That this species is a primitive type is indicated by its broadly conical form, short cardinal area, and single, rather than multiple rim of spines about the aperture. These features, and likewise the presence of the median septum on the posterior side (rather than on the anterior side as in *P. likharewi)* serve to distinguish it from the other species in the present fauna.

The specimens identified by Girty as *Richthofenia permiana* from the basal black limestone at Guadalupe Point, as well as one of Girty's specimens from the Glass Mountains, appear to agree in outer configuration with *P. uddeni.* Since the internal structures were not seen in some, and not well enough preserved in others to distinguish them from *P. permiana* conclusively, they are questionably referred to *P. uddeni.* It may be noted that *P. permiana* would not be expected to occur at the horizon of the basal black limestone (Bone Canyon member).

Distribution: Leonard formation (Glass Mountains) at 7–14, 20, 21, 24, 91x, 120 (good silicified specimens), 121, 128 (common), and Tb. Word formation (Glass Mountains) at T251. Bone Canyon member (Sierra Diablo) at 485. Leonard formation, transition beds (Shafter) at Th (15963—figured by Böse, pl. 2, figs. 10, 11, 14); above transition beds (Shafter) at Ti (16009—figured by Böse, pl. 2, figs. 12, 16).

Family LYTTONIIDAE

Genus PARAKEYSERLINGINA Fredericks (=EOLYTTONIA Fredericks)

Diagnosis: Shell concavo-convex, hinge-margin narrow. Pedicle valve gently and irregularly convex, expanding over the beak. Outer surface marked by uneven concentric growth lines; shell bilaminate, the external layer being fibrous, the internal one punctate. Within the pedicle valve there is a complexly lobate septal ridge corresponding to the brachial ridges which are supposed to be present in the brachial valve. There is a narrow median invagination of the ridge standing back from the front margin nearly to the beak, and 9 to 12 or more lateral lobes, which lie at a right angle to the median lobe or are directed somewhat backward. The septal ridge or fillet is distinctly looped, and does not, as in *Lyttonia* and *Oldhamina*, have the appearance of septa connected at their ends by loops; this is due to the feeble development of the invagination of the outer shell layer which in *Lyttonia* and *Oldhamina* rises between the septal ridges to form the axes of the septa. Brachial valve unknown, but supposedly like that of Lyttonia.

Genotype: *Keyserlingina darvasica* Tschernyschew.*

Geologic age: Lower Permian (Schwagerina zone of Darwas, Bokhara; lower Permian of Ussuriland; Wolfcamp formation).

Observations: This genus occupies an intermediate position between *Keyserlingina* and *Lyttonia.* From the former it differs in having a greater number of lateral lobes, which are longer, are bent toward the lateral margins, and lie closer together. From the latter it is distinguished by having fewer lateral lobes, which lie farther apart, and in having the median and lateral lobes not united in pairs to form the septa by the development of axes of the outer shell layer which project up between the lobes as in *Lyttonia.*

Fredericks has proposed two generic designations for species which appear to have the same diagnostic characters. In 1916* the name *Parakeyserlingina* was introduced for *Keyserlingina darvasica* Tschernyschew, while in 1923* he introduced the name *Eolyttonia* for *Oldhamina mira* and *O. ivanovi* Fredericks. The differences indicated between them hardly seem to be of generic value. The one occurs in the basal Permian of Bokhara and the other in beds of Artinskian age in Ussuriland (southeastern Siberia); it therefore seems likely that they lived synchronously between the time of *Keyserlingina* and that of *Lyttonia* and *Oldhamina.* Because of the little difference, if any, between the two, it seems best to recognize only the first named—*Parakeyserlingina,* although *Eolyttonia* would be a more satisfactory name.*

*Described and figured in: Fauna der Oberpalaeozoischen Ablagerungen des Darwas, Mém. Com. Géol. (Russie), n. s., liv. 104, 1914, pp. 13-14, 49.

*Mém. Com. Géol., (Russie), n. s., liv. 156, p. 67.

*Rec. Geol. Com. Russian Far East, no. 28 (1924), pp. 22, 25. In this reference the name *Eolyttonia* is said to have been proposed in 1922, but the original reference is not stated.

*Fredericks regards *Lyttonia tenuis* Waagen as an *Eolyttonia,* relying evidently on Waagen's few figures of that species. This hardly seems to be justified, for without actual specimens for study it is very easy to make errors in interpreting the structure of the septal fillet. The specimen figured by Kindle (Trans. Roy. Soc. Canada, ser. 3, vol. 20, sect. 4. p. 110) from British Columbia, under the name of *Leptodus* cf. *tenuis,* has the appearance of a *Parakeyserlingina,* as each septal fillet appears to consist of two ridges separated by an axial groove, but a definite judgment on this point is not possible.

According to Fredericks* the development of the Lyttoniidae took place in the following manner:

The ancestor of the family is supposed to be *Marginifera.* In that genus Fredericks believes the marginal fold to be due to abnormal development of the dental plates ("apical plates") resulting from reduction of the cardinal area. Strong transverse development of the fold leads to the formation of a closed ring as in *Paramarginifera* Fredericks (genotype *M. clarkei* Tschernyschew). This ring is said to be analogous to the spondylium of brachiopods having well-developed cardinal areas. Further development of the ring leads to invagination of the median anterior part, forming two lobes: this stage is that of *Pseudokeyserlingina* Fredericks (hypothetical). With the development of a pair of lateral invaginations of the marginal ridge we have *Prokeyserlingina* Fredericks (hypothetical), and with two more pairs, *Keyserlingina* Tschernyschew. Simultaneous with these changes comes the reduction of the brachial valve until it covers only the area inclosed by the marginal ridge. *Poikilosakos* Watson is thought to be an offshoot from the main stem of the evolution of the family, for it has greatly reduced muscle scars, one of which is more strongly developed than the other, and the marginal fillet is frilled. Further development of this line results in the formation of a greater number of lateral loops of the marginal fillet, which come to lie closer together. In *Parakeyserlingina* the invaginations of the marginal ridge are very long and narrow, but are grooved along the axis, so that they do not form a septa as in *Lyttonia. Lyttonia* and *Oldhamina* are still further specialized: they have a greater number of lateral invaginations, which are very narrow and have in the axial part of each a thickening of the outer shell layer ("interlobal callosity" of Fredericks) which rises between the parts of the marginal ridge on opposite sides of the invagination (and also in the median invagination of the shell) until it becomes higher than the bordering ridges and forms a septum. As a result the inside of the pedicle valve of *Lyttonia* and *Oldhamina* have numerous lateral septa and a long median septum, which are connected at their distal ends by loops; the original structure, that of an invaginated ridge, is thus obscured.

Whatever may be the truth of the supposed evolution from *Marginifera* to *Keyserlingina,* the evolution from *Keyserlingina* to *Lyttonia* and *Oldhamina* is well substantiated in both European and American forms of this group.

*On the subfamily *Lyttoniinae* Waagen: Mém. du Com. Géol. (Russie), n. s., liv. 156 (1916), pp. 55-79. In Russian.

Addenda to the Dissertation of G. N. Fredericks, "Paleontological Notes. 2, Some Upper Paleozoic Brachiopoda of Eurasia," presented in candidacy for the degree of Master of Mineralogy and Geognosy, pp. 1-2. 1917. In Russian.

Upper Paleozoic of the Ussuriland. I. Brachiopoda. Rec. Geol. Com. Russian Far East, no. 28 (1923), pp. 22-27. Vladivostok, 1924. In Russian.

Upper Paleozoicum of the Ussuriland. II. Permian Brachiopoda of Cape Kalouzin. Rec. Geol. Com. Russian Far East, no. 40 (1924), pp. 11-16. Vladivostok, 1925. In Russian.

Note sur l'origine de l'appareil septal de *Lyttoniinae,* Ann. Soc. paléont. Russie, vol. 3, pp. 108-110. In Russian.

New Lyttoniinae from upper palaeozoicum of the Oural, Bull. Soc. Oural. Sci. Nat., pp. 59-65. In Russian.

New Lyttoniinae from the Upper Carboniferous of Krasnoufimsk, pp. 83-89, 1927? In English.

In this connection it is necessary to consider the genus *Uralia* Likharew* (*Uralina* Schuchert and LeVene). This is based on what is supposed to be the brachial valve of a lyttoniid. This shell has an entire margin and a rounded outline; there is a median ridge and seven pairs of transverse folds. Likharew believes that in all the early forms of the Lyttoniidae the brachial valves had entire margins, and that the splitting of the shell into lobes occurred only in *Lyttonia* and *Oldhamina*. He conceives the brachial valve of the more primitive forms to be like that of *Uralina*, each fold in the brachial valve overlying a lobe of the marginal ridge in the pedicle valve. *Uralina* is thought to be a stage intermediate between *Keyserlingina* and *Lyttonia*, and to include probably *Oldhamina* (=*Eolyttonia*) *mira* Fredericks. If Likharew's supposition as to the probable structure of the brachial valve of the early lyttoniids were correct, therefore, *Uralina* would be a synonym of *Parakeyserlingina*. However, although brachial valves of the early lyttoniids have not been found, it has been argued convincingly by Watson* and others that the brachial valve covered only the space within the marginal ridge and that when closed its edge rested on the inner face of this ridge, leaving the margins of the pedicle valve uncovered all around. If it is true that the brachial valve of these forms was lobate, then *Uralina* can hardly belong to this group at all. The type specimen, indeed, can hardly be regarded as adequate material to make definite assignment to this or any other invertebrate group.

PARAKEYSERLINGINA FREDERICKSI King, n. sp.

Pl. XXXI, Figs. 7–9

Description: Shell large, very irregular. Pedicle valve unevenly convex; one specimen from T93 has the umbonal region greatly expanded laterally and strongly convex, arching over the dorsal side to form a cup. Shell bilaminate, the external layer being marked on the outside of the shell by fine, irregular growth wrinkles, while the internal layer forms the complexly fluted septal fillet. The fillet is infolded in at least 11 pairs of lateral lobes* and a long, narrow median lobe. The lateral lobes may be inclined at about a right angle to the median lobe, but generally slant somewhat forward. In the specimen from loc. T93 above referred to (the only one in which the posterior part is preserved) the first 5 lobes are inclined forward at angles as high as 50°, and are widely spaced from each other, while the later ones lie at nearly right angles. This may indicate a repetition of phylogeny in ontogeny, for in the earlier forms *Keyserlingina* and *Poikilosakos* the lateral lobes are directed forward. Each lobe is very narrow and has a groove along its axis. The inward terminations of the lobes are high and sharp; their elevation subsides distally. The vertical axes of the lobes are inclined forward at a greater or lesser angle. The outer margin of each lobe is crenulated by low vertical ridges, each about 1 mm. wide; these extend more or less interruptedly across the space between adjoining lobes. Between each lobe and parallel to the lobes there is a low broad ridge. Adjoining lobes are connected distally by the broad, low loop of the septal fillet. The median lobe of the shell is narrow and grooved in the median line just as the lateral lobes.

Brachial valve unknown, unless a brachial valve of a lyttoniid from loc. 15, having pinnate lobes lying at about 45° to the median axis, belongs to this species.

Observations: The specimens from loc. T93 have been referred to in several places as *Lyttonia*.* The genus *Lyttonia* is not known to occur in the Wolfcamp formation. This species cannot be satisfactorily compared with the other three members of the genus, *P. mira* (Fredericks), *P. ivanovi* (Fredericks), and *P. darvasica* (Tschernyschew), for none of these occurs in any abundance, and the few specimens figured show considerable variation. The closest resemblance appears to be with *P. ivanovi.*

Distribution: Wolfcamp formation (Glass Mountains) at 71?, 87 low, 93, T93 (types), and 194?. Hess formation (Glass Mountains) at 15?. Leonard formation (Glass Mountains) at 19?.

Genus LYTTONIA Waagen*

Diagnosis: Shell flattened irregularly, sprawling in growth, in youth attached by the beak of the pedicle valve, but later becoming free, the point of attachment becoming covered by a strong, irregular, lamellose growth. Pedicle valve gently convex, nearly flat. On the interior of the pedicle valve there is a low but thick median septum and as many as 40 pairs of thick, pinnately arranged, rounded lateral septa, which are directed transversely and are somewhat convex toward the front; they do not unite with the median septum, but are united at their distal ends by loops of the septal fillet. The septa consist of parallel outer ridges of the inner shell layer (the septal fillet) separated by an elevated axial part formed by a thickening of the outer shell layer ("interlobal callosity" of Fredericks).

Brachial valve smaller than the pedicle valve, divided into two halves by a median slit extending back from the front margin, and again divided by lateral incisions from each side into a number of smaller lobes; the lobes are slightly convex toward the front and correspond to the spaces between the septa. Internally there is a strong median septum, which probably ends forward in the longitudinal slit, and terminates at the hinge-line in an atrophied cardinal process.

Cardinal area, delthyrium, hinge-teeth, and crura are completely lacking; dental lamellae are present but very small and thin. Muscular impressions of the pedicle valve very weak and indistinct; in the brachial valve not distinguished. Shell bilaminate, the outer layer of the pedicle valve being smooth and the inner granular.

It is probable that each pinna of the brachial valve supported a double band of lophophore extending its entire length, and that the median septum was provided with a strip of lophophore on each side. Each pinna of

*Licharew, B.: Über einen neuen Vertreter de Fam. *Lyttoniidae* aus dem Obercarbon des Ural. Comtes Rendus de l'Acad. des Sc. de Russie, 1925, pp. 4 7, text fig.

*Geol. Mag., n. s., vol. 4 (1917), p. 215.

*The word "lobe" is here used for the inward-directed fold of the septal fillet.

*As in U. of Tex. Bull. 1762, p. 16.

*Editor's Note: The name *Leptodus* Kayser has priority and Kindle (89, p. 109) has shown that Waagen was not justified in rejecting it and substituting the name *Lyttonia*.

the brachial valve rests along its anterior edge on the side of a septum of the pedicle valve, and ends distally at the loop connecting adjoining septa; the cavity of the shell thus forms a series of canals leading to a pair of central channels running antero-posteriorly. Each lateral canal is open to the outside by a slit running the length of the dorsal pinna, formed by the gap between that pinna and the one behind it. Probably the ciliary currents were driven into these lateral canals and by the action of the strip of lophophore on the side of the median septum moved toward the posterior end.*

Genotype: *Lyttonia nobilis* Waagen.

Geologic age: Middle and upper Permian.

Observations: The following are the differences between *Oldhamina* and *Lyttonia: Lyttonia* is ovoid in outline and shallow because little arched, whereas *Oldhamina* is more arched and subhemispherical, its beak being short and incurved. There is a well developed apical callosity in *Oldhamina*, while in *Lyttonia* it is only slightly developed. The septa in *Oldhamina* are turned strongly forward, while in *Lyttonia* they diverge from the median line at nearly a right angle. *Lyttonia* differs from *Parakeyserlingina* in having a greater number of lateral septa, which have a thickened and elevated, rather than a grooved axial part.

Several species of this genus have been recognized, but Noetling and later Hayasaka have shown that they are probably only variations of one highly variable species.

LYTTONIA NOBILIS AMERICANUS (Girty)

Pl. XXXI, Figs. 10–13; Pl. XXXII, Figs. 1–9

1908 *Leptodus americanus.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 212–213, pl. 4, figs. 8–8b, pl. 25, figs. 1–3a.

Delaware Mountain formation, Guadalupe Point (sta. 2931). Delaware Mountain formation, Diablo Mountains (sta. 3764). Delaware Mountain formation, southern Delaware Mountains (sta. 2969).

1908 *Leptodus guadalupensis.* Girty, *idem.*, pp. 213–215, pl. 4, figs. 6–7.

Middle Capitan, Capitan Peak (sta. 2926). Basal Capitan, hill southwest of Guadalupe Point (sta. 2906). Delaware Mountain formation, "Comanche Canyon," Glass Mountains.*

Description: Shell large, concavo-convex, with an ovoid outline, the posterior part being narrower than the anterior. Pedicle valve slightly and irregularly convex, with entire margin. In the posterior part the margin of the pedicle valve may grow up and arch over the posterior part of the brachial valve, or turn back to lie on the outer posterior part of the shell; the inside of this growth is thickly set with granulations. As a result the umbonal region has an irregular, gnarly aspect. Outside of the shell smooth except for strong, uneven growth lirae and low concentric undulations, which do not parallel the course of the septa within the shell. In the posterior part of one specimen (from loc. 476) there is a broken area near the posterior margin which the growth lines appear to encircle, these lines being closely crowded posterior to the broken area but separated from one another in broad curves toward the sides and front of the shell; it may be that this broken area was a point of attachment during the first part of the growth of the shell. Another specimen (from loc. T240a) appears to have had a similar point of attachment which has been overgrown by the laminar outgrowth of the posterior margin, as has been described by Noetling for *L. nobilis.* An immature specimen from loc. 54 is attached to the concave surface of a brachial valve of *Marginifera popei.* (See also Girty, pp. 214–215, pl. 4, figs. 8–8b.) In a specimen from loc. 128 the posterior lateral margins have grown around the dorsal side of the shell so as to give the posterior part a cup-like form.

Within the pedicle valve there are at least 20 pairs of lateral septa, which are arranged pinnately on opposite sides of a median septum and opposed in pairs. In plan these lateral septa arch slightly toward the front and in section they are inclined forward. They are high and sharp at their proximal ends, but are low at the distal ends, where they are connected with the adjacent septa by a loop of the marginal ridge. An immature specimen from loc. 54 shows the first invagination of the septal fillet to be distinctly double, and divided along the axis by a deep groove. The second invagination appears to be a true septum, the space between the two sides of the septal fillet being filled by an "interlobal callosity." In the specimen from T240a the first four septa are distinctly double, as in *Parakeyserlingina*, and it appears thus to repeat in its ontogeny the phylogeny. The septa increase in length from the umbonal region toward the front margin, corresponding to the increase in the width of the shell. Separating the septa are regularly disposed interspaces, each about 2 mm. broad, which bear a broad median longitudinal ridge, conspicuously lower than the adjacent septa but strongly enough developed so that a prominent groove lies on each side of it; this structure is especially noticeable in molds of the inside of the pedicle valve, in which the grooves lying against the septa have the appearance of a continuous looped ridge which might be mistaken at first for the septal fillet (See Girty's plate 4, fig. 6, for example).* In the bottom of each of the grooves lying beside the septa, there is a row of regularly arranged pits, about 0.75 mm. apart, which give rise to shallow longitudinal depressions extending across the interseptal space and terminating at the crests of the septa, to which they give a strongly crenulate aspect.

A median septum extends nearly the length of the inside of the valve; it is slightly lower than the proximal ends of the lateral septa, but is of about the same width.

Brachial valve pinnate, smaller than the pedicle valve and somewhat concave. Its lateral margins are deeply

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*See Noetling, Fritz: Untersuchungen über die Familie Lyttoniidae Waagen emend Noetling, Paleontographica, bd. 51, pp. 129–153, pls. 15–18.

Also, Watson, D. M. S.: *Poikilosakos*, a remarkable new genus of brachiopods from the Upper Coal-measures of Texas, Geol. Mag., n. s., vol. 4 (1917), pp. 216–219.

*The last two localities are listed under the head of "horizon and locality" for *L. americanus*, but Girty states clearly in the text (pp. 214–215) that he had placed the Glass Mountains and Capitan specimens with *L. guadalupensis.*

*Confusion as to the actual nature of this structure led Fredericks to the conclusion that Girty's two species were "*Eolyttonia*" rather than true *Lyttonia.*

split by lateral incisions, so that the shell is divided into a series of small lobes corresponding to the interseptal spaces of the other valve. There is a broad median axis, narrowing toward the front, which is covered on the outside by coarse granulations; in the median line there is a lightly impressed furrow, on the outside, which corresponds to a median ridge on the inside. This furrow deepens toward the front and ends in a slit near the anterior margn. The lateral lobes bend downward on their posterior and anterior sides, so that they are semicircular in transverse profile. As a result, they are concave on the inner side.

Dimensions in mm. of several specimens:

	1 (loc. 158)	2 (loc. 4)	3 (loc. 152)	4 (loc. Tx148)	5 (loc. 128)
Length	60	45	45+	50+	42
Width	60	70	80	45	40

Observations: The only difference that can be made out between *L. nobilis americanus* and typical *L. nobilis* from the Salt Range is the presence of a long, well developed median septum in the pedicle valve of the former. In the Indian type a median septum occurred in the anterior part of the shell and is supposed to have been resorbed in the posterior part during the growth of the shell. The other distinguishing features mentioned by Girty, as well as those differentiating *L. americanus* and *L. guadalupensis* have been well shown by Hayasaka* to be unreal, and to rest either upon the imperfection of Girty's material or upon a misunderstanding of the actual structures observed. Whether the American form should not be considered a variety of *L. richthofeni* (Kayser) rather than of *L. nobilis* is a matter of some doubt. Hayasaka and others regard the two as synonymous, but since there is no such complete description of the Chinese species as there is of *L. nobilis* in Noetling's monograph, I have thought it best to compare the American form with the better known Indian type.

Girty's identification of *Oldhamina?* from the Capitan is certainly very doubtful, for many specimens of *Lyttonia* in North America are more or less convex longitudinally but do not show the characters of *Oldhamina*.

Distribution: Hess formation (Glass Mountains) at 4, 102, 103, 105, 106, 108, and 222. Leonard formation (Glass Mountains) at 8-14, T9, 11b, 15, T15, 24, 26, 31, 33, 37, 38, 81, 120, 121, 123, 124, 128, T183, Tb, and DI. Word formation (Glass Mountains) at 6, 32, 48, 51, 54, 55, 58, T140, 144, T144, 145, 146, 147, 148, T148, Tx148, 152, 154 158, 171, 192, 238, 239, T239, T240a, 241, 247, 249, 250, 251, 264, 265, Ta, Tc, and Tx. Altuda member (Glass Mountains) at 57. Hess formation (Sierra Diablo) at 476, 478, and 479. Bone Canyon member (Sierra Diablo) at 484 and 491. Victorio Peak member (Sierra Diablo) at 493 and 499. Delaware Mountain formation (Sierra Diablo) at 504. Limestone of Cerro Caballo (Las Delicias) at section 1, bed 11 west of the Noria; section 1, bed 15; and section 1, bed 12.

*Paleozoic Brachiopoda from Japan, Korea, and China, Sci. Repts. of Tôhoku Imperial University, ser. 2, vol. 6, no. 1, pp. 106-107.

LYTTONIA HORTONI King, n. sp.
Pl. XXXIII, Figs. 18–19

Description: Shell large, concavo-convex, outline rounded, expanding toward the anterior end. Within the pedicle valve there are as many as 20 pairs of lateral septa, convex toward the front, arranged opposite one another on opposite sides of the median septum. The septa have about the same height throughout their entire length; they are crowned with elongated nodes 2 to 3 mm. long, separated from each other by narrow transverse saddles. The nodes consist of inward extensions of the external shell layer, while the intervening saddles are covered across with the internal shell layer. In one specimen one of the septa bifurcates about 5 mm. distal to the median line of the shell. Median septum about the same height as the lateral septa, and interrupted in the same manner.

Brachial valve pinnately split, but with dissepiments across the interlobal slits corresponding to the saddles lying between the dashes of the septa within the other valve. A groove lies in the median line, above the median septum of the pedicle valve.

Dimensions in mm. of two specimens:

	1 (loc. 7)	(2 (loc. 220)
Length	60+	60
Width	110	97

Observations: Since this species is much less common than *L. nobilis americanus* the specific characters could not be made out as accurately as for the other species. However, the nature of the septa is so strikingly different from that in other described species of *Lyttonia* that it is easily distinguished by this character alone. Since the original looped brachial ridge appears to have been obliterated by the strong development of the invagination of the outer shell layer, which has assumed a peculiar interrupted form, this species would seem to be extraordinarily specialized.

Distribution: Hess formation (Glass Mountains) at 17b, 207, and 222. Leonard formation (Glass Mountains) at 7. Word formation (Glass Mountains) at 54 and T140.

Genus LEIORHYNCHUS Hall

Diagnosis: Shell rhynchonelliform, medium-sized to rather large, subovate in outline and commonly subglobular in form. Median fold and sinus well developed, the plications obsolete or nearly obsolete on the lateral slopes of the valves, more or less well developed on the fold and sinus. In the pedicle valve the hinge-teeth are small and are supported by slender, vertical dental lamellae. In the brachial valve a well defined median septum is present in the rostral part of the valve; it is divided internally to form a V-shaped crural cavity. Hinge-plate divided, the inner margin of each lateral part being supported by one of the lateral walls of the crural cavity. Cardinal process absent. Crura formed by the anterior extension of the inner margins of the two divisions of the hinge-plate.

Genotype: *Orthis quadricostata* Vanuxem.

Geologic range: Devonian to Permian.

Observations: This genus has generally not been recognized above the Mississippian, but several Pennsylvanian and Permian species are almost identical in external form with the Devonian and Mississippian ones. Since the sole distinction of the genus from *Pugnoides* is the outer configuration, there appears to be no reason for not referring them to *Leiorhynchus*. Moreover, the outer resemblance between the different species is so strong that they appear to be genetically related. In the lower Pennsylvanian are two species—*L. carboniferum* Girty and *L. rockymontanus* (Marcou). The genus does not occur in the Cisco or in the lower Permian of Trans-Pecos Texas, the next appearance being in the Leonard formation.

LEIORHYNCHUS BISULCATUM (Shumard)

Pl. XXXIII, Figs. 1-8

1858 *Camarophoria? bisulcata.* Shumard, Trans. Acad. Sci. St. Louis, vol. 1, p. 296 (date of volume, 1860).
Dark Permian limestone: Guadalupe Mountains; conglomerate at the mouth of Delaware Creek.

1859 *Camarophoria bisulcata.* Shumard, *idem*, p. 394, pl. 11, figs. 2a–d.
Dark and white limestone: Guadalupe Mountains; conglomerate at the mouth of Delaware Creek.

1908 *Pugnax? bisulcata.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 310–312, pl. 21, figs. 11–12.
Dark limestone, Pine Spring Guadalupe Mountains (sta. 2930).

1908 *Pugnax? bisulcata* var. *gratiosa.* Girty, *idem.*, p. 312, pl. 21, figs. 10–10c.
Dark limestone, Pine Spring Guadalupe Mountains (sta. 2930).

1908 *Pugnax? bisulcata* var. *seminuloides.* Girty, *idem*, pp. 312–313, pl. 21, figs. 13–16, pl. 29, fig. 9?.
Middle Capitan, Capitan Peak (sta. 2926); dark limestone, Pine Spring, Guadalupe Mountains (sta. 2930); Delaware Mountain formation, southern Delaware Mountains (stas. 2965, 2969, and 3500).

Description: Shell medium-sized, outline subcircular to subpentagonal, width about equal to length. Pedicle valve shallow, brachial valve generally strongly and evenly convex. Ventral beak small and erect, showing clearly the foramen and the false cardinal area. The cardinal margins form slightly more than a right angle. Dorsal beak small, rounded, and in general hidden beneath the beak of the pedicle valve. In the median posterior part of the pedicle valve there is a narrow fold, which is replaced toward the front by a broad, shallow sinus, first distinguishable near the middle of the valve; the sinus may be perfectly smooth or may bear as many as 4 low, rounded ribs, the usual number being 3. Median posterior part of the brachial valve depressed in a narrow sinus, which gives way to the front in a fold, which is high in the anterior part of the shell; the fold is smooth or is marked by as many as 5 low plications corresponding to the sulci of the sinus. Lateral slopes of both valves smooth or bearing as many as 4 low, rounded, indistinct plications. Anterior margin strongly deflected downward on each side of the sinus, but, except for angulations caused by the plications, nearly straight between these deflections.

The brachial valve has internally a median septum supporting a V-shaped crural cavity and a divided hinge-plate. The pedicle valve contains short dental lamellae.

Dimensions in mm. of several specimens:

	1(Las Del. sec. 2)	2(Las Del. sec. 2)	3(Shumard's type)
Length	15	16	13.5
Width	17	18	15
Thickness	11	10	9

Observations: There can be no doubt as to the correctness of the identification with Shumard's species. The name is here used in the broad sense in which it was originally applied, the two varieties recognized by Girty being regarded as synonyms. The variety "*gratiosa*" was established for those shells having 2 or 3 broad plications on the fold and sinus, and "*seminuloides*" for those with unplicated fold and sinus. From one calcareous concretion in the black shales northwest of Las Delicias I collected 56 specimens of *L. bisulcatum*, of which 29 would be placed in the typical variety of Girty, with more than 3 plications on the fold, 16 would go into the variety "*gratiosa*," and 11 in "*seminuloides*." The gradation is so complete, however, that many of these specimens would be difficult to place. Since all three of Girty's varieties were collected principally from his sta. 2930 it appears that they, too, were but stages of variation in a highly variable species. At Girty's localities, the variety "*seminuloides*" was the more abundant, while among my own specimens the typical form is the common one.

The most closely related species is *Leiorhynchus weeksi* (Girty) and its variety *nobilis*. That species is larger, has broader plications, and the umbonal part of the brachial valve is not depressed, and of the pedicle valve not elevated as in *L. bisulcatus*. Another related species is *L. rockymontanus* (Marcou), which is larger, broader, and has a less well defined fold and sinus.

Distribution: Leonard formation (Glass Mountains) at 128. *Waagenoceras* zone (Las Delicias) at section 1, bed 19, section 2, beds 4 and 6 (abundant).

LEIORHYNCHUS WEEKSI NOBILIS (Girty)

Pl. XXXIII, Figs. 9–11

1910 *Pugnax weeksi* var. *nobilis.* Girty, Fauna of the Phosphate Beds of the Park City Formation, U. S. Geol. Sur. Bull. 436, pp. 32–33, pl. 3, figs. 5–7.
Phosphate beds of the Park City formation: Wyoming and Idaho.

Description: Shell medium-sized, subovate to subpentagonal, width and length about equal. Ventral beak large, pointed, suberect, flattened; dorsal beak inconspicuous, strongly incurved. The umbonal regions of both valves are evenly convex. The fold of the brachial valve and the sinus of the pedicle valve originate at about mid-length; they are broad and well defined. There are three broad low plications on the fold and two in the sinus, and three less distinct plications on each lateral slope. The plications originate somewhat posterior to mid-length of the shell, and may even extend nearly to the beaks.

Dimensions in mm. of several specimens:

	1 (loc. 144)	2 (loc. 265)	3 (loc. 144)	4 (Girty's type)
Length	18	18	19	26
Width	18	17	20	24
Thickness	11	11	11	13

Observations: The specimens of the present collection are more like the unusual specimen figured by Girty on plate 3, fig. 7 than they are like the type specimen of the variety. As Girty pointed out in his description, his specimens are so variable that it is difficult to find natural lines of division permitting the distinction of varieties. Although typical forms of the variety *nobilis* are quite different from the very faintly plicated typical forms of *L. weeksi*, there is complete intergradation between them. The Word specimens show less variation, all of them being definitely referable to the variety. The most important distinction between *L. weeksi* and its variety and *L. bisulcatus* is that the latter has a depressed dorsal umbonal region, showing the beginnings of a sinus which soon loses its identity in the median fold.

Shimer has described a species* *(Paraphorhynchus obscurum)* from Rocky Mountain quartzite, near Banff, which resembles typical *L. weeksi* in every respect except that it is said to be radially striate, and for that reason is placed in *Paraphorhynchus*. In view of the agreement in other particulars, it seems plausible to suggest that the two species are identical, the surface ornamentation of the Canadian specimens being in some way due to their manner of preservation.

Distribution: Word formation (Glass Mountains) at 144 (common), 259, and 265.

Genus PUGNOIDES Weller

Description: Shells rhynchonelliform, below medium size, subovate in outline, with the fold and sinus well developed. Both valves marked by rounded or subangular plications which become obsolete in the posterior part of the shell. Internal characters of both valves as in *Leiorhynchus*.

Genotype: *Rhynchonella ottumwa* White.

Geologic range: Mississippian to Permian.

PUGNOIDES ELEGANS (Girty)

Pl. XXXIII, Figs. 12–13; Pl. XXXIV, Figs. 2–4

1908 *Pugnax elegans.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 315–316, pl. 15, figs. 13–14a.

Middle Capitan, Capitan Peak (sta. 2926); base of Capitan, hill southwest of Guadalupe Point (sta. 2906).

Description: Shell medium-sized, wider than long, with a very spreading triangular shape and a prominent fold and sinus. The plications are angular, and are 3 in number on the fold, 2 in the sinus, with 3 or 4 on each lateral slope. The median plication on the fold may be distinctly smaller than the adjacent ones. The lateral plications are rounder and fainter than those on the fold.

Dimensions in mm. of several specimens:

	1 (loc. 106)	2 (loc. 108)	3 (loc. 104)	4 (loc. Ax)
Length	13	11	13	18
Width	14	14	18	22
Thickness	9	8	9	14

Observations: This species is distinguished from *P. swalloviana* by its more spreading, triangular shape and the constant presence of three plications on the fold and two in the sinus. It is narrower and has fewer plications on the fold and in the sinus than *P. transversus*.

Distribution: Hess formation (Glass Mountains) at 104, 106, and 108. Leonard formation (Glass Mountains) at 15?, T15a, and Ax. Word formation (Glass Mountains) at 154. Hess formation (Sierra Diablo) at 475 and 479.

PUGNOIDES PINGUIS (Girty)

Pl. XXXIV, Figs. 15–17

1908 *Pugnax pinguis.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, p. 319, pl. 21, figs. 21–21c.

Dark limestone, Pine Spring (sta. 2930).

Description: Shell medium-sized, subtriangular or subpentagonal, with rounded angles except at the beak. Pedicle valve shallow, beak small and erect, median sinus broad and shallow, originating anterior to mid-length, prolonged forward and upward as a tongue, the end of which lies at a right angle to the profile of the rest of the valve. Brachial valve deep, flattened over the median posterior part, strongly curved near the margins. Fold low, not distinct, except at the front. Plications of variable shape, in some specimens being low and rounded, in others rather high and angular; they originate several mm. anterior to the beaks. Their number is 3 to 5 in the fold and 2 to 4 in the sinus, and 3 to 5 on each lateral slope, becoming smaller laterally. Within the pedicle valve there are strong short dental lamellae, and in the brachial valve a short median septum.

Dimensions in mm. of several specimens:

	1 (loc. 124)	2 (loc. D3)	3 (loc. 17c)	4 (Girty's type)
Length	13	13	15	13
Width	13	15	18	14.5
Thickness	10	11	12	9

Observations: This species is distinguished by the combination of flattened pedicle valve, geniculation of the tongue of the sinus, deep brachial valve, and few, strong plications. The shell is relatively narrower and has fewer plications in the fold and sinus than *P. shumardianus*. It is relatively narrower than *P. elegans*, has a larger number of plications, and does not have as deep a sinus or as high a fold.

Distribution: Hess formation (Glass Mountains) at 17b and 17c. Leonard formation (Glass Mountains) at 26, 120, 124, and D3. Word formation (Glass Mountains) at Tx.

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*In Upper Palaeozoic Faunas of the Lake Minnewanka Section, near Banff, Alberta, Geol. Sur. Canada, Bull. 42, 1926, pp. 46–47, pl. 7, figs. 1–3.

PUGNOIDES SHUMARDIANUS (Girty)

Pl. XXXIV, Figs. 13-14

1908 *Pugnax shumardiana.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, p. 316, pl. 5, figs. 15-17c.
Middle Capitan, Capitan Peak (sta. 2926).

Description: Shell medium-sized, triangular, wider than long. Pedicle valve mostly rather flat, but turned sharply upward near the front. Median sinus broad, shallow, and rather well defined, prolonged upward as a tongue. Beak erect. Sinus marked by 4 angular plications, the lateral slopes by three and a faint fourth one. Brachial valve convex, elevated in the median part as a fold, which merges into the general convexity posterior to mid-length of the shell. Umbonal region flattened. Fold marked by 5 plications, the lateral slopes by 3 or 4 lower plications. None of the plications extends to the beak, the umbones being smooth. The fold and sinus are less strongly marked as seen from above than from an anterior view. Within the pedicle valve there are two strong, short dental lamellae and in the brachial valve a low median septum.

Dimensions in mm. of several specimens:

	1 (loc. T15a)	2 (loc. T15a)	3 (loc. 241)
Length	12	10	11
Width	16	12	14
Thickness	7	6	8

Observations: This species differs from *P. swallovianus* in having a larger size, less convexity, and 5 instead of 3 plications on the fold. It has about the same number of plications as *P. transversus,* but is much narrower in proportion to length.

Distribution: Leonard formation (Glass Mountains) at T15a.

PUGNOIDES SWALLOVIANUS (Shumard)

Pl. XXXIV, Figs. 10-12

1859 *Camerophoria Swalloviana.* Shumard, Trans. Acad. Sci. St. Louis, vol. 1, p. 294, pl. 11, figs. 1a-e (date of volume, 1860).
Permian rocks of the Guadalupe Mountains in Texas and New Mexico; one of the most abundant and characteristic species of the upper white limestone.

1908 *Pugnax swalloviana.* Girty, The Guadalupian Fauna, U. S. Geol. Surv. Prof. Paper 58, pp. 314-315, pl. 15, figs. 8-12d, pl. 21, figs. 17-19?.
Middle Capitan, Capitan Peak (sta. 2926); dark limestone, Pine Spring (sta. 2930).

1910 *Pugnax osagensis* var. *occidentalis.* Girty, Fauna of the Phosphate Beds of the Park City Formation, U. S. Geol. Sur. Bull. 436, pp. 33-34, pl. 1, figs. 21-22.
Phosphate beds of the Park City formation: Montpelier, Idaho

1927 *Pugnoides osagensis* var. *occidentalis.* Girty, in Geol., etc. of Part of Southeastern Idaho, U. S. Geol. Sur. Prof. Paper 152, p. 80, pl. 28, figs. 9-11.
Phosphoria formation: Montpelier, Idaho.

Description: Shell small, subpentagonal, strongly biconvex, as wide as or wider than long, with the greatest width at about mid-length of the shell. Pedicle valve very convex longitudinally, folded downward in the anterior half of the shell to form a deep, sharply defined sinus, which extends forward and upward as a tongue. Beak large, high, and erect. The sinus contains 2, or rarely 1, plications, and each lateral slope bears 3 or 4 plications. Brachial valve strongly convex, but with a distinct mesial depression in front of the beak. The median fold arises posterior to mid-length of the shell, and attains a considerable height at the front margin. The fold contains 3, or rarely 2, high, angular plications, and there are 3 or 4 plications on each side. The plications of both valves originate somewhat posterior to mid-length of the shell. Within the pedicle valve there are two short strong dental lamellae, and in the brachial valve a hinge-plate which is supported on each side by short lamellae, and gives rise to the downward-curving crura at its anterior end. There is a low dorsal median septum.

Dimensions in mm. of several specimens:

	1 (loc. 144)	2 (loc. T240)	3 (Shumard's type)	4 (Phosphoria)
Length	9	11	10	14
Width	11	11	10	16
Thickness	6.5	8	7	9

Observations: This species is distinguished from *P. osagensis* by its lower fold and generally greater number of plications on the lateral slopes. The difference is, however, small. In the Wewoka form *P. osagensis percostata* there are as many plications on the lateral slopes, but they are smaller than in *P. swallovianus.* In *P. texanus* the median fold is broader and lower, and has 3 or 4 rather than 2 or 3 plications. *P. bidentata* differs only in being smaller, more round in outline, and generally much more gibbous. The specimens from the Phosphoria described as *P. osagensis occidentalis* do not differ in any way from the Texas forms, except that the specimens figured are somewhat larger.

Distribution: Word formation (Glass Mountains) at 144, 148, 162, T240, 241, 243, and Tx.

PUGNOIDES BIDENTATUS (Girty)

Pl. XXXIV, Fig. 1

1908 *Pugnax bidentata.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 318-319, pl. 21, figs. 20-20c, pl. 24, figs. 17-17c.
Dark limestone, Pine Spring (sta. 2930); basal black limestone, Guadalupe Point (sta. 2920). (Type from sta. 2920.)

Description (after Girty): "Shell small. Ventral valve rather strongly bent longitudinally and inflected at the sides. Sinus broad and deep, occupying most of the valve; defined by a rather sharp angulation, which forms, even where undefined, the line along which the shell is inflected. A slight groove lateral to the angulation adds to its prominence and is the only indication of lateral plication. The sinus contains a low median rib not visible except toward the front margin. Beak apparently rather large, high, and erect.

"Dorsal valve strongly convex. Fold high, broad, occupying most of the shell; defined at the sides by an angular groove, which is succeeded laterally by a low ridge, making one indistinct lateral plication on each side. The fold bears a rather strong median sulcus, so that its summit is divided into two plications. The plications of both valves are subangular and moderately strong, but disappear a slight distance from the margin."

The specimens in the present collection generally have 3 plications on the fold and 2 in the sinus, but the agreement with Girty's types in other particulars makes it very probable that the identification is correct. The number of plications is variable in most species of this genus.

Dimensions in mm. of several specimens:

	1(loc. 491)	2(loc. 16)	3(loc. 120)	4(Girty's type)
Length	8	8	10	8
Width	9	9	10	7
Thickness	7	7	5.5	5.5

Observations: This species is very close to *P. osagensis*, but has a relatively broader fold and sinus, in some specimens fewer plications on the fold and in the sinus, and generally a more gibbous form. It is smaller, narrower, and has fewer plications than *P. texanus*. *P. swallovianus* is larger, more subpentagonal in outline, and less strongly convex.

Distribution: Leonard formation (Glass Mountains) at 4, 12, 16, 24s, 25, 26s, 38, 120, 128, and D1. Bone Canyon member (Delaware Mountains) at 491.

PUGNOIDES TEXANUS (Shumard)

Pl. XXXIV, Figs. 5–9

1859 *Rhynchonella Texana.* Shumard, Trans. Acad. Sci. St. Louis, vol. 1, p. 393 (date of volume, 1860).
Dark (Permian) limestone: Guadalupe Mountains; conglomerate at the mouth of Delaware Creek, Texas.

1908 *Pugnax osagensis.* Girty (non Swallow), The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 317–318, pl. 24, figs. 16-16b.
Dark limestone, Pine Spring (sta. 2930?); Delaware Mountain formation, Guadalupe Point (sta. 2931); basal black limestone, Guadalupe Point (sta. 2920); Delaware Mountain formation, southern Delaware Mountains (sta. 2964).

1908 *Rhynchonella? texana.* Girty, *idem.*, p. 324.

Description: Shell small, transversely elliptical; lateral slopes converge toward the beak at an angle of 90° to 120°. Pedicle valve gently convex, marked in the anterior half by a strong median sinus, which is deflected upward as a tongue. Brachial valve more strongly convex, mesially elevated in front. Anterior part of the shell marked by high costae, three of which generally occur on the fold and two in the sinus, and from three to five on each lateral slope. Internally there are short dental lamellae in the pedicle valve; in the brachial valve there is a divided hinge-plate, which gives rise to the downward-curving crura.

Dimensions in mm. of several specimens:

	1(loc. 440)	2(loc. 223)	3(loc. 439)	4(Shumard's type)
Length	12	11	7	9
Width	14	12	8	7.5
Thickness	10	6	5	5.5

Observations: This species is very variable. In the lot from loc. 223 the sinus is rather shallow, the ventral umbo well arched, and the tongue curved up rather than geniculate. In other shells, typified by those from loc. 440a, the sinus is more abruptly deepened at the front, the ventral umbo smaller, and the front of the tongue at right angles to the plane of the lateral margins. The two types seem, however, to intergrade, and there does not seem enough basis for distinction.

P. texanus is very close to *P. osagensis* (Swallow). It is distinguished by being generally larger, having relatively somewhat broader plications, and having a shorter tongue-like extension of the sinus of the pedicle valve. In *P. osagensis,* moreover, the lateral plication next to the sinus tends to rise high at the front, while in *P. texanus* it is rather low, so that the profile of the shell does not show a sharp angulation in the ventral anterior part as does the Pennsylvanian species.

Girty believed that Shumard's *Rhynchonella texana* must actually belong to "*Rhynchonella*" rather than *Pugnax* because of the presence in it of a "false area," which Girty says is a character quite foreign to the group of *Pugnax.* Weller, however, mentions such a feature in some Mississippian *Pugnoides.* Shumard's description agrees very completely with the present form except that he states that the posterior margins converge at an angle of 63°. If 63° is taken to be the complement of the angle between the two lateral slopes, or 117°, there is then no disagreement, and it is probable that this was Shumard's meaning. The range of the forms identified by Girty as *Pugnax osagensis* into the dark limestone of the Delaware Mountain formation suggests that other forms than that here identified as *P. texanus* were included under that designation. It is very likely that the Delaware Mountain specimens so identified were varieties of *P. swalloviana.*

The small species *P. osagensis pusilla* Girty, of the Yeso formation of New Mexico, may be the same as *P. texanus,* since it is abundant at the same horizon, but Girty's figures show it as oval in outline, while specimens of *P. texanus* of the same size are triangular.

Distribution: Hess formation (Glass Mountains) at 105, 208, and 223 (abundant). Leonard formation (Glass Mountains) at 235. Lower Gym formation (Hueco Mountains) at 379. Middle Gym formation (Hueco Mountains) at 414, 420, 424, and 430. Upper Gym formation (Hueco Mountains) at 437, 438, 439, 440a, and 440b. Gym formation (Hueco Mountains) at 443 and 449. Bone Canyon member (Sierra Diablo) at 491?.

PUGNOIDES TRANSVERSUS King, n. sp.*

Pl. XXXIII, Figs. 14–17

Description: Shell rather large, transversely ovoid, much wider than long. Pedicle valve slightly convex, the median

*Recently described as *P. mesacostalus* Girty, Jour. Wash. Acad. Sci. Vol. 19. 1929, p. 413. (Editor's.)

third depressed in a strongly defined sinus, which originates near mid-length of the shell and extends forward some distance as a tongue of the front margin. Brachial valve evenly convex, with a sharply defined median fold, originating somewhat posterior to mid-length. Sinus marked by from 4 to 6, and the fold by from 5 to 7 angular plications. The median plication on the fold is smaller than the other 4, so that the fold has the appearance of possessing a median sinus. Each lateral pair of plications on the fold appears to have arisen from the bifurcation of a single one. Lateral plications 6 to 8 in number on each side. The plications originate about 3 mm. anterior to the beaks, and increase in number by intercalation on the lateral slopes. In the pedicle valve the dental lamellae are long and slightly diverging. In the brachial valve there is a short median septum, from the anterior end of which there arises a thickening of the inside of the shell; crura formed by the anterior extension of the inner margins of the two divisions of the hinge-plate.

Dimensions in mm. of several specimens:

	1 (loc. 222)	2 (loc. 222)	3 (loc. 222)	4 (loc. T107)	5 (loc. 107)
Length	15	16	17	16	16
Width	24	13	27	22	22
Thickness	10	12	14	11	11.5

Observations: This species is distinguished by its large size, its great width, and the presence of 4 to 6 plications on the fold and in the sinus.

Distribution: Hess formation (Glass Mountains) at T15, 107, T107, 212, and 222.

Genus RHYNCHOPORA W. King

Diagnosis: Shell rhynchonelliform, generally pentagonal ovoid in outline, the median fold and sinus well developed in the anterior half of the shell. Surface of both valves marked by simple, subangular or rounded plications which may be longitudinally grooved toward the front. Internally the dental lamellae are well developed in the pedicle valve. Brachial valve with a strong median septum in the rostral region, which is divided internally to form the walls of a crural cavity; this is covered over on its cardinal side by the undivided hinge-plate, which continues forward beyond the anterior termination of the crural cavity. Crura formed by the anterior extension of the part of the hinge-plate opposite the lateral walls of the crural cavity. Shell structure punctate.

Genotype: *Terebratula geinitziana* Verneuil.

Geologic range: Mississippian to Permian.

Observations: Weller, from whom the above diagnosis was adapted, believes that the undivided hinge-plate and complete closure of the crural cavity except anteriorly are the most important characters of the genus. He expressed uncertainty, however, as to whether these characters were shown in the genotype, a fossil of the European Permian. Likharew* has since shown that *R. geinitzianus* is internally like *R. hamburgensis* and other Mississippian species in these characters. Weller's diagnosis of *Rhynchopora* should therefore be regarded as expressing the typical characters of the genus. As noted below, *R. illinoisenses* may have a divided hinge-plate; if so, it is non-typical.

*Mém. Soc. russe Min., ser. 2, vol. 54, pp. 115-118, pl. 1.

RHYNCHOPORA ILLINOISENSIS (Worthen)

Pl. XXXIV, Fig. 18

1884 *Rhynchonella illinoisensis.* Worthen, Illinois State Mus. Nat. Hist. Bull., no. 2, p. 24.

1914 *Rhynchopora nikitini.* Kozlowski (non Tschernyschew?), Brachiopodes du Carb. Supér de Bolivie, Ann. de Pal., vol. 9, pp. 84–86, text fig. 22, pl. 9, figs. 67–70.

1915 *Rhynchopora illinoisensis.* Girty, Fauna of the Wewoka Formation, U. S. Geol. Sur. Bull. 544, p. 85, pl. 10, figs. 12–12c. See for synonymy.

Observations: There can be little doubt that this species is the same as that described from Bolivia by Kozlowski as *R. nikitini* Tschernyschew. If the identification with the European species is likewise correct, then Tschernyschew's name would be a synonym of Worthen's, the latter having been proposed a year before the former. Kozlowski's specimens are described as having a divided hinge-plate, a statement contrary to that in the generic diagnosis given above. Specimens of *R. illinoisensis* from the Gaptank formation likewise seem to have this character. If this feature is characteristic of the species, then *R. illinoisensis* is unlike not only *R. taylori* of the higher beds of the Permian, but also the Mississippian forms described by Weller.

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at 88s and T88. Wolfcamp formation (Glass Mountains) at 90.

RHYNCHOPORA TAYLORI Girty

Pl. XXXIV, Figs. 19–24

1908 *Rhynchopora taylori.* Girty, Fauna of Phosphate Beds of the Park City Formation, U. S. Geol. Sur. Bull. 436, p. 34, pl. 3, fig. 8.

Phosphate beds of the Park City formation, Montpelier, Idaho.

Description: Shell medium-sized to rather large, subpentagonal, wider than long, with the greatest width near mid-length. Convexity moderate, the brachial valve having only a very slightly convex profile along the median line, then turning sharply downward to meet the tongue-like median extension of the pedicle valve without any angulation at the front suture, the anterior part of the shell being flat. Sinus of the pedicle valve equal in width to about half that of the shell, marked by 6, or less commonly 7 or 8, regular rounded plications. Fold of the brachial valve broad, not very high, well-defined near the front. Each lateral slope is ornamented by about 8 to 11 plications, of which the outer ones are less distinct. Within the pedicle valve there are long, diverging dental lamellae. In the brachial valve a strong median septum is divided posteriorly to form the walls of the crural cavity; the latter is covered over on the cardinal side by an undivided hinge-plate. The shell texture is punctate.

Dimensions in mm. of several specimens:

	1 (loc. 144)	2 (loc. T240)	3 (Girty's type)
Length	11	12	12
Width	14	14	14.5
Thickness	9	—	8.5

Observations: This species is distinguished from the very similar *R. illinoisensis* by having a proportionately narrower fold, which has 1 or 2 less plications, while the lateral slopes are proportionately broader and have 1 to 3 more plications, the total number being about the same in both species. In extreme forms the limits of variation overlap.

Distribution: Word formation (Glass Mountains) at 6, 46, 54, 144, T240, 243, and Tc. Upper Gym formation (Hueco Mountains) at 436. Limestone of Cerro Caballo (Las Delicias) at section 1, beds 11 and 14.

Genus CAMAROPHORIA W. King

Description: Shells small to large, rhynchonelliform, rostrate, subovate to subpentagonal in outline, with well developed median sinus in the pedicle valve and fold in the brachial valve. Surface plicated or with the plications nearly or quite obsolete. In the pedicle valve the dental lamellae are continued forward into a well developed spondylium which either is supported by a median septum or rests directly upon the floor of the valve for a part or the whole of its length. In the rostral part of the brachial valve the hinge-plate is continuous and is supported by a strong median septum; between the hinge-plate and the floor of the valve the median septum also supports a concave cruralium which is continued far beyond the hinge-plate, becoming broader and more highly elevated toward the front; posteriorly the median septum passes through the cruralium for the support of the hinge-plate, but the extension of the septum above the concave surface of the cruralium soon disappears beyond the anterior margin of the hinge-plate.

Genotype: *Terebratula Schlotheimi* von Buch.

Geologic range: Devonian to Permian.

CAMAROPHORIA DELOI King, n. sp.*

Pl. XXXIV, Figs. 24–27

Description: Shell small, transversely elliptical, strongly biconvex. Pedicle valve about equal in depth to the brachial valve, depressed in the median anterior part of the shell to form an ill-defined sinus, which extends forward and upward as a tongue at the anterior margin. Brachial valve evenly convex, elevated in the median anterior part as a low fold. The fold and sinus are marked by 4 or 5 angular plications, which originate 2 to 4 mm. anterior to the beak. Each lateral slope bears 4 or 5 plications. New plications are introduced on the lateral slopes and in one specimen at the sides of the fold and sinus. Within the pedicle valve the dental lamellae curve around to join, forming a spondylium, which is supported by a median septum.

Dimensions in mm. of several specimens:

	1 (loc. 376)	2 (loc. 241)	3 (southern Arizona)
Length	9	11	10
Width	11	14	12
Thickness	7.5	8	8

Observations: This species is distinguished by its *Pugnoides*-like exterior, with more numerous plications than are the rule in *Camerophoria.* The shell is also smaller and more strongly convex than other species of *Camerophoria* in this fauna.

Distribution: Lower Gym formation (Hueco Mountains) at 376 (type) and 379. Word formation (Glass Mountains) at 241. Lower Permian, Sawmill Canyon, near Onyx Mine, Santa Rita Mts.; Snyders Hill, 18 miles southwest of Tucson, Arizona.

CAMAROPHORIA THEVENENI Kozlowski

Pl. XXXIV, Fig. 28

1914 *Camarophoria Thevenini.* Kozlowski, Brachiopodes du Carb. Supér. de Bolivie, Ann. de Pal., vol. 9, pp. 86–88, text fig. 23, pl. 9, figs. 71–76; pl. 10, fig. 15.

Description: Shell small, wider than long, subtriangular. Ventral beak conical, incurved, with a triangular delthyrial foramen, in which lies the cardinal process of the other valve. Median part of the pedicle valve depressed, and extended forward as a tongue. There are 2 or 3 low plications in the sinus, which originate some distance anterior to the beak. Lateral slopes marked by one or two fainter plications. Brachial valve more strongly convex than the other, with a low median fold, which bears 3 or 4 plications. Lateral slopes marked by 2 or 3 low plications which arise near the anterior margin.

Within the pedicle valve the dental lamellae curve downward toward each other to form a spondylium, which is supported by a median septum.

Demensions in mm. of one specimen: length, 12; width, 13; thickness, 7.

Observations: This species, like *C. huecoensis,* has somewhat the outer form of a *Pugnoides.* It is distinguished from other species of the genus in the present fauna by its fewer and fainter plications. It is much smaller than *C. venusta.*

Distribution: Wolfcamp formation (Glass Mountains) at T82?, 93, and 195. Leonard formation (Glass Mountains) at 123. Lower Gym formation (Hueco Mountains) at 400.

CAMAROPHORIA VENUSTA Girty

Pl. XXXIV, Figs. 29–31; Pl. XXXV, Figs. 1–5

1908 *Camarophoria venusta.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 303–304, pl. 31, figs. 6–6c.

Middle Capitan, Capitan Peak (sta. 2926); Delaware Mountain formation, "Comanche Canyon," Glass Mountains.

Description: Shell large, subtriangular, generally wider than long. Pedicle valve shallow, with an elongate, slightly incurved, pointed beak. Delthyrium broadly triangular, nearly filled by the beak of the other valve. One specimen

*Editor's Note: This species is in part embraced in *C. huecoensis* Girty, Jour. Wash. Acad. Sci., Vol. 19, 1929, p. 412.

from loc. 174 shows small deltidial plates between the incurved beak of the brachial valve and the rounded foramen that occupies the apex of the valve. Sinus more than a third the width of the shell, deep and well-defined, arising about 8 mm. from the beak and expanding to the front margin. There are 3 to 7, but generally about 5, sharp plications in the sinus and 4 to 6 more rounded ones on each side. In some specimens some of the plications bifurcate toward the front. Brachial valve strongly convex, with a broad, well-defined fold. The sinus bears 4 to 8 plications, and each lateral slope 4 to 6.

Within the pedicle valve there are small hinge-teeth on each side of the broad delthyrium. The sides of the delthyrium are supported by plates which curve toward each other downward to the median line of the inner wall of the shell, where they join in an even curve to form a spondylium. The median septum supporting the spondylium is very greatly reduced and mainly exists as a thickening of the shell along the median line only. In the brachial valve the hinge-plate is prolonged forward into a concave elevated cruralium, which is supported by a median septum. On each side of the cruralium is attached a thin crus, which extends forward about half the length of the cruralium, and curves downward. The cruralium extends farther forward than the spondylium of the other valve, and terminates in three rounded lobes.

Dimensions in mm. of several specimens:

	1 (loc. 174)	2 (loc. 107)	3 (loc. 484)	4 (Girty's type)
Length	27	23	18	18
Width	34	26	27	19
Thickness	21	16	15	11

Observations: Girty's type specimen is not typical of the species as here described, being proportionately narrower and having a greater number of plications on its lateral slopes.* Some of the forms in the present collection are very close to the type, however, and grade into typical forms which are broad and coarsely plicate. Since the species is very variable, and since the type came from the Glass Mountains, it appears highly unlikely that the specimens of the present collection are not conspecific.

Camarophoria venusta is similar to many of the Eurasian forms from the Upper Carboniferous and Permian, but as it is a variable species, and the Eurasian Camerophorias have been rather minutely split, comparison is difficult. Probably the most similar species is *C. purdoni* Davidson. The extremely low ventral median septum may serve to distinguish *C. venusta* from some of the other species.

Distribution: Wolfcamp formation (Glass Mountains) at 76, 94s?, and 193?. Hess formation (Glass Mountains) at 1, 4, 106, 107, T107, 207, 222, and Tv. Leonard formation (Glass Mountains) at 4, 8–14, T9, 12, 14, 15, T15a, 16, 22, 26, 26s, 30–31, 82, 104, 105, 120, 124, 127, 128, 174, 226, 227, T233, Ax, Tb, D1, and D4. Word Formation (Glass Mountains) at 44–46, T141, 144, Tx148, 150, 155, 162, T240, 246, and 247. Bone Canyon member (Guadalupe Mountains) at 221. Bone Canyon member (Sierra Diablo) at 484. Leonard formation (Baylor Mountains) at 502. Delaware Mountain formation (Sierra Diablo) at 504. Leonard formation (Shafter) at 515. Altuda member (Glass Mountains) at 171.

*Editor's Note: The broader shells included above have been described by Girty as *C. inaequalis*. Jour. Wash. Acad. Sci., vol. 19, 1919, p. 411.

CAMAROPHORIA? INDENTATA (Shumard)

Pl. XXXIV. Fig. 32

1859 *Rhynchonella indentata.* Shumard, Trans. Acad. Sci. St. Louis, vol 1, p. 393 (date of volume, 1860).
White (Permian) limestone: Guadalupe Mountains.

1908 *Rhynchonella? indentata.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 321–322, pl. 15, figs. 20–20c.
Middle Capitan, Capitan Peak (sta. 2926); dark limestone, Pine Spring (sta. 2930).

Description: Three specimens are assigned to this species. The one from the limestone of Cerro Caballo has the following characters:

Shell medium-sized, subpentagonal, longer than wide, with the greatest width in the anterior part. Convexity low, but the shell is considerably crushed. Pedicle valve depressed in the median part into a very poorly defined sinus, which originates at about mid-length. It is prolonged somewhat forward as a tongue, but does not curve upward as sharply as in most other species of the genus. Brachial valve evenly and slightly arched, rising into a depressed fold only near the front. Surface marked by simple angular plications, which appear to originate a short distance anterior to the umbos. The median fold and sinus bear 3 or 4 plications, and each lateral slope about 7. There are also well marked concentric varices of growth. Within the pedicle valve the dental lamellae form a spondylium, which is supported by a low median septum, and in the brachial valve there is a high median septum, which presumably supports a cruralium. Length, 19 mm.; width, 17 mm.; thickness, 9 mm.

It may be seen that the description does not accord very well in some respects with that of Shumard. The low convexity of the shell is due to its having been considerably flattened by crushing. Except for the thickness, the dimensions of Shumard's type are somewhat less than those of this specimen, the length being 14 mm., the width 12, and the thickness 10. In view of the general agreement in number and strength of plications, relative size of median fold and sinus, etc., it seems best to identify the Mexican specimen questionably with Shumard's species.

The specimen from the Altuda member accords much better with Shumard's description, being much more strongly convex.

Observations: Girty described "short dental plates" in this species. This would at first seem to exclude it from belonging to *Camerophoria*, but since the spondylium lies near the floor of the valve, the dental plates may appear in many specimens to be quite distinct because the part near the floor of the valve, where they curve inward toward each other, is not well preserved. If *R.? indentata* is not a *Camerophoria* it would be difficult to know in what group to place it. This species resembles *Uncinuloides guadalupensis* in that the plications are small and extend nearly to the beaks, but it does not have the peculiar configuration of the front margin which characterizes *Uncinuloides*. Girty states that *R.? indentata* differs from his species *R.? longaeva* in being larger and has a false area and flattened dorsal umbo. No specimens referable to the latter species were collected, so that I am unable to make comparison with my own specimens.

Distribution: Limestone of Cerro Caballo (Las Delicias) at bed 14, section 1. Word formation (Glass Mountains) at 265. Altuda member (Glass Mountains) at 57.

Genus UNCINULOIDES King, novum

Diagnosis: Shell rostrate, subtriangular in outline, with a well developed median sinus in the pedicle valve and fold in the brachial valve, anterior margin broad and flattened, lying nearly perpendicular to the longitudinal axis of the shell. Surface marked by fine, flattened costae, longitudinally grooved on the truncated anterior part of each valve. In the pedicle valve the dental plates converge toward the floor of the valve, and curve together to form a spondylium, which may rest on the inner wall of the valve or may be slightly elevated and supported by a low median septum. Hinge plate and cruralium of the brachial valve similar to those of *Camerophoria.*

Genotype: *Rhynchonella guadalupae* Shumard.

Geologic age: Permian.

Observations: This genus has in every respect the external form of *Uncinulus*, but the internal characters of *Camerophoria.* The fact that the spondylium rests on the floor of the pedicle valve or is supported by only a very low median septum is a difference from many species of *Camerophoria,* but in *Camerophoria venusta* the structure is quite comparable. A large number of species in the Permian of Eurasia have been identified as *Uncinulus.* In no instance have the internal characters of any of these genera been described in enough detail to permit certain identification with either *Uncinulus* or *Uncinuloides.* All that is stated as to the internal characters of these species is that there are diverging dental lamellae in the pedicle valve and a median septum in the brachial valve. It might at first be thought that the divergence of the dental lamellae would exclude these species from a genus in which a spondylium is present, yet an examination of the specimens from the Glass Mountains shows that the spondylium generally lies on the floor of the valve, and when the surface is cut or broken away, the dental lamellae appear to join the inner wall of the shell at some distance from each other, the true nature of the structure being apparent only when seen from the inside in an etched specimen. The Permian species assigned by various authors to *Uncinulus* are as follows:*

U. theobaldi Waagen, Virgal group of the Salt Range (said by Diener to be a synonym of *U. jabiensis); Artinsk* of Russia; lower Permian, *Schwagerina* horizon, Darwas, Bokhara; Permian of Ussuriland(?).

U. jabiensis Waagen, Chideru group of the Salt Range; Upper Permian of the Himalayas at Chitichun I and Malla Sangcha; Permian of the Residency of Djambi, Sumatra; *Waagenoceras* horizon of Basleo, Timor; *Lyttonia* horizon of the Kitakami Mountains, Japan; Upper Permian near Djulfa, Armenia (?); lower Permian, *Schwagerina* horizon, Darwas, Bokhara.

*Many of these species are so narrowly limited that there has been much discussion as to their validity.

U. posterus Waagen, Chideru group of the Salt Range; Jarkalo, China.

U. timorensis (Beyrich), *Waagenoceras* horizon of Basleo, Timor; Permian of Residency of Djambi, Sumatra; Upper Permian of the Himalayas at Malla Sangcha; Lantsankiang Valley of China.

U. hanieli Broili, *Waagenoceras* horizon of Basleo, Timor.

U. wichmanni (Rothpletz), Timor.

U. wangenheimi (Pander), *Schwagerina* limestone of the Urals.

U. velifer Gemmellaro, Sosio limestone of Sicily; Trogkofel formation of the Karnic Alps.

U. amor Gemmellaro, Sosio limestone of Sicily.

U. siculus Gemmellaro, Sosio limestone of Sicily.

U. arthaberi Tschernyschew, lower Permian, *Schwagerina* horizon, Darwas, Bokhara; Upper Permian of Djulfa, Armenia.

I think it quite likely that all these are actually *Uncinuloides,* for the time separating the latest occurrence of undoubted *Uncinulus* from the first occurrence of these Permian species is a vast one, extending from the Lower Devonian to the Permian.

UNCINULOIDES GUADALUPENSIS (Shumard)

Pl. XXXV, Figs. 6–7

1858 *Rhynchonella Guadalupae.* Shumard, Trans. Acad. Sci. St. Louis, vol. 1, p. 295 (date of volume, 1859).
White (Permian) limestone: Guadalupe Mountains.

1859 *Rhynchonella Guadalupae.* Shumard, *idem.*, p. 392, pl. 11, figs. 6a–c.
White (Permian) limestone: Guadalupe Mountains.

1908 *Rhynchonella? guadalupae.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 323–324, pl. 16, figs. 10–10b.
Top of Capitan, Capitan Peak (sta. 2966?).

Description: Shell medium-sized, subtriangular, with rounded basal angles, width and length about equal. Lateral margins nearly straight, diverging at about a right angle; sides flattened, with an angulation at the junction of the valves. Anterior marginal region truncated, there being no angulation where the two shells meet. Pedicle valve not very strongly convex, beak high and somewhat incurved over a distinctly defined cardinal area, which includes a triangular deltidial plate on each side of an oval delthyrium. Sinus of the pedicle valve broad and shallow, originating somewhat posterior to mid-length of the shell and curving upward through an angle of about 90° to form a tongue in the truncated anterior face of the shell. Brachial valve regularly convex, umbo flattened, curvature gentle from the beak nearly to the front margin, where the shell is deflected strongly downward to meet the tongue of the pedicle valve; median fold low and broad, well-defined only near the front. Surface marked by many fine rounded costae, which extend to the beaks, where, however, they are very small and faint. Toward the anterior part of the shell the costae become broad and flattened, and are separated by narrower striae. On the flattened anterior region of the shell the costae are medially grooved, so that they appear double. There are 9 or 10 costae in the fold and on the sinus of a mature shell, and 15 to 19 on each side.

Within the pedicle valve the hinge-teeth are supported by dental lamellae which are produced forward more than a third the length of the valve to form a spondylium, which rests upon the floor of the valve, not being elevated on a median septum. In the brachial valve the hinge-plate is broad, and produced forward as a trough-like cruralium, which extends more than half the length of the shell and is supported in the posterior part by a high septum. From each side of the hinge-plate there arise thin downward-curving crura.

Dimensions in mm. of several specimens:

	1 (loc. T128)	2 (loc. 120)	3 (loc. D1)	4 (R. guadalupae Sh.)
Length	17	16	17+	14.5
Width	22	20	36	19
Thickness	13	12	—	12

Observations: A specimen identified by Girty was said to have a perforated hinge-plate—a character that could not be verified or disproved in the specimens of the present collection. *Rhynchonella? indentata* and *R.? longaeva* of Girty somewhat resemble *U. guadalupensis*, but seem to be considerably smaller and more coarsely plicate, and do not have the characteristic shape of *Uncinuloides.* Hardly any important difference may be seen between *U. guadalupensis* and *U. jabiensis* Waagen, the common Asiatic species. Probably the latter has somewhat stronger costae.

Distribution: Upper Wolfcamp formation (Glass Mountains) at 196. Upper Hess formation (Glass Mountains) at 207. Leonard formation (Glass Mountains) at 3, 7, 16, 24, 30–31, 31, 37, 83, 194, 120, 128, 231, Tb, and D1. Word formation (Glass Mountains) at 51, 54, and Tx148.

Family SPIRIFERIDAE

Genus SPIRIFER Sowerby

Diagnosis (after Weller): Shells small to very large, generally wider than long, rarely longer than wide, hinge-line straight, narrower than the greatest width of the shell and the cardinal extremities rounded, or more commonly the greatest width of the shell is along the hinge-line and the cardinal extremities are angular and more or less extended, in some conspicuously acuminate. Median sinus in the pedicle valve and fold in the brachial valve generally well developed, more rarely absent. Surface of both valves marked by radiating plications which may be simple without division from the point of origin at the cardinal margin to the anterior margin, or may divide in various ways; the plications may be present upon the lateral slopes only or upon both the lateral slopes and the fold and sinus. Besides the plications the surface may also be marked by fine radiating lirae or by fine or coarse concentric growth lines, or by both radiating and concentric markings. The pedicle valve has the beak variously elevated above the hinge-line and variously incurved, the cardinal area varying from very narrow to high, generally arched but in some nearly or quite flat, the delthyrium rather broadly triangular and open; the surface of the cardinal area is transversely striate and the inner shell layers bear a series of vertical canals at whose ends along the hinge-line the shell tissue may be produced in a row of denticles which articulate with a row of pits in the opposite valve. Internally the hinge-teeth are strong and are supported by short or undeveloped dental lamellae; the muscular area is of moderate size and may be deeply impressed, ovate or obcordate in outline, occupied in large part by the diductor scars, which are generally marked by radiating or branching furrows. The brachial valve has a very narrow cardinal area divided by a broadly triangular delthyrium; the cardinal process is a low, transverse, sessile apophysis with its surface vertically striated; the muscular impressions much less strongly marked than in the pedicle valve; the dental sockets narrow and of moderate depth, the socket plates well developed and at their ends suporting the crural bases. Crura long, straight, and slightly divergent, spiralia directed obliquely outward and backward toward the cardinal extremities; primary lamellae not united by a jugum, the position of the jugum being indicated by the presence of a pair of spine-like processes upon the primary lamellae a little in front of their junction with the crura.

Genotype: *Anomites striatus* Martin.

Geologic range: Silurian to Permian.

Observations: This genus has, like *Productus,* recently been divided into a large number of genera* but as a large number of these are of doubtful value, they are not recognized as distinct genera in the present paper.

SPIRIFER CONDOR d'Orbigny

Pl. XXXV, Figs. 8–10; Pl. XXXVI, Fig. 1

1842 *Spirifer condor.* D'Orbigny, Voy. dans l'Amér. mér. t. 3, pt. 4, pl. 5, figs. 11–14.

1869 *Spirifer striatus* var. *multistriatus.* Toula, Sitzb. d. Kais. Acad. d. Wiss., Wien, vol. 59, p. 3, pl. 1, figs. 2–4.

1902 *Spirifer condor.* Tschernyschew, Mem. Com. Geol. Russie, vol. 16, p. 141, pp. 531–532, pl. 12, figs. 1–2, pl. 38, figs 1–2.

1914 *Spirifer condor.* Kozlowski, Brachiopodes du Carb. Supér. de Bolivie, Ann. de Pal., vol. 9, pp. 67–70, pl. 1, fig. 1; pl. 7, figs. 10–14, text fig. 16.

1914 *Spirifer condor.* H. L. F. Meyer, Carbonfaunen aus Bolivia und Perú, Neues Jahrbuch für Mineralogie, etc., vol. 37, pp. 604–610, text fig. 1.

1919 *Spirifer condor.* Douglas, Geological Sections through the Andes, Quart. Jour. Geol. Soc., vol. 70, p. 32, pl. 9, figs. 1a–c.

1929 *Spirifer condor.* Steinmann, Geologie von Perú, p. 47, fig. 42.

Description (modified from Kozlowski): Shell large, subtriangular, very much wider than long, the width being greater in proportion to length in younger individuals. The width may exceed twice the length. Pedicle valve somewhat more convex than the other, median part regularly arched, with a median sinus which originates at the beak and is prolonged forward at the anterior margin as a tongue. The sinus is narrow and well defined by bordering costae which are somewhat larger than those in the

*Fredericks, George: Table pour définition des genres de la Fam. *Spiriferidae* King. Bull. de l'Ac. Sci. URSS. 1926, nos. 4–5, pp. 393–423.

sinus. Beak broad and somewhat incurved over the cardinal area, which is about 10 times as wide as high and has a gently concave transverse profile. Surface of the area marked by horizontal and vertical striae, the latter being more abundant and distinct. Delthyrium triangular, somewhat wider than high, covered by deltidial plates, which are divided from one another by a suture along the median line; the anterior end of the plates is concave toward the ventral beak, the dorsal beak having fit into this depression, leaving the delthyrium open.

Brachial valve less convex and shorter than the other, with a low beak not curving over the cardinal line. Dorsal area very low. A median dorsal sinus corresponds to the fold of the other valve.

Surface of both valves covered by rounded radial costae, about 1 mm. wide, separated by grooves of about the same width, originating at the apices, where, on each valve, there are only about 4 costae on each side of a median one. Between the beak and the anterior margin each of the original costae bifurcates from 3 to 5 times, depending on the size of the specimen; the newly added costae very shortly attain the same size as the others, so that there is an average of 50 subequal costae, lying somewhat diagonal to the margin. The costae in the fold originate from the original median costa by continuous bifurcation, while those in the sinus, on the other hand, originate from the costae at the sides, rather than in the center of the sinus. Fine concentric imbrications are also present, which are distantly spaced over most of the surface but close together in the marginal region.

Within the pedicle valve there is, on each side of the delthyrium, a strong obtuse hinge tooth, below which is a thickening of the shell which is prolonged backward as a thickening of the delthyrial border until it merges with the apical callosity, which is very strongly developed, filling the entire apical region beneath the deltidial plates. Adductor muscular impressions long and narrow, extending from the apical callosity about three-fourths the length of the shell; they are separated medially by a low ridge.

Dimensions in mm. of several specimens:

	1 (loc. Tmm)	2 (loc. 375)	3 (loc. 88)	4 (Kozlowski)
Length	28	31	27	43
Width	56	63	52	80
Thickness	24	—	—	34

Observations: The Texas specimens agree perfectly with those described by Meyer and Kozlowski from Bolivia. Those figured by Tschernyschew from the *Cora* and *Schwagerina* beds of the Uralian show no characters by which they might be distinguished from the typical ones. The *S. cameratus* Derby from Bolivia is tentatively regarded as not synonymous, for it shows some differences and probably comes from a much lower horizon. The species described by Shumard as *S. organensis*, collected in the Organ Mountains near Ft. Filmore, New Mexico, is very probably a synonym of this species; it may have been collected from the lower Gym horizon.

This species is placed by Fredericks in the genus *Anelasma* of Ivanov,* which is distinguished from *Spirifer* by lacking true dental lamellae, having only ridges bordering the inside of the delthyrium. *S. condor* certainly fits into this genus by definition, but as there is no certainty that the species placed in *Anelasma* form a natural group, it is thought best not to recognize it.

Distribution: Wolfcamp formation *Uddenites* zone (Glass Mountains) at 88 and T88. Upper Wolfcamp formation (Glass Mountains) at 85, T93, 194, and 196. Lower Gym formation (Hueco Mountains) at 375, 376, 377a, 377b, 381, 387, 401, and Tmm.

SPIRIFER MARCOUI INFRAPLICA King, n. var.

Pl. XXXVI, Figs. 2–4

Description: Shell large, much wider than long, with the greatest width at the hinge-line. Pedicle valve strongly convex longitudinally but of low transverse curvature. Cardinal area high and flat except at the apex, which is incurved; in large shells the sides of the area may be subparallel to the hinge-line for most of the width of the shell, then, near the lateral margins, sloping abruptly to the hinge. Beak broad, short, not greatly bent over. Sinus deep and rounded, originating near the beak. Brachial valve strongly convex on its lateral slopes, but less strongly on the median fold. Beak somewhat elevated; cardinal area rather high. Median fold high and rounded, prominent only near the front. On one specimen (from loc. Tq) the crest of the fold is not situated exactly along the median line, but somewhat to one side.

Entire surface marked by subequal rounded radial costae, of which 4 to 5 occur in the space of 5 mm. Fasciculation does not take place. From 15 to 20 costae occur on the fold and sinus and 30 to 40 on each lateral slope. Fine concentric striae give the surface a cancellated appearance.

Within the pedicle valve there are strong diverging dental lamellae.

Dimensions in mm. of several specimens:

	1 (loc. 499)	2 (loc. Tq)	3 (loc. 126)	4 (Waagen's)	*(S. marcoui)*
Length	38	45	32	58	53
Width	77	70	54	92	82
Thickness	27	—	23	45	38

Observations: No perfect specimens of this variety were found. It is very close to the widespread Eurasian species *S. marcoui*, which was thought by Waagen to be a representative of the form identified by Marcou as *S. striatus* from Pecos Village, New Mexico. Since Marcou's collection was from a much lower horizon geologically, its identity is to be regarded as doubtful. *S. marcoui infraplica* is distinguished from *S. marcoui* by having a narrower fold and sinus, the former of which is lower and the latter shallower, and the sides of the sinus are more sharply defined from the lateral slopes. A very similar species is *S. logani* from the Mississippian, which has a broader

*Ivanov: Sur la systématique et la biologie du genre *Spirifer* et de quelque brachiopodes de C-ii et C-iii du Gouv. du Moscou, Bull. de Sect. Géol. de la Soc. des Amies des N., Anthr. et G. de M., 1925, p. 109.

median fold and sinus and a lower cardinal area. Some specimens of the two might be difficult to distinguish.

Distribution: Leonard formation (Glass Mountains) at T9, 122, Tb, and D16. Bone Canyon member (Sierra Diablo) at 485. Victorio Peak member (Sierra Diablo) at 496 and 499. Hess formation (Finlay Mountains) at 511. Leonard formation, transition beds (Shafter) at Tq (no. 15984).

Subgenus NEOSPIRIFER Fredericks*

Diagnosis: Shell similar in configuration to *Spirifer* but with the costae arranged in fascicles, generally of three. The fascicles may be distinct only in the posterior part of the shell, becoming obsolete toward the front. As in *Spirifer* there are short dental lamellae, and the muscle scars of the pedicle valve are divided by a median ridge.

Type: *Spirifer fasciger* Keyserling.

Geologic range: Pennsylvanian and Permian.

Observations: Although Fredericks selected as his type for this group a widespread Eurasian species (known in southeastern Asia generally as *Spirifer musakheylensis* Davidson), it is more particularly an American type. Whereas in Europe the middle part of the Pennsylvanian is characterized by *Choristites mosquensis*, in North America by far the most abundant spiriferid in rocks of the same age is *Neospirifer triplicatus*. In the Texas Permian fauna *Neospirifer* is the predominant type, while in Eurasia it is no more important than many other groups of spirifers.

SPIRIFER (NEOSPIRIFER) BAKERI King n. sp.

Pl. XXXVII, Figs. 4–6

Description: Shell large, subpentagonal, wider than long, with the greatest width at the hinge-line; cardinal angles acute or even very sharp, the shell being greatly extended at the hinge-line in young stages. Young specimens are relatively short in proportion to length, the increase in length taking place after the greatest width has been attained. Pedicle valve evenly convex longitudinally, the curvature decreasing gradually from the back to the anterior margin. Beak broad, short, pointed, not greatly incurved. Cardinal area low and broad, concave. Median sinus broad, evenly rounded, and rather deep, defined on each side by a high, angular ridge. From the ridges bordering the sinus there is an even slope on each side toward the ears. Brachial valve equal in convexity to the other, with a low median fold, which rises abruptly from the otherwise evenly convex shell, and has a rounded crest. Within the pedicle valve there are short dental lamellae which support strong hinge-teeth.

Surface marked by low, rounded costae, which in the posterior part increase by bifurcation, and are grouped in prominent bundles of three, in which the median costa is larger than the two lateral ones. Toward the front they do not divide, and become broad and indistinct. The costae in the fold and sinus are smaller than those on the lateral slopes and not at all bundled; toward the front the fold and sinus may be almost smooth.

*Fredericks, George: Études paléontologiques. 2. Les Spiriferides du carbonifère supérieur de l'Oural. Bull. du Com. Géol., vol. 38, no. 2, 1919, p. 311.

———: Table pour définition des genres de la Fam. *Spiriferidae* King, Bull. de l'Ac. Sci. URSS, 1926, no. 4-5, p. 406.

Dimensions in mm. of several specimens:

	1 (loc. 46)	2 (loc. 53)	3 (loc. 7)	4 (loc. 46)
Length	37	29	20	22
Width	64	43	34	54
Thickness	22	—	—	17

Observations: This species is distinguished from *S. triplicatus*, *S. pseudocameratus*, and similar species by the sharp definition of the median sinus by lateral ridges and the low plications, which become indistinct toward the front. The young, relatively short specimens of this species are very close to *S. niger* Waagen from the Amb group of the Salt Range.

Distribution: Leonard formation (Glass Mountains) at 7. Word formation (Glass Mountains) at 46 (common, types), and 58.

SPIRIFER (NEOSPIRIFER) COSTELLA King, n. sp.

Pl. XXXVII, Figs. 1–3

Description: Shell rather large, alate in youth but approximately semicircular at maturity; hinge-line equal to the greatest breadth. Pedicle valve gently and evenly convex both transversely and longitudinally. Cardinal area high, triangular, and strongly concave. Delthyrium a broad triangle. Beak high, sharply pointed and incurved. Median sinus narrow and shallow, originating at the very apex of the beak. Dental lamellae short but strong. Brachial valve of low convexity, with a low apex and low cardinal area. Median fold low and rounded.

Surface marked by fine radial costae, originating at the apices as about 8 costae, each of which shortly splits into three parts, and toward the front margin splits several more times. About 7 costae occur in the space of 5 mm. All the costae originating from one original rib are grouped together in a raised fascicle, which is most pronounced in the median part of the shell and becomes lower and less distinct anteriorly. Generally about 7 or 8 costae compose each fascicle. The fascicles are not very strongly marked, and in some specimens are hardly noticeable. The surface is ornamented likewise by prominent lamellose erect striae of growth, which are very closely arranged and cover both valves. There are also irregular, strong imbricating marks of growth paralleling the anterior and lateral margins.

Dimensions in mm. of several specimens:

	1 (loc. 174)	2 (loc. 174)	3 (loc. 126)
Length	35	27	20
Width	50	45	35
Thickness	21	—	—

Observations: This species is most closely related to *S. fasciger* Keyserling (=*S. musakheylensis* Davidson). The size of the costae, type of bundling, lamellose striation, and general outline are quite similar. The European species, however, has a higher fold and deeper sinus, a relatively much lower cardinal area, and a more triangular outline.

Distribution: Leonard formation (Glass Mountains) at 24, 123, 126, and 174 (types). It is not common at any locality.

SPIRIFER (NEOSPIRIFER) MEXICANUS LATUS King, n. var.

Pl. XXXVII, Fig. 7; Pl. XXXVIII, Fig. 1

Description: Shell transversely elliptical, with a very short hinge-line, equaling less than half the width of the shell; greatest width at about mid-length. Pedicle valve strongly convex, being somewhat deeper than the other valve. Beak high, pointed, and incurved over the narrow, concave cardinal area, which is only about twice as wide as high and is not well defined from the rest of the shell. Sinus shallow but well-defined, originating at the apex. Brachial valve evenly convex, with a low but distinct median fold. Both valves are covered by moderately coarse radial costae, which to some extent, especially on the brachial valve, are arranged in bundles of about 3 costae each. Of the internal characters, only the strong dental lamellae of the pedicle valve were distinguished.

Dimensions in mm. of several specimens:

	1 (loc. 123)	2 (loc. 128)	3 (loc. 491)
Length	26	19	28
Width	32	22	34
Thickness	17	—	—

Observations: This variety is very easily distinguished by its elliptical outline and the very high, narrow, poorly defined cardinal area. The only difference from the typical form of the species is that this variety is relatively much broader. A closely related species is *S. oldhamianus* Waagen, in which the cardinal area is very similar, but the shell is broader and has a higher fold and deeper sinus.

Distribution: Leonard formation (Glass Mountains) at 5, 12, 26s, 120, 123 (type), 126, 128, Tg?, T233, and D1. Bone Canyon member (Sierra Diablo) at 491. Hess formation (Glass Mountains) at 8 and 104.

SPIRIFER (NEOSPIRIFER) PSEUDOCAMERATUS Girty

Pl. XXXVIII, Figs. 4–6; Pl. XXXIX, Figs. 1–3

1859 *Spirifer cameratus.* Shumard, Trans. Acad. Sci. St. Louis, vol. 1, p. 391 (date of volume, 1860).
(Permian) sandstone and white limestone: Guadalupe Mountains.

1908 *Spirifer* sp. b. Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 363–364.
Delaware Mountain formation, Guadalupe Point (sta. 2919); Delaware Mountain formation, southern Delaware Mountains (stas. 2967, 3501); Delaware Mountain formation, "Comanche Canyon," Glass Mountains.

1920 *Spirifer pseudocameratus.* Girty, in Ore Deposits of Utah, U. S. Geol. Sur. Prof. Paper 111, pp. 644–645, pl. 56, figs. 10–15.
Permian: Utah.

Description: Shell large, wider than long, but not alate. Greatest width at the hinge-line, the cardinal angles being acute in wide shells and more nearly rectangular in shells of greater proportionate length; the angle varies likewise according to the size of the shell.

Pedicle valve convex, especially in the umbonal region; beak small and strongly incurved. Cardinal area of moderate height, lying oblique to the plane of the shell margin. Sinus relatively narrow, of moderate depth, fairly well defined, occupied by one or two small costae. The ribs bordering the sinus bifurcate in such a way that costae extend from them forward along the flanks and even into the bottom of the sinus, attaining the same size as the original costae of the sinus, so that the latter lose their identity. Brachial valve moderately convex. Fold low and narrow but well-defined, divided by a median groove, each side bears costae which have arisen by bifurcation of the ribs bordering the median groove.

On the lateral slopes of both valves there are strongly fasciculate ribs, composed of groups of 3 or 4 costae, which may be subequal or with one costae larger than the others. There are from 3 to 5 fascicles on each side of the beak, and 4 or 5 other costae are developed distal to these toward the cardinal angles.

Within the pedicle valve the delthyrium is closed in its apical half by deltidial plates, underneath which the shell is thickened as an apical callosity. Hinge-teeth strong, their lower sides extending into the dental lamellae, which connect with the floor of the valve on each side of the deeply impressed diductor muscle scars.

Dimensions in mm. of several specimens:

	1 (loc. 121)	2 (loc. 156)	3 (loc. 174)	4 (loc. 493)
Length	42	52	36	40
Width	65	80	52	62
Thickness	28	32	22	27

Observations: The only difference between the Texas specimens and the types of the species, from Utah, is that the latter have a rather strongly bilobate fold on the brachial valve, the median groove being somewhat deeper than in those of the present collection. This species is distinguished from *S. cameratus* and *S. triplicatus* by being generally somewhat larger, with commonly a greater relative length, coarser, more irregular costae, and a narrower and lower fold and sinus. Girty regards the specimens from Nevada identified by Meek as *S. cameratus* as probably *S. pseudocameratus.*

Distribution: Leonard formation (Glass Mountains) at 8?, T9, 15?, T15?, 26, 26s, 37, T119, 120, 121 (abundant), 124, 125?, 128, T128?, 129, 174 (abundant), Tb, Tba?, D3, D5, D7, and D12. Word formation (Glass Mountains) at 6, 44–46, 47, 54, 58, 138?, T140, 144, T144, T144a, 146, 148, T148, Tx148, 150, 155, 192, 239, T239?, 241, 246, 250, 255, 256 (abundant), 257, Tu, and Tx?. Bone Canyon member (Sierra Diablo) at 484. Victorio Peak member (Sierra Diablo) at 492, 493, and 496. Victorio Peak member (Brackett Draw) at Taa. Leonard formation (Baylor Mountains) at 503. Delaware Mountain formation (Sierra Diablo) at 504. Leonard formation (Shafter) at Tj (thin-bedded zone) and 518. Limestone of Cerro Caballo (Las Delicias) at section 1, beds 11, 12 (¼ mile S of 21), 14, and 19.

SPIRIFER (NEOSPIRIFER) HUECOENSIS King, n. sp.

Pl. XXXVIII, Figs. 2–3

Description: Shell large, transversely elliptical, hinge-line somewhat shorter than the greatest width, which is at about mid-length; sides evenly rounded. Pedicle valve of low convexity. Beak low, bluntly pointed, very strongly incurved over the cardinal area, which is narrow, very sharply defined, and nearly flat in its anterior and lateral parts but very strongly incurved under the apex. Sinus shallow, originating at the beak, very broad near the anterior margin, where there is a spatulate forward prolongation. Brachial valve bearing a low median fold, which is indistinct in the posterior part but is prominently elevated near the anterior margin. Surface of both valves marked by low, rounded radiating costae, 3 or 4 of which occur in the space of 5 mm. Near the apex they are somewhat bundled, but over most of the surface they are subequal and not at all fasciculate. In the anterior part of the shell they become low, and the surface may be nearly smooth. There are also closely spaced lamellar growth lines and strong concentric varices of growth in the anterior region.

Within the pedicle valve (of a specimen from loc. 107) there is a strongly developed apical callosity, and strong hinge-teeth, which are not supported by distinct dental lamellae. The muscle scars are deeply impressed and not divided by a median ridge.

Dimensions in mm. of several specimens:

	1 (loc. 389)	2 (loc. 389)	3 (loc. 107)	4 (loc. 107)
Length	41	37	43	36
Width	58	59	60?	68
Thickness	25	20	25	30

The specimen from loc. 107, no. 4, is exceptionally broad.

Observations: This species is distinguished from *S. mexicanus* Shumard and its varieties by its larger size, greater relative width, and low, sharply defined cardinal area.

Distribution: Hess formation (Glass Mountains) at 104? and 107 (common). Lower Gym formation (Hueco Mountains) at 389 (common, types).

SPIRIFER (NEOSPIRIFER) TRIPLICATUS Hall

Pl. XXXIX, Fig. 4

1852 *Spirifer triplicata.* Hall, Stansbury's Exploration and Survey Great Salt Lake of Utah, p. 410, pl. 4, figs. 5a–e.

1914 *Spirifer cameratus.* Kozlowski, Brachiopodes du Carb. Supér. de Bolivie, Ann. Pal., vol. 9, p. 70, pl. 5, figs. 6–11.

1915 *Spirifer cameratus.* Girty, Fauna of the Wewoka Formation, U. S. Geol. Sur. Bull. 544, pp. 87–91, pl. 11, figs. 4–4b. See for synonymy.

1920 *Spirifer triplicatus.* Girty, in Ore Deposits of Utah, U. S. Geol. Sur. Prof. Paper 111, pp. 645–646, pl. 54, fig. 22.

Observations: According to Girty the upper Pennsylvanian fossils generally designated as *S. cameratus* should be called *S. triplicatus.* This species has stronger fasiculation of the costae, higher and more angular fold and sinus, a more triangular outline, and a relatively wider hinge-line than *S. cameratus* which occurs in the Pottsville and equivalent strata.

Distribution: Wolfcamp formation, *U d d e n i t e s* zone (Glass Mountains) at 88, T88, 88s, 94s, 175, 175a, and 201. Wolfcamp formation (Glass Mountains) at 75, 77, 87, 89, 91a, 93, 93s, 193, 196, and 198.

SPIRIFER (NEOSPIRIFER) TEXANUS Meek

Pl. XXXIX, Fig. 5

1871 *Spirifer (Trigonotreta?) texanus.* Meek, Proc. Acad. Nat. Sci. Phil., vol. 23, pp. 179–181.

1921 *Spirifer texanus.* Plummer and Moore, Penn. Formations of N. Central Texas, U. of Texas Bull. 2132, p. 148, pl. 21.

Observations: This species is distinguished from *S. triplicatus* by its greater length in proportion to width, its short hinge-line, and its high, incurved ventral beak. The shell seems to be thicker than specimens of *S. triplicatus* of the same size.

Distribution: Wolfcamp formation, *U d d e n i t e s* zone (Glass Mountains) at 88, 88s, and T88. Wolfcamp formation (Glass Mountains) at 91a and 92.

Subgenus ELIVINA Fredericks*

Diagnosis: Shells medium-sized to large, biconvex, the hinge-line narrower than the greatest width, the cardinal angles rounded, mesial sinus in the pedicle valve and fold in the brachial valve well developed. The pedicle valve with a fairly high cardinal area; internally the dental lamellae are well-developed and extend forward for some distance, inclosing the muscle scars, which are situated on a raised platform. There is no median ridge or septum dividing the muscle scars. Surface of both valves covered with low, broad, rounded costae, more or less arranged in fascicles. Shell impunctate.

Type: *Spirifer tibetanus* Diener.

Geologic range: Permian.

Observations: Other representatives of this subgenus are *S. rajah* Salter and *S. sulcifer* Shumard. *Elivina* was established for plicatocostae (fasciculate) shells having well-developed dental lamellae but no "euseptoid" or "euseptum." I propose to restrict the name to shells having those internal characters and the external configuration similar to that of the genotype. As the genotype was the only species assigned to this subgenus by Fredericks, this does not decrease the contents of the group as originally constituted, but gives it greater value because of the recognition of a greater number of distinctive features. *Spirifer lyra* Kutorga is similar to species of *Elivina* in all but incomplete dental lamellae, or, as Fredericks calls this structure, "delthyrial ridges." Fredericks makes *Spirifer lyra* the type of his subgenus *Eliva.* If, as seems likely, the distinguishing characters are of less importance than supposed by Fredericks, the species of the *Spirifer lyra* and *S. tibetanus* groups should be assigned to the same subgenus.

It may be said that *Elivina* is externally like *Spiriferella,* but is impunctate. The genotype of *Spiriferella, S. saranae,*

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*Fredericks, G.: Études paléontologiques. 2. Les Spiriferides du carbonifére supérieur de l'oural. Bull. du Com. Geol., vol. 38, no. 2, 1919, pp. 314–315.

———: Table pour définition des genres de la Fam. *Spiriferidae* King, Bull. de l'Ac. Sci. URSS, 1926, nos. 3–4, p. 409.

differs further in having the dental lamellae coalesce over a ventral median septum ("euseptum" of Fredericks), but Weller* includes in *Spiriferella* shells having discrete, diverging dental plates. In that respect the Mississippian *Spiriferella* species resemble *Elivina*, but they still have a punctate shell.

SPIRIFER (ELIVINA) SULCIFER Shumard

Pl. XXXIX, Fig. 6; Pl. XL, Figs. 1-5

1858 *Spirifer sulcifera*. Shumard, Trans. Acad. Sci. St. Louis, vol. 1, p. 293 (date of volume, 1860).
White (Permian) limestone: Guadalupe Mountains.

1859 *Spirifer sulciferus*. Shumard, *idem.*, p. 391, pl. 11, figs. 3a-c.
White (Permian) limestone: Guadalupe Mountains.

1908 *Spirifer sulcifer*. Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, p. 363, pl. 13, figs. 10-10b.

1908 *Spirifer* sp. a. Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 362-363, pl. 21, fig. 2.
Dark limestone, Pine Spring (sta. 2930).

Description: Shell large, subpentagonal, length somewhat greater than the width, greatest width near or somewhat in front of mid-length, cardinal angles obtuse. Pedicle valve strongly convex, the curvature being greatest in the umbonal region and decreasing gradually forward. Cardinal area high and narrow, in large shells not perfectly triangular, being truncated at the sides, delthyrium broad triangular, closed by strongly developed deltidial plates. Median sinus broad and rather deep, originating near the apex and increasing in size toward the front. Brachial valve of much lower convexity than the other, a little wider than long, with a very low, broad median fold.

Surface of the pedicle valve marked by broad rounded costae, the largest of which border the median sinus. The costae are grouped in 3 or 4 fascicles on each side of the sinus; each fascicle consists of 3 or 4 costae, which generally do not subdivide anterior to the umbonal region. Small costae lie at the sides of the median sinus. The brachial valve bears on its low median fold generally 4 costae, which are not fasciculate, and several fascicles of costae on each side. Concentric striae of growth are likewise present on both valves. Shell impunctate.

Internally there are, in the pedicle valve, strong diverging dental lamellae, which are mostly enveloped in the apical callosity. The muscle scars lie between them on a platform, which is considerably elevated at the front. On each side of the muscular impressions the inside of the shell is covered with coarse granules.

Dimensions in mm. of several specimens:

	1 (loc. 246)	2 (loc. 246)	3 (loc. 146)	4 (Shumard's type)
Length	50	28	37	16.5
Width	47	24	32	14
Thickness	22+	15	18	10

Observations: Shumard's type of this species was a very small specimen, but it is indistinguishable from immature individuals of this large species. Girty suggested comparison of his *Spirifer* sp. a with *S. sulcifer*, which he knew only from Shumard's description. Study of the complete material from the Glass Mountains shows that Girty's specimen was a very typical brachial valve of *S. sulcifer*.

The external form of this species is nearly identical with that of many species of *Spiriferella*, but since *S. sulcifer* is impunctate, it cannot belong to that genus. Its closest relation is with *S. tibetanus* and *S. rajah*, which Diener has clearly shown not to be *Spiriferella*. From the former it differs in having a lower and broader cardinal area, and from the latter in having a lower dorsal median fold and a greater number of plications on the fold. The difference from *S. rajah* is, however, so small (see, for example, plate 119 of Wanner's Permische Brachiopoden von Timor) that it seems likely that *S. rajah* and *S. sulcifer* were representatives in the two continents of one varying form. This conclusion is borne out by the distribution of the two: *S. rajah* occurs in the high Permian shales in the Himalayas and in the *Waagenoceras* horizon of Timor, while *S. sulcifer* occurs abundantly in and above the *Waagenoceras* horizon of the Glass Mountains. *S. tibetanus* seems to have been an earlier form, for it is nowhere associated with *S. rajah*, occurring in the *Schwagerina* limestone of the Urals and the Trogkofel formation of the Karnic Alps.

Distribution: Middle and Upper Word formation (Glass Mountains) at T140, 144, T144, 146, 148, T148, Tx148, 150, 154, 158, T240a, 241, 243, T243, 246 (common), 247 (abundant), 248, 252, 255, 265, and Tc. One of the most characteristic fossils of the upper Word limestone.

Genus SQUAMULARIA Gemmellaro

Diagnosis: Shells medium-sized to large, subovate, subcircular or subovate in outline, with the hinge-line narrower than the greatest width of the shell, rounded cardinal extremities, and moderately developed or obsolete fold and sinus. Cardinal area of the pedicle valve rather small and arched, with poorly defined margins, the surface generally rounding with but little or no interruption into the lateral slopes of the valve; delthyrium rather large and open. Internally there are no dental or septal plates. Brachial valve less convex than the other, with a narrow cardinal area; internally the brachidium is similar to that of *Spirifer*. Surface of both valves covered by regular, concentric bands bearing fine prostrate spines, the tubes of which do not penetrate the full thickness of the shell.

Genotype: *Squamularia rotundata* Gemmellaro.

Geologic range: Pennsylvanian and Permian.

Observations: Species of this genus differ from those of *Reticularia* in the absence of dental or septal plates. *Reticularia* does not occur above the Mississippian.

SQUAMULARIA GUADALUPENSIS (Shumard)

Pl. XL, Figs. 6-8

1859 *Spirifer Guadalupensis*. Shumard, Trans. Acad. Sci. St. Louis, vol. 1, p. 391 (date of volume, 1860).
White (Permian) limestone: Guadalupe Mountains.

1908 *Squamularia guadalupensis*. Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 367-369, pl. 14, figs. 4-11a.

*Mississippian Brachiopoda, Mon. 1, Ill. Geol. Sur., p. 412. 1914.

Middle Capitan, Capitan Peak (sta. 2926); basal Capitan, hill southwest of Guadalupe Point (sta. 2906); Delaware Mountain formation, Guadalupe Point (sta. 2919); Delaware Mountain formation, southern Delaware Mountains (sta. 2962); Delaware Mountain formation, "Comanche Canyon," Glass Mountains.

?1909 *Squamularia perplexa.* Girty, Fauna of the Manzano Group, U. S. Geol. Sur. Bull. 389, pp. 66–68.

Yeso formation, Mesa del Yeso; San Andres formation, San Andres.

Description: Shell large, ovoid, with the length about equal to or somewhat greater or less than the width, strongly biconvex; hinge-line equal to a little more than half the greatest width, which is near mid-length. Pedicle valve high, with a long, conical, incurved beak. Cardinal area triangular, three times as wide as high, poorly defined. There is no median sinus, but a slight emargination is present at the front. Brachial valve lower than the other, evenly convex, with an incurved beak which projects somewhat beyond the cardinal margin. Outer shell layer thin, generally not preserved; it is marked by narrow, regular, concentric sublamellose bands, which are marked by slender, closely crowded spine bases which originate at the posterior margin of the band and extend forward, giving rise to spines at the anterior margin of the band. If the surface is exfoliated, as is generally the case, the shell has a reticulate appearance, there being fine radial lirae at uneven intervals over the surface, which cross the concentric bands.

Dimensions in mm. of several specimens:

	1(loc. 1)	2(loc. 106)	3(loc. D3)	4(loc. 246)	5(Girty)
Length	25	31	16	23	45
Width	29	35	17	26	38
Thickness	15	20	12	17	—

Observations: This species is the longest ranged brachiopod in the Glass Mountains faunas. No important difference could, however, be seen between specimens from the Hess and those from the Capitan, and, while the Wolfcamp specimens are incomplete, they show very well that the surface is identical with that of the Capitan specimens. Most of the specimens in the present collection, however, seem to be rather more transverse than those described by Girty. Girty distinguishes two varieties of the species. The Glass Mountains specimens seem to be referable to the typical form.

S. guadalupensis is distinguished from *S. perplexa* by having very fine spines rather than large double-barrelled spines. The specimens from New Mexico identified by Girty as *S. perplexa* are, to judge from their geologic horizon and large size, probably *S. guadalupensis.* Girty stated that a separation from *S. guadalupensis* would be difficult. *S. guadalupensis* is very close to *S. indica* (Waagen), but is probably not as elongate, and it shows other minor differences in general form.

Distribution: Wolfcamp formation (Glass Mountains) at 93, 196, and 198. Hess formation (Glass Mountains) at 1, 24, 106 (common), T205, and 208. Leonard formation (Glass Mountains) at 7, 8, 8–14, T9, 12, 15, 26s, 82, 83, 104 (common), T119, 120 (common), T120, 121, 124, 128, 174, 231, 232, Tb, Tba, D1, D3, D12, and D22. Word formation (Glass Mountains) at 46, 54, 132, 141, 170, 246, 247, T251, 256, and 263?. Altuda member (Glass Mountains) at 43 and 57 (abundant). Bone Canyon member (Sierra Diablo) at 485. Victorio Peak member (Sierra Diablo) at 493. Leonard formation (Shafter) at 518 (common). Word? formation (Shafter) at Tp.

SQUAMULARIA PERPLEXA (McChesney)

1860 *Spirifer perplexa.* McChesney, Desc. New Spec. Foss., p. 43 (date of imprint, 1859).

1914 *Reticularia lineata* Mart., var. *perplexa.* Kozlowski, Brachiopodes du Carb. Supér. de Bolivie, Ann. de Pal., vol. 9, pp. 73–76, text fig. 18, pl. 1, figs. 3–4; pl. 10, figs. 19–27.

1915 *Squamularia perplexa.* Girty, Fauna of the Wewoka Formation, U. S. Geol. Sur. Bull. 544, pp. 92–94, pl. 11, figs. 1–3a. (See for synonymy.)

Observations: A few imperfect specimens are assigned to this species. They differ from the common *Squamularia guadalupensis* of higher horizons in their smaller average size and especially in having large double-barrelled spines; a feature excellently illustrated by Kozlowski.

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at 88s, 95, 201, and 203. Wolfcamp formation (Glass Mountains) at 90?.

Genus AMBOCOELIA Hall

Diagnosis (After Weller): Shells small, plano-convex or slightly concavo-convex, subcircular to subsemielliptical in outline, the hinge-line generally a little narrower than the greatest width of the shell, the cardinal extremities rounded. Surface of valves smooth or with fine concentric lines of growth, rarely minutely spinose, shell substance impunctuate. Pedicle valve strongly convex with very prominent umbonal region, the beak strongly incurved, marked by a narrow, median, groove-like sinus which is generally strongest posteriorly; cardinal area well defined, concave, the delthyrium rather large and open, with incomplete deltidial plates. Internally the hinge-teeth are prominent, with recurved tips, not supported by dental lamellae; the muscular area small, the interior surface about the muscle scars strongly pitted. Brachial valve convex at the beak, becoming flat or concave forward, with a rather broad cardinal area lying in nearly a right angle to the area of the other valve; cardinal process bifurcating posteriorly, elongate, resting on the bottom of the valve except at the posterior end, the spires of the brachidium loosely coiled with few volutions, attached by long crura which are continuous with the primary lamellae; the jugum in the same rudimentary condition as in *Spirifer.*

Genotype: *Orthis umbonata* Conrad.

Geologic range: Silurian to Permian.

AMBOCOELIA GUADALUPENSIS Girty

Pl. XLI, Figs. 1–5

1908 *Ambocoelia planiconvexa* var. *guadalupensis.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 370–371, pl. 14, figs. 12–14a.

Middle Capitan, Capitan Peak (sta. 2926) and peak north of Pine Spring (sta. 2902); Delaware

Mountain formation, southern Delaware Mountains (sta. 2936).

1910 *Ambocoelia arcuata.* Girty, Fauna of the Phosphate Beds of the Park City Formation, U. S. Geol. Sur. Bull. 436, p. 35, pl. 6, figs. 15–17.
Phosphate beds of the Park City formation: Sublette Range, Wyoming; Thomas Fork, Wyoming; Montpelier, Idaho.

Description: Shell large for the genus, hinge-line narrower than the greatest width, which is near mid-length. Pedicle valve highly inflated, especially in the umbonal region, with a long projecting, incurved beak. Cardinal area poorly defined, high, triangular, generally lying at an angle of about 135° to the plane of the margin, about a third occupied by the delthyrium, which is higher than wide. There is no trace of a median sinus. Brachial valve transverse, gently convex, somewhat flattened at the cardinal angles, hinge-line straight. Beak small and depressed. Surface marked only by fine concentric lines. Within the brachial valve are rather long prominent crural plates.

Dimensions in mm. of several specimens:

	1 (loc. 491)	2 (loc. 265)	3 (loc. T120)	4 (*A. arcuata*)	5 (*A. guadalupensis*)
Length	17	14	13	15	11.5
Width	16	15	12	13	12.5
Thickness	10	8	7	—	—

Observations: This species averages much larger than *A. planoconvexa*, is relatively longer, has a more convex brachial valve, and lacks a median sinus. Girty mentions as differences also that *A. guadalupensis* has a lower cardinal area and longer, stronger, and more closely proximate crural plates. The specimens in the present collection agree with Girty's figures and description, but in them the cardinal area is fully as high relative to the size of the shell as in *A. planoconvexa*. In describing *A. arcuata*, Girty mentioned as a difference from *A. planoconvexa* the broader delthyrium of the former. His specimen figured on plate 6, fig. 17 shows a broad opening below the apex, but this seems to be broader than the delthyrium, which is shown in fig. 16 and is quite like that of the Texas Permian species, and certainly not conspicuously larger in proportion than that of *A. planoconvexa*. The characters mentioned in the first sentence, and which were emphasized by Girty in his discussion of *A. arcuata*, easily serve to distinguish this species. *A. arcuata* was not compared with *A. planoconvexa guadalupensis* in the original description, but the two descriptions agree so well, and the specimens in the present collection would so easily fit in either one of the descriptions that there can hardly be any doubt as to their identity.

Distribution: Leonard formation (Glass Mountains) at 12, 25, 31, and T120. Word formation (Glass Mountains) at 144, T240a, 265, and Tc. Middle Gym formation (Sierra Diablo) at 414. Bone Canyon member (Delaware Mountains) at 490 and 491. Bone Canyon member (Guadalupe Mountains) at 221?. Leonard formation (Shafter) at 518.

AMBOCOELIA PLANOCONVEXA (Shumard)

1855 *Spirifer plano-convexa.* Shumard, Missouri Geol. Survey Second Ann. Rept., p. 202.

1914 *Ambocoelia planoconvexa.* Kozlowski, Brachiopodes du Carb. Supér. de Bolivie, Ann. de Pal., vol. 9, pp. 76–77, text fig. 19, pl. 1, fig. 5; pl. 10, figs. 1–14.

1915 *Ambocoelia planiconvexa* Girty, Fauna of the Wewoka Formation, U. S. Geol. Sur. Bull. 544, pp. 94–96, pl. 11, figs. 6–7b. (See for synonnymy.)

Observations: This species occurs only in the *Uddenites* zone. At loc. 88s most of the specimens of it are pyritized, like the ammonoids from the same locality.

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at 88, T88, 88s, and 94s. Wolfcamp formation (Glass Mountains) at 195?.

Genus MARTINIA McCoy

Diagnosis (after Weller): Shells generally of medium size or smaller, subcircular, subovate or subelliptical in outline, the hinge-line narrow, the cardinal extremities rounded, the surface of the valves smooth or nearly so. Cardinal area of the pedicle valve small, with poorly defined lateral margins, the surface curving with little or no differentiation into the lateral slopes of the valve; delthyrium rather large. Dental and septal plates not present; muscle scars small, scarcely impressed and ill-defined. In the brachial valve the muscle scars are also inconspicuous, the crura and primary lamellae of the brachidium are elongate, the bases of the spiral coils are situated well forward and their apices are directed toward the cardinal extremities.

Genotype: *Anomites glabra* Martin.

Geologic range: Devonian to Permian.

MARTINIA RHOMBOIDALIS Girty

Pl. XLI, Figs. 6–10

1908 *Martinia rhomboidalis.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 364–365, pl. 13, figs. 11–14c.
Middle Capitan, Capitan Peak (sta. 2926); basal Capitan, hill southwest of Guadalupe Point (sta. 2906); Delaware Mountain formation, Guadalupe Point (sta. 2919); Delaware Mountain formation, southern Delaware Mountains (stas. 2935, 2962).

Description: Shell medium-sized to large, length equal to or somewhat greater or less than the width. Hinge-line equal to about half the greatest width. General outline rhombic. Pedicle valve rather strongly convex in the posterior part, with decreasing curvature toward the front. Beak narrow and pointed, elevated and incurved over the not very high cardinal area. Median sinus broad and shallow, originating about 20 mm. in front of the beak as a flattening, becoming broader and deeper toward the front, which extends forward in the median part as a tongue. Brachial valve subcircular to subquadrate, with a small incurved beak, and an inflated umbo. From the median line the shell falls away rapidly to the lateral slopes, leaving a rounded subangular fold the entire length of the valve. Outer surface smooth. If the shell is partly exfoliated there are fine radial lirae. Dental and septal plates absent.

Dimensions in mm. of several specimens:

	1 (loc. 123)	2 (loc. 8–14)	3 (loc. 494)	4 (Girty's type)
Length	33	25	30	22
Width	24	24	37	20

Observations: Although this species occurs in great abundance at loc. 57, there being hundreds of specimens in the rock, few can be worked out to show the valves in conjunction. The species is not very common at any locality in the lower formations. It differs from *M. wolfcampensis* in having a smaller, less strongly inflated ventral umbo. *M. shumardiana* Girty, which is distinguished from *M. rhomboidalis* by its stronger fold and sinus, is hardly more than a variety of the latter. The closest foreign relatives of *M. rhomboidalis* are *M. elongata* Waagen and *M. variabilis* Gemmellaro, especially the latter. It would be difficult to point out differences without actual specimens for comparison.

Distribution: Leonard formation (Glass Mountains) at 8–14, 12?, 13?, T15, 16, 21, 26s, 34, 77, 98, T119, 120, 123, 124, T128, 232, 245, D1, D12, and D16. Word formation (Glass Mountains) at 6? and 241?. Bone Canyon member (Guadalupe Mountains) at 221. Victorio Peak member (Sierra Diablo) at 494. Altuda member (Glass Mountains) at 43 and 57 (very abundant).

MARTINIA WOLCAMPENSIS King, n. sp.

Pl. XL, Figs. 9–13

Description: Shell medium-sized, about equal in length and width. The hinge-line equals about half the greatest width, which is at about mid-length. Pedicle valve strongly convex in the posterior part, becoming more flattened toward the front. Ventral umbonal region broad and highly inflated, beak strongly incurved. Cardinal area high, not well defined, mostly occupied by a broad delthyrium. Near the front of large shells there is a broad, shallow, median sinus which extends forward at the anterior margin a short distance as a tongue. Brachial valve transversely elliptical, beak small and low. This valve has very low convexity, there being a convex median region and flattened lateral slopes. Surface smooth except for irregularly spaced radial lirae on some specimens, and finer concentric lirae. Dental and septal plates are absent. In the pedicle valve the muscle scars lie in an elongate depression along the median line.

Dimensions in mm. of several specimens:

	1 (loc. 94)	2 (loc. 94s)	3 (loc. 87)	4 (loc. 201)
Length	25	28	21	18
Width	24	32	22	17
Thickness	10+	11+	15	12

There is some variation in the development of the median sinus. The specimens from locs. 75 and 87, for example, have a well developed median depression at a size at which the specimens from loc. 94 are still evenly convex.

Observations: This species differs from *M. rhomboidalis* Girty in having a more convex umbonal region of the pedicle valve, a less convex brachial valve, and a regularly ovoid rather than rhomboid outline. Of the foreign species, it is closest to the specimens figured by Tschernyschew as *M. triqueta* Gemmellaro, and indeed it would be difficult to point out any differences between them. However, Tschernyschew's figures show considerable difference from true *M. triqueta*, which has a much less highly inflated ventral umbo. The similarity of the Uralian specimens to *M. wolfcampensis* is much greater, and it may be questioned if they are not identical.

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at 88, 88s (type), T88, 94, 94s, 95, 96, 175a, 201, and 202. Wolfcamp formation (Glass Mountains) at 75, 87 low, 93, and 196.

Genus SPIRIFERINA d'Orbigny

Diagnosis: Shell spiriferoid, transverse; fold and sinus angular and not sharply differentiated from the plicae, which are few in number and angular. Anterior margin of the valves strongly serrated, with a few sharp folds, decreasing in amplitude from and including the median fold. Ventral cardinal area curved, with more or less rounded margins which curve over into the lateral slopes; beak small and incurved. Delthyrium open; internally the dental lamellae are well-developed, and diverge toward the floor of the valve, and their anterior extremities are concave. Ventral median septum well-developed, extending farther forward than the dental lamellae. In the brachial valve the spiralia are directed laterally, the primary lamellae being joined by a complete, simple transverse jugum. Shell composed of two layers, of which the inner is strongly punctate and the outer covered with fine, tubular, spinose projections, which, when broken, give the shell a pustulose appearance. Concentric, irregularly arranged lamellae of growth are generally present.

Genotype: *Terebratulites rostrata* Schlotheim.

Geologic range: Middle Mississippian to Lias.

Observations: The name *Spiriferina* is here used as restricted by North, the lamellose forms with large fold and sinus being placed in *Punctospirifer*. According to the restricted usage, the only Pennsylvanian species of *Spiriferina* (except for the Mississippian holdovers in the Bend fauna) are *S. campestris* White and *S. gonionotus* Meck (if the latter is not identical with *S. campestris*). The common *S. kentuckyensis* is placed with *Punctospirifer*. Mississippian species of *Spiriferina* (restricted) are *S. norwoodana* (Hall), *S. salemensis* Weller, and *S. spinosa* (Norwood and Pratten). Girty,* in discussing the divisions of *Spiriferina* in the American Carboniferous, pointed out the presence of the two major subdivisions now distinguished as *Spiriferina ss.* and *Punctospirifer*. He suggests a different origin for the two groups of "*Spiriferina*." The group now known as *Punctospirifer* has been derived by Hall and Clarke from the lamellose-septate group of spirifers *(Delthyris)*. Girty compares the spinose (or true) *Spiriferina* to some of the ostiolate spirifers, but says that since the ostiolate spirifers lack a ventral median septum, an attempt to derive *Spiriferina* from them would be rather fanciful. Continuing, Girty remarks that there is a little known group of spirifers (including *S. aciculifer* and *S. schucherti)* in the early Mississippian that have a spinose surface, but it was not known whether they were or were not septate and punctate, so that "it thus remains in doubt as to whether the *spinosa* group drew its ascent

*U. S. Geol. Sur. Prof. Paper 58, pp. 372–374. 1908.

from the same or different stock from *Spiriferina transversa*" (*Punctospirifer*). In 1914, however, Weller established the genus *Acanthospira* (*Acanthospirina* Schuchert and LeVene), with *Spirifera aciculifera* Rowley as the genotype, for spinose spirifers having a non-punctate shell and no median septum. The presence of these characters strongly suggests that *Acanthospirina* is the connecting link between the ostiolate spirifers and *Spiriferina*. The geologic range of the three forms is still further suggestive. The ostiolate spirifers are especially characteristic of the Devonian. *Acanthospirina* occurs in the Louisiana limestone, of the lower Kinderhook. The first appearance of true *Spiriferina* is in the Salem limestone. Thus we see that *Acanthospirina* not only holds an intermediate position structurally but also chronologically. In conclusion, it may be stated as likely that *Punctospirifer* and *Spiriferina* were two differently derived groups of similar external form.*

SPIRIFERINA ANGULATA KING, n. sp.

Pl. XLII, Figs. 12–13

Description: Shell large, much wider than long, with the greatest width at the hinge-line, semicircular, strongly biconvex. Cardinal area of the pedicle valve of moderate height, concave, beak rather low. Shell folded into very high, angular plications; median fold and sinus not very much larger than the plications and sulci, which are 4 or 5 in number on each side. The anterior margin is deeply serrate, the median digitation being as long as the entire thickness of the shell, and the lateral ones becoming gradually less toward the wings. The shell structure is strongly punctate, and there are occasional zig-zag growth varices.

Dimensions in mm. of several specimens:

	1 (loc. 478)	2 (loc. 478)	3 (loc. 479)
Length	17	13	14?
Width	28	22	28
Thickness	18	—	—

Observations: This species is distinguished by its strongly biconvex form and very high, sharp plications. I know of no other species of the genus in which there is a combination of these characters.

Distribution: Hess formation (Glass Mountains) at 106 and 211. Leonard formation (Glass Mountains) at Tha. Hess formation (Sierra Diablo) at 476, 478 (types), and 479.

SPIRIFERINA HILLI Girty

Pl. XLII, Figs. 1–6

1908 *Spiriferina hilli.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, p. 379, pl. 30, ffis. 15–15b.

Delaware Mountain formation, "Comanche Canyon," Glass Mountains.

1915 *Spiriferina Hilli.* Haack, Permfauna aus Nordmexiko, Zeit. der deutsch. geol. Gesell., 66 Bd. (1914), pp. 495–497, pl. 39, figs. 2–9.

Pichagüa, near Las Delicias.

*See North, F. J.: *Syringothyris* and *Spiriferina*, Quart. Jour. Geol. Soc. London, vol. 76, pt. 2 (1920), pp. 162-227.

Description: Shell small, wider than long, being widest somewhat in front of the hinge-line. Cardinal area high, rather variable in its degree of inclination to the shell margin; beak incurved. Median sinus distinctly larger than the lateral plications, but not very deep. According to Girty, it may contain a low median plication. Lateral plications 4 to 6 in number, decreasing in size laterally, the two plications bordering the sinus being considerably larger than the others. Brachial valve wider than long, with a small incurved beak. Median fold somewhat larger than the lateral plications, which number from 4 to 6 on each side. Surface smooth except for unevenly distributed growth varices, which are most closely spaced near the anterior and lateral margins. Shell structure rather coarsely punctate but not as coarsely as *S. laxa*. Some of the internal characters were described by Haack.

Dimensions in mm. of several specimens:

	1 (loc. 208)	2 (loc. 223)	3 (loc. D20)
Length	12	6	9
Width	15	8	10

Observations: This species is distinguished from *S. laxa* by its much smaller size, greater length in proportion to width, and somewhat finer punctae. Haack states that the nearest foreign relative is *S. multiplicata* (Sowerby) rather than *S. cristata*, to which it was compared by Girty. *S. laxa* is more nearly related to the latter, both those forms being large and very coarsely punctate, while *S. multiplicata* and *S. hilli* are small and finely punctate.

Distribution: Hess formation (Glass Mountains) at 4, 208, and 223. Leonard formation (Glass Mountains) at 123?, T205?, 224, D3, D7, D9, and D20. Leonard formation transition beds (Shafter) at Th. Limestone of Pichagüa (Las Delicias) at Cerro Pichagüa.

SPIRIFERINA LAXA Girty

Pl. XLII, Figs. 7–11

1908 *Spiriferina laxa.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 377–378, pl. 21, figs. 3–3b.

Dark limestone, Pine Spring (sta. 2930) and Guadalupe Point (sta. 3762s?); Delaware Mountain formation, southern Delaware Mountains (sta. 2969?).

1908 *Spiriferina welleri.* Girty, *idem*, pp. 380-382, pl. 14, figs. 17–19b.

Middle Capitan, Capitan Peak (sta. 2926); basal Capitan, hill southwest of Guadalupe Point (sta. 2906); dark limestone, Pine Spring (sta. 2930?); Delaware Mountain formation, southern Delaware Mountains (sta. 2969?); Delaware Mountain formation, Glass Mountains.

1915 *Spiriferina Haarmanni.* Haack, Permfauna aus Nordmexiko, Zeitsch. der Deutsch. Geol. Gesell., bd. 66 (1914), pp. 492–495, pl. 38, figs. 7a–c; pl. 39, figs. 1a–c.

Pichagüa, near Las Delicias.

Description: Shell large, wider than long or of about equal length and width, with the greatest width at the hinge-line; more or less unsymmetrical. Shape of the pedicle valve transversely semicircular. The shell is not very strongly convex. Cardinal area inclined backward at about 100° from the plane of the margin, concave near the apex but nearly flat near the hinge-margin, defined from the rest of the shell by an angulation near the beak but less clearly set off toward the sides. Beak pointed and incurved. Delthyrium large, higher than wide, bordered on each side by a ridge which, where it reaches the cardinal line, forms the outer surface of the hinge-tooth. Sinus broad but not much broader or deeper than the lateral sulci. Near the front it may contain one or two small plications. On each side of the sinus there are 4 or 5 large subangular plications, becoming smaller toward the sides. Brachial valve less strongly arched than the other, with a small, low beak and a very narrow cardinal area. The fold is only slightly larger than the lateral plications, which are 4 to 6 in number on each side.

Outer shell layer dense and finely papillose, marked near the front by several subimbricating lamellae. The main part of the shell is very coarsely punctate, the punctae being easily seen with the naked eye if the outer shell layer is worn away, when the shell is given a spongy appearance.

Within the pedicle valve the hinge-teeth have the form of blunt protuberances on each side of the delthyrium; their bases extend backward into the thickened dental lamellae, which reach to the bottom of the shell only in the apical region. Median septum thin, rising to a sharp crest just in front of the hinge-line. In the brachial valve there are well defined dental sockets, bordering which are protuberances that give rise on their anterior faces to the crura. In the median posterior part of the shell there is a thick ridge, the cardinal process.

Dimensions in mm. of several specimens:

	1 (loc. T240)	2 (loc. 192)	3 (loc. 46)	4 (*S. welleri*)	5 (*S. laxa*)	6 (*S. haarmanni*)
Length	16	16	12	17	16	22
Width	16	17	20	24	23	32
Thickness	9	—	—	—	—	17

It may be seen that the ratio of length to width is very variable in the Glass Mountains specimens, but that in the three species here placed in synonymy it is practically identical. (The figures for *S. haarmanni* are taken from Haack's plate rather than from the text.)

Observations: That the names *S. laxa*, *S. welleri*, and *S. haarmanni* have been applied to a single species seems certain. Any of the specimens in the present collection would fit equally the description of the three supposed species, and no significant difference can be found between any of the descriptions. A very well preserved specimen collected by myself from Cerro Pichagüia, the same hill from which the type of *S. haarmanni* was collected, shows no difference from the Word specimens. Several points of difference may, however, be noted between it and the types of Haack. Haack states that there are 3 or 4 punctae in the inner layer in the space of 1 mm., near the anterior margin. In my own specimen a measurement in the anterior part of the shell gives 8 punctae in 1 mm. If Haack's figures were correct the punctae would be incredibly large. Haack says that the median septum of the pedicle valve is not very high. This certainly must be due to imperfect preservation, for my own specimen has a high septum. The large pores said by Girty to exist in the outer shell layer of *S. laxa* were not observed in the present specimens.

Spiriferina laxa is characterized by its large size, large, high plications, which are not much smaller than the median fold, and by the coarsely punctate inner shell layer and papillose outer layer. The most similar American species is *S. pyramidalis* Girty, of the Capitan. The differences between them mentioned by Girty are the more rounded outline of *S. pyramidalis* and the higher cardinal area. Girty himself suggested that *S. pyramidalis* might be only a young stage of *S. laxa*. *Punctospirifer? pulchra* is a large, coarsely punctate shell, but has a relatively much broader fold and sinus, a greater number of lateral plications, and well-marked concentric lamellae. As Haack has shown, the closest relation of the species is to *S. cristata* (Schlotheim) and *S. nasuta* Waagen. The latter differs especially in that the fold and sinus are both broader and deeper. After comparing his specimens from Pichagüia with some from the Salt Range, Haack concludes that *S. haarmanni* (=*S. laxa*) is the American variant of the Indian and Chinese form.

Distribution: Word formation (Glass Mountains) at 46, T140, 142, 144, T144, T148, Tx148, 192, T239, T240, 247, 259, and 265. Altuda member (Glass Mountains) at 43. Bone Canyon member (Sierra Diablo) at 485?. Limestone of Pichagüia (Las Delicias) at Cerro Pichagüia. The species is common only at loc. 192.

SPIRIFERINA PYRAMIDALIS Girty

Pl. XLII, Fig. 14

1908 *Spiriferina pyramidalis*. Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 378–379, pl. 14, figs. 20–21b.
Middle Capitan, Capitan Peak (sta. 2926); Delaware Mountain formation, southern Delaware Mountains (sta. 2969?).

Description: Shell medium-sized, much wider than long, subtriangular, widest at the hinge-line. Pedicle valve high and conical, with a broad, high, nearly flat cardinal area, which is strongly defined by angles at its junction with the sides of the shell, and lies nearly perpendicular to the plane of the margin. Delthyrium large, nearly twice as high as wide. Median sinus not greatly larger than the lateral sulci. On each side of the sinus there are 4 strong plications, becoming smaller toward the wings. Brachial valve strongly convex, beak incurved over a narrow cardinal area. The median fold is much higher than the lateral plications, resulting in a strong deflection of the anterior margin. There are 3, and a faint fourth, lateral plications. Within the pedicle valve the median septum rises to a crest near its anterior end. Surface of both valves marked by fine, closely but irregularly distributed concentric lamellae. The shell is strongly punctate. Length of brachial valve, 11 mm.; width, 21 mm.; height of ventral cardinal area, 7.5 mm.

Observations: This species resembles those of *Punctospirifer* in having many concentric lamellae, but they are not as closely and regularly set as in that genus, and, moreover, *S. pyramidalis* has a relatively smaller fold and sinus and much more extended ears than do most specimens of *Punctospirifer*. It is closely related to *S. laxa*, but has a much higher and less curved cardinal area.

Distribution: Word formation (Glass Mountains) at 264 (one specimen).

Genus PUNCTOSPIRIFER North

Diagnosis: Shell spiriferoid, wider than long, with the greatest width near the hinge-line; cardinal angles slightly rounded or subangular; cardinal area moderately high and concave. Median fold and sinus considerably larger than the plications, which are numerous, small, and rounded. Surface of both valves crossed by regularly disposed imbricating lamellae, which in adult specimens may be more or less obsolescent, especially in the posterior part of the valve. Delicate hair-like spinules of varying abundance and arrangement are also present. Shell structure fibrous and strongly punctate. Within the pedicle valve the dental lamellae are slightly divergent; median septum well developed, thickened at its base, terminating somewhat abruptly about half-way toward the anterior margin. No marked development of an apical callosity, the three vertical septa appearing as distinct structures in sections near the beak. A low median crest bisects the muscle scars of the brachial valve; spiralia large, connected by a slender jugum, which forms a shallow V-shaped process, with its apex directed ventrally and backward.*

Genotype: *Punctospirifer scabricosta* North.

Geologic range: Lower Mississippian to Permian (at least).

Observations: This genus differs from *Spiriferina* in the following respects: It is more alate. There is a greater number of plications, which are smaller and less angular, and the fold and sinus are relatively smaller. The surface is lamellose and finely spinose, rather than smooth except for irregularly arranged growth lamellae and relatively large spines. Finally, the jugum is V-shaped with the apex directed backward, rather than straight, or curved toward the front* as in *Spiriferina*. In establishing this genus, North emphasized especially the relatively greater size of the fold and sinus, rather than the lamellose surface. Following Girty* I would regard the latter character as of primary importance. Unfortunately, neither the specimens which I studied, nor those described by Weller in "Mississippian Brachiopoda" showed the structure of the jugum, but since *Punctospirifer kentuckyensis* as described by Hall and Clarke has an angular, backward pointing jugum, it seems likely that the other American forms having the external characters of *Punctospirifer* would agree in that respect. The Mississippian species of *Punctospirifer* are *P. subtexta* (White), *P. solidirostris* (White), *P. subelliptica* (McChesney), and *P. transversa* (McChesney). The only Pennsylvanian species above the Bend is *P. kentuckyensis* (Shumard).

Hall and Clarke have shown that the group now comprised in *Punctospirifer* probably arose from *Delthyris*.* As indicated in the discussion of *Spiriferina*, that genus and *Punctospirifer* may have had independent origins.

*North, F. J.: *Syringothyris* and *Spiriferina*, Quart. Jour. Geol. Soc. London, vol. 76, pt. 2 (1920), pp. 208–214.

*See Kozlowski's figure of *Spiriferina campestris* White, in Ann. de Pal., vol. 9, text fig. 17.

*U. S. Geol. Sur. Prof. Paper 58, pp. 371–373.

PUNCTOSPIRIFER BILLINGSII (Shumard)

Pl. XLII, Figs. 15–18

1858 *Spiriferina Billingsii*. Shumard, Trans. Acad. Sci. St. Louis, vol. 1, p. 294 (date of volume, 1860).
White and dark (Permian) limestone: Guadalupe Mountains, and conglomerate at mouth of Delaware Creek, New Mexico.

1859 *Spiriferina Billingsii*. Shumard, *idem.*, p. 391.
White and dark (Permian) limestone: Guadalupe Mountains.

1908 *Spiriferina Billingsii*. Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 374–376, pl. 13, figs. 16–19d, 21–21b, 24–24c; pl. 14, figs. 15–16.
Middle Capitan, Capitan Peak (sta. 2926); dark limestone, Pine Spring (sta. 2930); Delaware Mountain formation, Guadalupe Point (sta. 2930?); Delaware Mountain formation, southern Delaware Mountains (sta. 2969?); Delaware Mountain formation, "Comanche Canyon," Glass Mountains.

Description: Shell medium-sized, wider than long, strongly biconvex, with the hinge-line shorter than the greatest width of the shell, cardinal angles rounded. Pedicle valve greatly arched, with a high, extended beak, which is incurved over a broad triangular, concave, poorly-defined cardinal area. Median sinus broad and angular, extending from the apex to the front. The lateral slopes each bear from 4 to 9 small rounded plications, which are simple and gradually enlarge from the beak to the front. Brachial valve evenly convex, with a strong median fold, elevated toward the front above the general convexity. The lateral slopes bear small plications corresponding to those of the pedicle valve. Surface marked by regular, strong imbricating, concentric lamellae, from 7 to 13 of which occur in the space of 5 mm.

Dimensions in mm. of several specimens:

	1 (loc. T148)	2 (loc. Tx)	3 (Shumard's type)
Length	11	10	18.5
Width	12	11	22.5
Thickness	9	—	14.5

Observations: Save for the smallest size of the specimens from the Glass Mountains, there is no difference between them and the typical ones as described by Shumard and Girty. Girty recognized three varieties of *Spiriferina billingsii: S. billingsii retusa, S. evax,* and *S. sulcata*, all

*According to Miss Muir-Wood (Notes on the Silurian brachipod genera *Delthyris*, *Uncinulina*, and *Meristina*, Ann. and Mag. of Nat. Hist., ser. 9, vol. 15, 1925, p. 83) some of the species of *Delthyris* in the Upper Devonian and Mississippian should be placed in *Tylothyris* North. In his original description, North (Quart. Jour. Geol. Soc. London, vol. 76, pt. 2, 1920, p. 195) said that his genus *Tylothyris* differed from the Silurian *Delthyris* in its much greater size, smaller and more numerous costae, and the marked development of an apical callosity. None of these would ordinarily be regarded as valid for generic distinction. Miss Muir-Wood, however, shows that in true *Delthyris* the lamellae are fimbriate, while in *Tylothyris* no ornament has been described on the lamellae. The Upper Devonian and Lower Mississippian shells formerly classed as *Delthyris* which do not have fimbriate lamellae may, she suggests, be *Tylothyris*.

from the Capitan. None of them was recognized in the present collections. The most closely related foreign species is *P. ornata* (Waagen), which differs in having larger and fewer lateral plications. *P. billingsii* is a larger form than *P. kentuckyensis*, and, though related closely to *P.? pulchra* of the Phosphoria, has a quite different configuration.

Distribution: Word formation (Glass Mountains) at 54, 144, T148, 192, T2?9, 241, 243, Ta, Tc, and Tx. Altuda member (Glass Mountains) at 43 and 50. Not common at any locality.

PUNCTOSPIRIFER KENTUCKYENSIS (Shumard)

1855 *Spirifer Kentuckyensis.* Shumard, Missouri Geol. Survey Second Ann. Rept., p. 205.

1915 *Spiriferina kentuckyensis.* Girty, Fauna of the Wewoka Formation, U. S. Geol. Sur. Bull. 544. pp. 85–87, pl. 11, figs. 8–8a.

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at T88. Wolfcamp formation (Glass Mountains) at 89. Rare.

Family RHYNCHOSPIRINIDAE

Genus HUSTEDIA Hall

Diagnosis (after Weller): Shells small, subovate in outline, with nearly equally convex valves, marked by rather coarse, subangular, simple plications, the shell structure punctate. Pedicle valve with a prominent umbo perforated at its apex by a subcircular foramen; cardinal area small, with sharply defined lateral margins, the delthyrium closed by deltidial plates and in contact with the foramen at its apex only. Internally the inner surface of the pseudodeltidium bears a split tube attached by its closed side to the deltidial plates, with its open side directed toward the interior of the shell. In the brachial valve the hinge-plate projects considerably beyond the hinge-line posteriorly, being recurved into the umbonal cavity of the pedicle valve, the upper face convex and elevated medially, the posterior margin sinuate and crescentic with the horns of the crescent very short; from the lateral margins of the plate arise a pair of strong lobes which bear the erect slightly recurved crura. At the base of the cardinal process and in the median line, there arises a free, slender, lingulate process which curves upward and backward with somewhat less curvature than the hinge-plate, and rises to the highest point attained by the latter; the inner surface of this process is deeply grooved and at its base it is supported by a median septum which extends for a third the length of the valve. Spiralia approximate, with 8 or 9 volutions, the apices directed laterally; jugum posterior in position, regularly curved from the points of origin on the primary lamellae forward and inward, giving rise at its center to a simple stem-like process. The posterior margins of the coils and the jugum are fimbriated.

Genotype: *Terebratula mormonii* Marcou.

Geologic range: Mississippian to Permian.

Observations: This genus is distinguished from *Eumetria* by having fimbriate spiralia and jugum and a simple rather than forked extremity of the stem-like process from the jugum. Most species have coarser plications than those of *Eumetria*, but *H. pusilla* is finely plicate.

HUSTEDIA BIPARTITA Girty

Pl. XLII, Fig. 19

1908 *Hustedia bipartita.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 398–399, pl. 30, figs. 19–20a.

Dark limestone, Pine Spring (sta. 2930?) and Guadalupe Point (sta. 3762e?), Guadalupe Mountains. Delaware Mountain formation, southern Delaware Mountains (sta. 2969); Delaware Mountain formation, "Comanche Canyon," Glass Mountains.

Description: Shell similar to *H. meekana* but with the median plication of the brachial valve undeveloped at the beak and never reaching the size of the plications on each side, with the result that there is a median depression in the general surface of the valve. There are 11 plications on the brachial valve of the specimen of *H. bipartita* in the present collection, and the beak, as in *H. meekana*, is small, pointed, and erect. Length, 9 mm., width, 8 mm., thickness, 6 mm.

Observations: Perhaps this group should be regarded as no more than a variety of *H. meekana*, for in the latter species the median plication of the brachial valve may at its origin be somewhat smaller than those on each side.

Distribution: Leonard formation (Glass Mountains) at D2.

HUSTEDIA HESSENSIS King, n. sp.

Pl. XLII, Figs. 43–46

Description: Shell rather large for the genus, moderately convex, longer than wide. Pedicle valve evenly rounded at the front, with nearly straight posterior lateral slopes which converge to meet at the beak at an angle of about 70°. Ventral beak high, only slightly incurved; cardinal area well defined, somewhat concave, more than two-thirds as high as wide. Foramen large and subcircular. Both valves are folded into high, broad, subangular plications, averaging about 10 in number; the plications may be somewhat irregular, some of them being higher than the adjoining ones. Surface marked by fine, irregular, concentric growth lirae. Internal characters not determined.

Dimensions in mm. of several specimens:

	1 (loc. 478)	2 (loc. 106)	3 (loc. 208)	4 (loc. 474)
Length	14	16	15	10
Width	11	14	14	9
Thickness	10	10	—	5

Observations: This species is distinguished by the large size, angularity, and irregularity of its plications, its acutely pointed posterior part of the pedicle valve, its elevated ventral umbo, and its high cardinal area. A closely related, if not identical, species is *Retzia compressa* Meek, from the Permian of California. The description and figures of that species are inadequate for proper comparison.

Distribution: Hess formation (Glass Mountains) at 105, 106, 208, 211, 212, and 222. Hess formation (Sierra Diablo) at 469, 474, 476, 478 (types), and 479.

HUSTEDIA HUECOENSIS King, n. sp.

Pl. XLII, Figs. 40–42

Description: Shell large for the genus, outline subcircular or elongate ovoid, convexity low and about the same in both valves. Ventral beak high, not greatly incurved over the small, well defined cardinal area. Apical foramen large and round. Surface ornamented by 16 to 18 low, subangular plications. Fold and sinus absent, though the median plication or sulcus may be slightly larger than the others.

Dimensions in mm. of several specimens:

	1 (loc. 440a)	2 (loc. 440a)	3 (loc. 440a)	4 (loc. 440b)
Length	14	15	13	9
Width	13	15	10.5	7
Thickness	8	7	9.5	5

Number 4 is probably an immature specimen of this species, and number 3 is an exceptionally narrow, thick specimen which is considerably different from the typical form of the species, but appears to be connected with the typical form by complete gradation.

Observations: The typical form of this species is distinguished from others in the west Texas Permian by the combination of low convexity, relatively large size, and numerous plications. The narrow forms are less easily distinguishable from *H. meekana,* but are more finely plicated. *H. hessensis* similarly has low convexity, but there are fewer and sharper plications.

Distribution: Upper Gym formation (Hueco Mountains) at 437, 440a, and 440b.

HUSTEDIA MEEKANA (Shumard)

Pl. XLII, Figs. 34–39

1858 *Retzia* (?) *Meekana.* Shumard, Trans. Acad. Sci. St. Louis, vol. 1, p. 295 (date of volume, 1860).
White and dark (Permian) limestone: Guadalupe Mountains; conglomerate at the mouth of Delaware Creek.

1859 *Retzia Meekana.* Shumard, *idem*, p. 395, pl. 11, figs. 7a–b.
White and dark limestone: Guadalupe Mountains; conglomerate at the mouth of Delaware Creek.

1908 *Hustedia meekana.* Girty, The Guadalupian Fauna, U. S. Geol. Surv. Prof. Paper 58, pp. 394–396, pl. 14, figs. 22–26a; pl. 21, figs. 5–8a; pl. 24, figs. 14–14a; pl. 29, fig. 8; pl. 30, figs. 16–17.
Top of Capitan (sta. 3762a), middle Capitan, Capitan Peak (sta. 2926); basal Capitan, hill southwest of Guadalupe Point (sta. 2906); dark limestone, Pine Spring (sta. 2930), Guadalupe Point (stas. 3762b and 3762d), hill southwest of Guadalupe Point (sta. 2924); basal black limestone, Guadalupe Point (stas. 2920 and 2967); Delaware Mountain formation, southern Delaware Mountains (stas. 2969 and 3500); Delaware Mountain formation, "Comanche Canyon," Glass Mountains.

1915 *Retzia (Hustedia) Meekana.* Haack, Permfauna aus Nordmexiko, Zeitsch. der deutsch. geol. Gesell., bd. 66 (1914), pp. 497–501, text figs. 1–2; pl. 39, figs. 10a–c.
Pichagua, near Las Delicias.

Description: Shell medium-sized to large for the genus, longer than wide, valves subequally convex, with a subcircular brachial valve and a high, pointed pedicle valve. Hinge-line equal in width to about a fourth the width of the shell. Cardinal area of the pedicle valve well defined, a little less than twice as wide as high, regularly incurved. Apical foramen large and ovoid. On average specimens there are 12 plications on the pedicle valve and 11 on the brachial, but the last one or two on each side are very small. The plications are large and subangular, and the sulci are the reverse of the plications. There are faint growth varices, especially near the front. Shell finely punctate. The internal structures have been described in detail by Haack, who shows that they are similar to those of *H. mormonii,* except that the prongs on each side of the cardinal process are stronger and higher and the median septum shorter; moreover, the points of origin of the jugum from the beginning of each of the spiralia are said to be broader.

Dimensions in mm. of several specimens:

	1 (loc. 123)	2 (loc. 46)	3 (loc. 491)	4 (loc. 236)	5 (Shumard's type)
Length	10	12.5	11.5	18	11.5
Width	9	11.5	9.5	19	10.5
Thickness	7	8.5	8.0	--	9.0

Observations: According to Girty, there are generally 9 plications on the brachial and 10 on the pedicle valve. The greater number mentioned in the above description may be accounted for by the fact that the plications farthest on each side are very small, and show only in very well preserved specimens. Girty has pointed out that a feature mentioned by Shumard as an important specific character, the supposed presence of small costae superimposed on the larger ones, is due to exfoliation of the outer surface. This probably is shown more in the Capitan specimens than in those of the present collection, most of which are silicified. *H. meekana* differs from *H. mormonii* in having larger and fewer plications, a more elongate and erect beak, and in attaining a larger size. Haack has shown that *H. meekana* is very close to the specimens grouped by Waagen in his species *Eumetria indica.* They are said to differ in that the latter has perhaps smaller costae, somewhat greater length than width, and a more strongly convex pedicle valve. There is, however, enough variation among the specimens of the present collection to include some such minor differences from the typical form, and it may be that Waagen's species is not even varietally distinct, as regarded by Haack. Haack suggested that the Mexican form be distinguished as var. *mexicana* because of its supposed greater arching of the brachial valve, but from his figures the distinction hardly seems justifiable. The brachial valve is not preserved in my own specimens from Mexico.

Distribution: Hess formation (Glass Mountains) at 4, 17a, 105, 107, T107, 223, and Tv. Leonard formation (Glass Mountains) at 7, 8, 12, 15, T15a, 19, 25, 26, 37, 82, 83, T119, 120, 123, 124, 128, 232, T233, 234, 236, Tb, Tba, D2, D3, D5, D7, D9, D17, D18, and D22. Word formation (Glass Mountains) at 44–46, 46, 51, 54, 55, T141, 144, 148, T148, Tx148, 154, 162, 168, 192, 237, T239, D239, T240a, 241, 243, T243, 245, 246, 247, 248, 253, 265, and Ta. Altuda member (Glass Mountains) at 42, 43, and 50. Bone Canyon member (Delaware Mountains) at

491. Victorio Peak member (Sierra Diablo) at 499. Leonard formation (Baylor Mountains) at 502 and 503. Delaware Mountain formation (Sierra Diablo) at 504. Leonard formation (Shafter) at 515 and 518. Limestone of Cerro Caballo (Las Delicias) at section 1, beds 11, 12, and 14. Limestone of Pichagüa (Las Delicias) at Cerro Pichagüia.

HUSTEDIA MORMONII (Marcou)

Pl. XLII, Fig. 33

1858 *Terebratula Mormonii.* Marcou, Geology of North America, p. 51, pl. 6, figs. 11–11c.

1914 *Hustedia mormonii.* Kozlowski, Brachiopodes du Carb. Super. de Bolivie, Ann. de Pal., vol. 9, pp. 77–78, pl. 1, fig. 2; pl. 9, figs. 1–34; pl. 10, figs. 34–35. (See for best description and figures.)

1915 *Hustedia mormoni.* Girty, Fauna of the Wewoka Formation, U. S. Geol. Sur. Bull. 544, pp. 103–104, pl. 12, figs. 5–6a. (See for synonymy.)

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at 88, T88, and 94. Wolfcamp formation (Glass Mountains) at 75?, 87 low, 87 high, 89, 90, 91, T91, 93, T93, 193, and 196. Lower Gym formation (Hueco Mountains) at 376, 377a, 389, 290, 395, and 401.

HUSTEDIA MORMONII PAPILLATA (Shumard)

Pl. XLII, Figs. 27–32

1858 *Retzia papillata.* Shumard, Trans. Acad. Sci. St. Louis, vol. 1, p. 294 (date of volume, 1860).
Dark (Permian) limestone: Guadalupe Mountains.

1859 *Retzia papillata.* Shumard, *idem.*, p. 395, pl. 11, figs. 9a–c.
Dark (Permian) limestone: Guadalupe Mountains.

1908 *Hustedia papillata.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 397–398, pl. 30, figs. 18–18b.
Basal Capitan, hill southwest of Guadalupe Point (sta. 2906?); dark limestone, Pine Spring (sta. 2930); Delaware Mountain formation, Guadalupe Point (sta. 2967?); Delaware Mountain formation, "Comanche Canyon," Glass Mountains.

Description: Shell small, elongate ovate, valves subequally convex. Beak of the pedicle valve long, not greatly incurved over the small concave cardinal area, which is well defined from the rest of the shell. Apical foramen large and round. Median fold and sinus absent. Plications subangular; 12 to 18 in number on the pedicle valve and from 11 to 17 on the brachial. Surface finely papillose.

Dimensions in mm. of several specimens:

	1 (loc. 54)	2 (loc. 243)	3 (loc. Tx)	4 (Shumard's type)
Length	9.5	9	7	10
Width	7.5	7	5.5	8
Thickness	6	5.5	4	7

Observations: This variety is hardly distinguishable from *H. mormonii.* It seems generally to have the ventral beak less incurved than in that species. It is distinguished from *H. meekana* by being more elongate and more finely plicated. Shumard originally supposed his species to be characterized by its papillose surface, but that feature is, of course, present in any species of the genus. The greater number of plications mentioned in the above description than in the descriptions of Girty and Shumard is due to the counting of the very small plications on the sides.

Distribution: Leonard formation (Glass Mountains) at 124, 128, T226, 233, D3, and D7. Word formation (Glass Mountains) at 6, 46, 54, T140, 143, 144, 238, 239, 243, T251, 264, Tu, and Tx.

HUSTEDIA PUSILLA (Girty)

Pl. XLII, Figs. 20–26

1908 *Pugnax? pusilla.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 319–320, pl. 24, figs. 18–18b.
Basal black limestone, Guadalupe Point (sta. 2967).

Description: Shell small, moderately convex, somewhat longer than wide. Pedicle valve evenly rounded at the front, with nearly straight posterior lateral slopes which meet at the beak at somewhat less than a right angle. Cardinal area well defined, about twice as wide as high, not strongly convex. Apical foramen large and round. Some specimens have a well-marked, broad median deflection of the front margin and even a trace of a median fold in the brachial valve and sinus in the pedicle valve, but in other specimens the margin is straight except for the zigzag of the plications. The shell is folded into fine, subrounded plications, averaging about 16 in number, which originate at the beak.

Within the brachial valve the crura project ventrally, then recurve sharply to join the primary lamellae, which first extend dorsally parallel to the crura, then curve about parallel to the roof of the brachial valve. On each side the jugum arises from the distal side of the primary lamella, curves ventrally around the lamella and extends proximally into a small plate which lies parallel to the plane of the primary lamella; the ventral side of this plate gives rise to a lamella which extends ventrally, and near the middle of the posterior part of the shell joins the lamella of the jugum which arises from the other primary lamella at an acute angle; the united lamellae of the jugum then are produced obliquely toward the apical part of the valve in a sharply pointed spur. The spiralia are coiled at least 6 times. The edges of the spiralia and the posterior process of the jugum are set with fine spines.

Dimensions in mm. of several specimens:

	1 (loc. 46)	2 (loc. T236)	3 (loc. 44–46)	4 (loc. 46)
Length	8	6.5	6	12
Width	6.5	6	6	9.5
Thickness	4	3.5	2.5	—

Observations: This species is distinguished externally by its fine plications and by the occasional presence of a median fold and sinus. Internally the mode of origin of the jugum from the primary lamellae is different from that described in other species of the genus, in which the jugum appears to arise directly from the ventral side of the primary lamella on each side. Otherwise the internal characters are like those of other species of *Hustedia* rather than like *Uncinella*, to which there is considerable external resemblance. The specimens of the present collection are undoubtedly the same species as Girty's *Pugnax? pusilla*. The apical foramen figured in Girty's specimen would hardly be present in a rhynchonellid.

Distribution: Wolfcamp formation (Glass Mountains) at 195a?. Hess formation (Glass Mountains) at T82a and D2. Word formation (Glass Mountains) at 44–46, 46, 51, 53, 54, T236, and 241?. Limestone of Cerro Caballo (Las Delicias) at section 1, bed 14, west of the Noria. Limestone of Pichigüia (Las Delicias) at Cerro Pichagüia.

Family ATHYRIDAE

Genus COMPOSITA Brown

Diagnosis (after Weller): Shells small or medium-sized, subovate, subquadrangular to subpentagonal in outline, biconvex, with the fold and sinus developed in the anterior part of the shell or in some extending backward to the umbonal region; both the fold and sinus may be marked by a rather sharp median sulcus. The surface of the valves smooth or marked only by concentric growth-lines which are not extended into lamellae. Beak of the pedicle valve incurved so as to conceal the delthyrium, but the foramen generally exposed, encroaching upon the umbonal region of the valve. Internally the hinge-teeth are prominent, recurved at the tips, and supported by short but rather stout dental lamellae which are not produced forward about the muscular area; between the dental lamellae is a deep, transversely striated pedicle cavity, and in front of this an ovate muscular area extending about half the length of the valve; the diductor scars are faintly developed, and the adductors occupy a narrow, more sharply defined central area. In the brachial valve the dental sockets are broad and deep, the socket walls are connected by a hinge-plate which is extended posteriorly beyond the margin of the valve into the umbonal cavity of the opposite valve; the lateral margins are thickened and are produced forward into the crura. Spiralia and jugum similar to those of *Athyris*.

Genotype: *Spirifer ambiguus* Sowerby.

Geologic range: Mississippian to Permian.

COMPOSITA EMARGINATA AFFINIS Girty

Pl. XLIII, Fgs. 12–17

1908 *Composita emarginata* var. *affinis*. Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, p. 389, pl. 15, figs. 6–7b.

Middle Capitan, Capitan Peak (sta. 2926); Delaware Mountain formation, southern Delaware Mountains (stas. 2969? and 3500?); Delaware Mountain formation, "Comanche Canyon," Glass Mountains.

Description: Shell large, suboval to subpentagonal, moderately convex, both valves being of about the same depth. The proportion of length to width varies considerably, but all specimens are longer than wide, and relatively more elongate than the average of specimens of *C. subtilita*. Beak of the pedicle valve elevated and incurved, with a round foramen. Near the front of most specimens there is a shallow median depression at the front of the pedicle valve, which is more or less prolonged as a tongue. In the brachial valve the shell is regularly arched transversely, except (in most specimens) at the front, which is slightly more elevated, corresponding to the sinus of the other valve. The fold and sinus are developed only in the anterior part of the shell, and generally only at a much larger size than in *C. subtilita*. Surface smooth except for a few lamellose concentric elevations near the front. Some specimens have a semblance of indistinct radial lirae. Within the pedicle valve there is a deep, longitudinally striated pedicle cavity between the short dental lamellae; in front of it there is an ovate, rather faintly defined area containing the flabellate diductors and the narrow adductor scars. The surrounding pallial region is pitted. In the brachial valve the hinge-plate is large and similar to that of *C. subtilita*.

Dimensions in mm. of several specimens:

	1 (loc. 247)	2 (loc. 247)	3 (loc. 247)	4 (loc. 145)	5 (Girty's specimen)
Length	33	31	31	32	26
Width	29	25	29	25	20
Thickness	17	16	18	19	14

Observations: Were it not for Girty's statement that "this form graduates more or less completely into *Composita emarginata*" I would have no hesitation in recognizing it as distinct. Characteristic forms are quite different from the typical Capitan species, which is characterized by the presence of a median sinus on both valves, which causes the anterior margin to recede. No such character was seen in any of the specimens here examined. Specimens from the Capitan labeled by Girty as *Composita emarginata* seem, however, to agree better with the form here described. *C. emarginata affinis* differs from *C. subtilita* in its lower relative convexity and the development of the fold and sinus only in the anterior part of large shells, at a size much larger than in typical *C. subtilita*. This variety is slightly larger than average specimens of *C. subtilita*. It is rather difficult to distinguish *C. emarginata affinis* from some forms of *C. subtilita*.

Distribution: Middle and upper Word formation (Glass Mountains) at 47, 144, T144, 145, T148, Tx148, 150, 159?, 162, 192, 240?, T240, 243?, 246, 247 (abundant), 248, 257, and 259?. Altuda member (Glass Mountains) at 43, 50?, and 47?. Delaware Mountain formation (Sierra Diablo) at 504. Limestone of Cerro Caballo (Las Delicias) at section 1, beds 12 and 14.

COMPOSITA MEXICANA (Hall)

Pl. XLIII, Figs. 1–11

1857 *Terebratula mexicana*. Hall, Emory's Rept. U. S. and Mexican Boundary Surv., vol. 1, pl. 20, fig. 2. (Carboniferous: Texas?)

1908 *Composita mexicana*. Girty, U. S. Geol. Sur. Prof. Paper 58, pp. 389–390.

Delaware Mountain formation, "Comanche Canyon," Glass Mountains.

1908 *Composita mexicana* var. *guadalupensis*. Girty, *idem*, p. 390, pl. 24, figs. 11–13b.

Basal black limestone, Guadalupe Point (stas. 2920 and 2967).

1909 *Composita mexicana.* Girty, Fauna of the Manzano Group, U. S. Geol. Sur. Bull. 389, p. 68, pl. 8, fig. 1.

Yeso formation, Mesa del Yeso; San Andres formation, San Andres.

Description: Shell small, subpentagonal, widest at about two-fifths the distance from the front margin to the beak; width about equal to the length. Ventral beak large and inflated. Sinus strongly developed toward the front, producing a strong forward and upward deflection of the anterior margin. Brachial valve rather strongly convex, bearing near the front a high, narrow fold, which is accentuated by a strong depression of the shell on each side. Concentric growth lamellae are unevenly distributed over the surface, and may be closely crowded near the front. There is considerable variation in the configuration of this species. The convexity is variable, and the length may exceed the width. The amount of development of the fold and sinus varies greatly, some shells having hardly any at all, and thus being indistinguishable from some small specimens of *C. subtilita,* while others are very strongly emarginate at the front, both the median fold and sinus and the bordering reflexions of the shell forming waves in the margin.

Dimensions in mm. of several specimens:

	1(loc. 436)	2(loc. 397)	3(loc. 223)	4(loc. 439)	5(loc. 451)
Length	11	17	15	13	14
Width	10	15	13	14	14
Thickness	7	11	10	9	7

Observations: It is hardly feasible to attempt to separate from typical *C. mexicana* the form distinguished by Girty as *C. mexicana guadalupensis,* the only distinguishing features of which are the lower fold and shallower sinus, and lower convexity. There is so much variation in the species that a number of varieties might be recognized, but their distinction would hardly be profitable. *C. mexicana* typically is quite different from *C. subtilita,* but intermediate types exist. It is much smaller and has a much more strongly marked fold and sinus.

Distribution: Hess formation (Glass Mountains) at 1, 112, 113, and 223 (abundant). Leonard formation (Glass Mountains) at 123 and 233. Lower Gym formation (Hueco Mountains) at 376, 377b, 379, 389, 381, 390, and Tzzaa. Middle Gym formation Hueco Mountains) at 418, 419, 420, and 424. Upper Gym formation (Hueco Mountains) at 436b, 437b, 438, 439, 440a, 440b, 442, 443, 447, and 449. Gym formation (Diablo Plateau) at 446 and 451. Hess formation (Sierra Diablo) at 462 and Te (abundant). Victorio Peak member (Sierra Diablo) at 499. Leonard? formation (Shafter), thin-bedded zone, at Tj.

COMPOSITA MIRA (Girty)

Pl. X, Fig. 13; Pl. XLIV, Figs. 3-8

1877 *Athyris roissyi.* Meek, U. S. Geol. Expl. 49th Par. Final Rept., vol. 4, pt. 1, p. 82, pl. 9, figs. 3-3b.

Carboniferous limestone: Ruby Group; Wachoe Mountains; Mahogany Peak; Egan Range, Nevada.

1899 *Athyris mira.* Girty, Geology of the Yellowstone National Park, U. S. Geol. Sur. Mon. 32, pt. 2, p. 570.

1926 *Composita mira* Girty, in Ore Deposits of Utah, U. S. Geol. Sur. Prof. Paper 111, pp. 646-647, pl. 56, figs. 16-16a.

Permian: Utah.

Description: Shell medium-sized to large, subcircular, not very strongly convex. Beak of the pedicle valve broad and incurved, with a round apical foramen. Beak of the brachial valve small and obtusely pointed. Near the front of the pedicle valve there is a low, narrow sinus, not greatly extended forward as a tongue. In the brachial valve there is no break in the regularity of the transverse convexity except at the front, where there is a low elevation corresponding to the sinus of the other valve. The surface is marked by strong, irregularly disposed varices of growth, which, because of the small amount of forward extension of the sinus, have the form of regular curves, the forward projection corresponding to the development of the sinus being present only in the anterior part.

Dimensions in mm. of several specimens:

	1(loc. 174)	2(Las Delicias, sec. 1, bed 11)	3(Meck's type)
Length	23	27	42
Width	22	27	43
Thickness	14	—	20

Observations: This species is similar in a general way to *C. subtilita,* but typical forms of the two are quite different. The outline is more rounded, the fold and sinus are less strongly developed, and the ventral sinus is not prolonged as far forward as a tongue, the convexity is lower, and the growth varices are stronger. In addition, the type specimen is much larger than most specimens of *C. subtilita* and has more numerous growth lamellae, but in these respects the Texas and Mexican specimens show little difference from *C. subtilita.* There is a great deal of variation in this species within certain limits. The relative convexity and the strength of the sinus are especially variable, but they all show greater similarity to *C. mira* than to *C. subtilita. C. mira* differs from *C. emarginata affinis* mainly by its rounded rather than elongate outline; indeed it is quite likely that it is a species intermediate between *C. subtilita,* which occurs as high as the Leonard, and *C. emarginata affinis,* which first appears in the middle Word.

Distribution: Leonard formation (Glass Mountains) at 13, 21, 123, 124, 126, 128, 174, Tb, D3, and D17. Word formation (Glass Mountains) at 44-46, 46, 51, 54, 144, T144a, 153, and T233. Upper Wolfcamp formation? (Sierra Diablo) at 460. Hess formation (Sierra Diablo) at Te. Bone Canyon Member (Sierra Diablo) at 484. Leonard formation (Baylor Mountains) at 503. Word formation (Sierra Diablo) at 506. Leonard formation (Shafter) just above brecciated zone, at Td. Limestone of Cerro Caballo (Las Delicias) at section 1, beds 11 and 13-17, and section 2, between El Tordillo and Cerro Caballo on bed 12.

COMPOSITA PERSINUATA (Meek)

Pl. XLIII, Figs. 18–19

1877 *Athyris? persinuata.* Meek, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 1, pp. 81–82, pl. 9, figs. 4–4b.

Light-colored Carboniferous limestone of White Pine Mountains, Nevada.

Description: Shell rhomboid, strongly biconvex, somewhat longer than wide, lateral margins rounded, shell margin deeply sinuous. Pedicle valve strongly convex in the umbonal region, depressed in front into a narrow, rounded median sinus, which is not very deep but projects forward and upward at the front as a long tongue; the sinus originates in the anterior part of the shell. Brachial valve about as deep as the other, elevated at the front in a narrow, high, rounded median fold, which originates a little in front of the middle of the shell and extends forward somewhat at the front margin, where it meets the tongue of the other valve at less than a right angle. Surface marked by concentric imbrications, which are few and not very strongly developed. The specimen from loc. 55 is exceptionally narrow, as shown by the following table giving in mm. the dimensions of several specimens:

	1 (loc. 241)	2 (loc. 155)	3 (loc. 55)	4 (Meek's specimens)
Length	22	22	16	32
Width	20	21	11	39
Thickness	15	15	10	24.5

Observations: *C. persinuata* is distinguished from *C. mira,* which occurs at the same horizons by being smaller, more elongated, more strongly convex, and having a stronger fold and sinus. The main difference from *C. subtilita* is its much narrower fold and sinus. The only difference between the Glass Mountains specimens and the type from Nevada is the much smaller size of the former. The good agreement of the other characters indicates that the size is a feature of lesser importance.

Distribution: Word formation (Glass Mountains) at 55, 155, T239, and T251. The species is not common at any locality.

COMPOSITA SUBTILITA (Hall)

Pl. XLIII, Fig. 20; Pl. XLIV, Figs. 1–2

1852 *Terebratula subtilita.* Hall, Stansbury's Exped. Great Salt Lake, Rept., p. 409, pl. 4, figs. 1–2b.

1909 *Composita subtilita?* Girty, Manzano Group of the Rio Grande Valley, U. S. Geol. Sur. Bull. 389, pp. 68–72.

Yeso formation, Mesa del Yeso; San Andres formation, Fra Cristobal; Abo sandstone, Abo Canyon.

1914 *Seminula argentea.* Kozlowski, Brachiopodes du Carb. Supér. de Bolivie, Ann. de Pal., vol. 9, pp. 79–82, text fig. 20, pl. 11, figs. 1–46. (See for best complete description and figures of this species.)

1915 *Composita subtilita.* Girty, Fauna of the Wewoka Formation, U. S. Geol. Sur. Bull. 544, pp. 96–101, pl. 12, figs. 4-4c; pl. 5, fig. 7; pl. 6, fig. 13. (See for synonymy.)

Observations: This species is common at many localities in the Wolfcamp, Hess, and Leonard formations. In the Gym formation it is represented by small specimens which are associated in places with *C. mexicana* but have the fold and sinus less strongly or even very faintly developed. Since the only difference from *C. mexicana* is the faint development of the sinus, it may perhaps be proper to regard the Gym types as a variety intermediate between typical *C. subtilita* and *C. mexicana,* an idea borne out by the occurrence there of *C. subtilita* only in the lower part of the formation, while *C. mexicana* is most common in the upper part. The upper Hess formation of the Glass Mountains contains an abundance of *C. subtilita* which are entirely similar both externally and internally to average specimens of *C. subtilita.* In the Wolfcamp formation at loc. 456 there are two exceptionally large specimens, which are somewhat deformed.

Distribution: Wolfcamp formation, *U d d e n i t e s* zone (Glass Mountains) at 88, 201, 202, and 203. Wolfcamp formation (Glass Mountains) at 89, 90, 92, 93, and 196. Hess formation (Glass Mountains) at 4, 100?, 104, 106, 107 (abundant), T107, 178?, 207, 208, 211, and 223. Leonard formation (Glass Mountains) at 3, 7, 8, 8–14, T9, 12, 13, 15, 16, 19, 20, 23, 24, 26s,* 31, 35, 37, 38, 82, 83, 119, 120, 232, Tba, D2, D3, and D20. Hess formation (Sierra Diablo) at 469, 474, 479, and Te. Bone Canyon member (Sierra Diablo) at 483. Victorio Peak member (Sierra Diablo) at 494. Leonard formation (Baylor Mountains) at 502. Gym formation (Wylie Mountains) at 507. Gym formation (Carrizo Mountains) at 510. Lower Gym formation (Hueco Mountains) at 389, 395 (abundant), 401, 402, 404, 405, 407, and 409. Leonard formation (Shafter) at 514, above transition beds at Ti, Cieneguita beds at Tg.

COMPOSITA SUBTILITA ANGUSTA King, n. var.

Pl. XLIV, Figs. 9–10

Description: Under this designation are included some shells of variable size but similar configuration. The specimens from the *Uddenites* zone, which were taken as the types, are rather small, but those from loc. 456 are larger, and two of them are very large shells for the genus, but both these latter were crushed and distorted so that their reference to this species is very uncertain. Shell considerably longer than wide, subpentagonal, with the greatest width at about mid-length. Pedicle valve evenly rather strongly convex longitudinally; beak broad and incurved. The transverse profile is regularly convex, or slightly depressed in the median part near the anterior margin which is prolonged forward as a tongue. There can hardly be said to be a true sinus. Brachial valve strongly and evenly convex, elevated at the front to correspond to the tongue of the other valve. The surface is smooth except for low varices of growth near the margins and faint, irregular radial marks which occur on some more or less exfoliated specimens, and therefore probably do not have the nature of surface markings. Of the internal characters only the dental lamellae of the pedicle valve were made out.

Dimensions in mm. of several specimens:

*Identified by Schuchert (Am. Jour. Sci., ser. 5, vol. 14, p. 395, 1927) as *Notothyris schucherti.*

	1 (loc. 199)	2 (loc. 199)	3 (loc. 199)	4 (loc. 456)
Length	17.5	16	13	25
Width	13	13	11.5	19
Thickness	10	—	7	14.5

Observations: The specimens referred to this variety agree in being narrow, rather strongly convex, and with an extended anterior tongue but no true median sinus. These features distinguish it especially from *C. subtilita.* It is quite different from *C. mexicana,* which is much more deeply sinuate and generally smaller in size. Some of the lower Gym specimens referred to *C. subtilita* show a certain general resemblance to *C. subtilita angusta* in the amount of development of the fold and sinus, etc., but are relatively considerably broader, and thus much closer to if not identical with *C. subtilita.*

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at 95, 168, 199 (types), and 201. Wolfcamp formation (Glass Mountains) at T93? and 193. Upper Wolfcamp formation (Sierra Diablo) at 456 (abundant, but generally crushed). Leonard formation (Glass Mountains) at 124?.

Family TEREBRATULIDAE

Genus DIELASMA W. King

Diagnosis: Shell terebratuliform. Pedicle valve with or without a median sinus, and with well developed dental lamellae internally, foramen large and encroaching on the umbonal part of the valve, beak strongly incurved. Brachial valve generally without median fold; internally there may be crural plates which are separate from the dental socket plates, or the crura may be supported on the septal plates; the free part of the brachidium is short with diverging descending lamellae. In the inner posterior part of the valve there is a concave, transverse plate for muscular attachment, which joins the inner surface of the crural plates or the dental socket plates a little above their bases, resting against the inner surface of the valve along the median line for a part or the whole of its length, or free throughout; where attached along the median line a pair of slender cavities, triangular in cross-section, converge from the general cavity of the shell toward the beak, but where, on the other hand, the transverse plate is not attached along its median line, there is a single, broad, low cavity beneath the plate extending toward the apex; the plate extends forward to a greater or less distance beyond the attachment of the crural plates and is pointed, rounded, or emarginate in front, its surface marked by concentric wrinkles parallel with its anterior margin which are generally discontinuous along the median line.

Genotype: *Terebratula elongatus* Schlotheim.

Geologic range: Devonian to Permian.

Observations: Weller's diagnosis of the genus, from which the above has been modified, is too specific to include some of the varieties of internal structures of the group. As there is some question as to the structures in the genotype it is thought best to change the diagnosis enough to admit such species as *D. problematicum wordensis.*

Weller* states that "the crural plates are separated from the socket walls, one of the most essential features of *Dielasma* as here defined." In *P. biplex* the crural plates are undeveloped, the crura being supported on the septal plates. This seems to be true also of *D. bovidens* as figured by Kozlowski, and of *D. breviplicatum* Waagen. Waagen believed that in the last named species there was also a median dorsal septum; if his observation was correct, it is an important difference from most other species of the genus. The mode of junction of the septal plates with the roof of the valve is quite different from that in both *D. breviplicatum* and *D. bovidens,* in which the septal or muscle-bearing plates join one another in the median line but do not meet the roof of the valve.

DIELASMA PROBLEMATICUM WORDENSE

King, n. var.

Pl. XLIV, Fig. 16

1915 *Dielasma* cf. *biplex.* Haack, Permfauna aus Nordmexiko, Zeit. der deutsch geol. Gesell., bd. 66 (1914), p. 502, pl. 39, figs. 12a–b.
Pichagua, near Las Delicias.

Description: Shell medium-sized, longer than wide, subpentagonal, widest at about mid-length. Pedicle valve of low, even longitudinal curvature. The transverse profile in the posterior part of the shell is flattened or somewhat depressed in the middle, then bent dorsally at an acute angle to meet the margin of the other valve without any angulation. At about mid-length the angulations at the sides merge into the lateral margin, the entire transverse profile of the shell is slightly concave, and the two valves meet at an acute angle. At the front the shell curves upward toward the fold of the other valve. There is a low median angulation corresponding to the median sulcus of the fold of the brachial valve. Brachial valve of low longitudinal convexity but strongly bent transversely and much deeper than the pedicle valve. The median part of the valve is a high crest from which the shell falls away steeply on each side. At about mid-length there originate two rounded folds, which increase in size toward the front; between them is a median sulcus.

Dental lamellae of the pedicle valve short and strong. Two long dental sockets originate on each side of the cardinal process; the socket plates diverge from the apex and are attached to the roof of the valve along the cardinal margins. Joined to the proximal sides of the socket plates are septal plates, which descend obliquely toward the median line of the valve, but in the posterior part join before they reach the roof of the valve, while farther forward they become fixed to the roof but gradually diverge from each other so that they no longer meet. On the dorsal faces of the septal plates are the upper parts of the crura, which originate at the cardinal process and extend across the septal plates, projecting from them toward the front. There are no crural plates supporting them; they rest solely on the septal plates. The crura descend nearly straight to about mid-length of the shell, diverging somewhat. The crosspiece is not preserved in the specimen studied.

*Mississippian Brachiopoda, Ill. Geol. Sur. Mon. 1, pp. 256–257.

Dimensions in mm. of one specimen from T144: length, 19; width, 12; thickness, 9.5.

Observations: This variety is remarkable for having the two plications on each side of the fold of the brachial valve. It differs from typical *D. problematicum* (Davidson) in having its greatest width near rather than posterior to mid-length.

Distribution: Word formation (Glass Mountains) at T144 (one specimen). Limestone of Pichagüia (Las Delicias) at Cerro Pichagüia (two specimens).

DIELASMA BOVIDENS (Morton)

Pl. XLIV, Fig. 11

1836 *Terebratula bovidens.* Morton, Am. Jour. Sci., (1), vol. 29, p. 150, pl. 2, fig. 4.

1903 *Dialasma bovidens.* Girty, Carb. Formations and Faunas of Colorado, U. S. Geol. Sur. Prof, Paper 16, pp. 409-411, pl. 7, figs. 11-11a. (See for synonymy.)

1914 *Dielasma bovidens.* Kozlowski, Brachiopodes du Carb. Supér. de Bolivie, Ann. de Pal., vol. 9, pp. 88-90, text fig 24, pl. 9, figs. 61-65. (See for best description.)

Distribution: Wolfcamp formation, *Uddenites* zone (Glass Mountains) at 95, 199, 201, and 203. Wolfcamp formation (Glass Mountains) at 91a. Lower Gym formation (Hueco Mountains) at 395 and 397.

DIELASMA SHAFTERENSE King, n. sp.

Pl. XLIV, Fig. 21

Description: Shell large, spatulate, longer than wide, with the greatest width at about mid-length. In the anterior half of the shell the outline is semicircular; the posterior half has nearly straight sides which converge to the beak at an angle. The longitudinal convexity of the pedicle valve is low and even, being greatest at the beak and decreasing toward the front. Almost at the beak there originates a slight median depression which broadens and deepens toward the front, where it occupies the entire width of the shell, so that the transverse profile is strongly and evenly concave there. Brachial valve almost straight in longitudinal profile but strongly convex transversely, with the median part elevated; beak broad and extending back below the ventral umbo. Surface of both valves smooth; shell finely punctate.

Within the pedicle valve there are strong diverging dental lamellae. In the brachial valve there is a median muscle-bearing plate which is attached along the median posterior part of the shell and joins the inner surfaces of the crural plates a little above their bases.

Length, 29 mm.; width, 24 mm.; thickness, 13 mm.

Observations: This species is distinguished from *D. bovidens* by having the greatest width near mid-length rather than near the front, in having rounded rather than straight lateral margins in the pedicle valve (except in the posterior part), and in being proportionately much broader. It has the median sinus developed much farther from the beak than in *D. spatulatum,* and is relatively much broader than *D. prolongatum* Girty. The closest resemblance is with some Uralian species, such as *D. giganteum* Tschernyschew, which is, however, a much larger shell with a less deep sinus.

Distribution: Leonard formation, Cieneguita beds (Shafter) at Tf (no. 15953).*

DIELASMA SPATULATUM Girty

Pl. XLIV, Figs. 17-20

1859 *Terebratula elongata.* Shumard, Trans. Acad. Sci. St. Louis, vol. 1, p. 392 (date of volume, 1860). (Permian): Guadalupe Mountains.

1908 *Dielasma spatulatum.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 330-331, pl. 16, figs. 3-4c.
Top of Capitan, Capitan Peak (sta. 2966?); Middle Capitan, Capitan Peak (sta. 2926); dark limestone, Pine Spring (sta. 2930), Guadalupe Point (sta. 3762d?); Delaware Mountain formation, southern Delaware Mountains (sta. 2962?).

1908 *Dielasma cordatum.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 331-332, pl. 16, figs. 2-2c.
Middle Capitan, Capitan Peak (sta. 2926).

Description: Shell medium-sized, spatulate, longer than wide, with the greatest width toward the front. Pedicle valve not very convex, strongly bent upward at the lateral margins. Beak large, projecting over that of the other valve. At about mid-length of the shell a slight concavity appears along the median line, which broadens but remains shallow and ill-defined, and does not at any point occupy most of the width of the shell; the sinus causes some upward deflection of the front margin. Brachial valve of very low convexity, with a gentle, even, transverse arching except for a downward deflection of the shell at the lateral margins. Beak small and not incurved. There is a low elevation at the front corresponding to the sinus of the other valve. Surface smooth except for fine concentric growth varices, which are most closely crowded toward the margins. Shell finely punctate. Within the pedicle valve there are strong dental lamellae.

Dimensions in mm. of several specimens:

	1 (loc. 144)	2 (loc. T240)	3 (loc. T240)	4 (type *D. spat.)*	5 (type *D. cor.)*
Length	21	18	16	20	19
Width	17	15	13.5	16.5	14.5
Thickness	10	10	9.5	10	8.5

Observations: Girty stated that in *D. cordatum* the median sinus was narrower than in *D. spatulatum.* The specimens in the present collection are more or less intermediate, and could as well be placed in one or the other of Girty's species. The good agreement of the two in other respects, as well as their occurrence together, makes their identity hardly doubtful. As Girty has noted, *D. spatulatum* is very similar to *D. truncatum* Waagen.

Distribution: Leonard formation (Glass Mountains) at Ax?. Word formation (Glass Mountains) at 46, 144, 148, 171, 239, T239, T240, 243, 255, and Tc. Word formation, yellow limestone (Shafter) at Tp. (no. 16013).*

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*Identified as *Dielasma bovidens* in Geol. Shafter Silver Mines Dist., U. of Texas Bull. 24, p. 14.

*Probably the form identified as *Seminula argentea* Shepard? in the "Geol. of the Shafter Silver Mine Dist." U. of Tex. Bull. 24, p. 23.

DIELASMA? sp.

This includes a heretogeneous group of terebratulids, most of which are almost certainly, and the others probably *Dielasma*. Those from T233 and Taa are broad and of low convexity, those from 241 are large and thick, and those from locs. 8–14, D1, and D3 are narrow and deep.

Distribution: Leonard formation (Glass Mountains) at 8–14, 12, T233, Ax, D1, and D3. Word formation (Glass Mountains) at 241. Victorio Peak member (Brackett Draw) at Taa.

DIELASMA SCHUCHERTI MINOR King, n. var.

Pl. XLIV, Figs. 12–14

Description: Shell small, outline longitudinally subelliptical, tapering toward the beak. Pedicle valve of low, even convexity, beak broad and incurved, pierced by a round foramen. The median anterior part is somewhat prolonged forward and upward as a tongue, and is marked by a low median plication and two lateral ones, which are developed only at the very front. Brachial valve more strongly arched than the other, somewhat elevated near the front and marked by two plications corresponding to the sulci between the plications of the other valve. Surface smooth, shell finely punctate. The internal characters are indeterminable, though in some specimens dental lamellae seem to be distinguishable. Length of a specimen from loc. 239: 8 mm.; width, 6.5 mm.; thickness, 4 mm.

Observations: A comparison of these shells with actual specimens of *Dielasma schucherti** from the Whitehorse sandstone shows that the only difference between them is the smaller size of the Word specimens, average specimens of the latter being only about half as large as those from Oklahoma.

D. schucherti and its variety are very similar to *D. problematicum wordense*, but are relatively much broader and of lower convexity. In general outline they resemble *Notothyris schucherti* Girty, of the Delaware Mountain and Capitan, but have a distinct fold and sinus as in typical *Dielasma*, and have one less plication in the anterior part of the shell than does Girty's species. The generic reference of *Notothyris schucherti* is very doubtful. The genus *Notothyris* is based on internal characters, which were not determined by Girty for his species. Moreover, the external resemblance of *N. schucherti* to *Dielasmina guadalupensis* is so great that it hardly appears to be more than a variety of that species.

Beede's species is very close to *Dielasma biplex* Waagen, but is easily distinguishable by minor differences in configuration. *Dielasma schucherti minor* is still further distinguished from Waagens' species by its much smaller size.

Distribution: Middle Word formation (Glass Mountains) at 144, 239 (abundant), and D239.

Genus DIELASMINA Waagen

Diagnosis: Similar to *Dielasma*, but instead of having a well marked fold and sinus, folded into a series of subequal plications limited to the marginal part of the shell, without any distinct fold or sinus.

Genotype: *Dielasmina plicata* Waagen.

Geologic range: Permian.

*Beede, J. W.: Invertebrate Paleontology of the Upper Permian Red Beds of Oklahoma and the Panhandle of Texas, Kans. Univ. Science Bull., vol. 4, 1907, pp. 148–150.

DIELASMINA GUADALUPENSIS Girty

Pl. XLIV, Fig. 15

1908 *Dielasmina guadalupensis.* Girty, The Guadalupian Fauna, U. S. Geol. Sur. Prof. Paper 58, pp. 333–334, pl. 16, figs. 6–7a; pl. 21, figs. 22–22a.
Capitan formation, Capitan Peak (sta. 2926); dark limestone, Pine Spring (sta. 2930).

1915 *Dielasmina Guadalupensis.* Haack, Permfauna aus Nordmexiko, Zeit. der deutsch. geol. Gesell. bd. 66 (1914), p. 501, pl. 39, figs. 11a–c.
Pichagua, near Las Delicias.

Description: Shell small, inflated, longer than wide, with the greatest width at mid-length. Pedicle valve strongly and evenly convex longitudinally, with a small incurved beak. The transverse profile is evenly of low convexity except for two narrow, rounded plications which originate at about mid-length, and two indistinct marginal folds. Brachial valve of low, even convexity, in the anterior part folded into 3 strong, rounded plications. Surface smooth. Within the pedicle valve are two strong, short dental lamellae. Dimensions in mm. of the only specimen: length, 13; width, 10; thickness, 8.

Observations: The specimen in the present collection is unlike Girty's type in being smaller and having the plications well developed at a size when the other is smooth or only faintly plicated. The differences do not, however, appear to justify a distinct name. The differences between *D. guadalupensis* and *D. perinflata* (Shumard) are so small that it hardly seems proper to regard them as distinct. If not, the latter name would be used, as it is the older. *D. guadalupensis* and *D. perinflata* are less strongly plicated than most Eurasian species of the genus.

Distribution: Upper Hess formation (Glass Mountains) at 223.

INDEX TO LOCALITIES*

1 Hess: Small hill 1 mile northwest of the summit of Iron Mountain.
2 Wolfcamp, upper: Section 14, shale, west of Iron Mountain.
3 Leonard: 1 mile west of the summit of Iron Mountain, about 50 feet above the base.
4 Hess?: .6 mile north of hill 5021, Altuda Quadrangle.
5 Leonard: Section 14, below soft shale of the Clay slide, about 250 feet below the top. Same as 301?
6 Word, lower: near Clay slide, section 14.
7 Leonard: Section 14, bed 16.
8 Hess: Section 14 (contains some lower Leonard fossils also).
9 Leonard: Section 14, below middle limestone layer of bed 9.
10 Leonard: Section 14, middle limestone layer of bed 9.
11 Leonard: Section 14, between middle limestone layer of bed 9, and top of bed 12.
12 Leonard: Section 14, top of bed 12.
13 Leonard: Section 14, base of bed 14.
14 Leonard: Section 14, lower part of bed 15.

*References to bed and section numbers in the Glass Mountains are to stratigraphic sections described in Part One of this memoir. Collections from these localities were made by R. E. King and P. B. King.

15 Leonard: Section 15.
16 Leonard: Section 15, slightly above the base, or near the base.
17 Hess: Projecting spur of range just west of the Marathon-Sullivan Ranch road; the lower part, 17a, the middle 17b, the upper 17c.
18 Hess: Section 12.
19 Leonard: Basal, section 12, bed 1.
20 Leonard: Section 12, bed 1.
21 Leonard: Section 12, near middle of bed 24.
22 Leonard: Section 12, middle of bed 24.
23 Leonard: Section 12, near middle of bed 24, below hill 4920, and north of locality 21.
24 Leonard: Section 12, some distance above middle of bed 24, but below top of hill 4920.
25 Leonard: Section 12, upper part of bed 24, southwest side of hill 4920.
26 Leonard: Section 12, bed 26, southwest side of hill 4920.
27 Leonard: Section 12, beds 19 to 24, southwest side of hill 4920.
28 Leonard: Section 12, middle of bed 24, southwest side of hill 4920.
30 Leonard: Section 12, bed 28, south of Sullivan Peak.
31 Leonard: Section 12, bed 34, south of Sullivan Peak.
31a Leonard: Section 12, bed 36, south of Sullivan Peak.
32 Word, lower: South of Cathedral Mountain.
34 Leonard: .5 mile south of tank at locality 4555.
35 Hess: .5 mile east-northeast of hill 4902, southern Altuda quadrangle, at base of escarpment.
36 Leonard: Section 11, bed 4, on hill 5300.
37 Leonard: Section 15, bed 10, tank west of north end of Iron Mountain.
38 Leonard: Basal, .25 mile east of hill 5300.
39 Hess: Section 10, top of bed 1.
40 Leonard, upper: Southeast of James Ranch.
41 Capitan, Altuda member: East side of Altuda Mountain.
42 Capitan, Altuda member: Valley northeast of Altuda.
43 Capitan, Altuda member: Top of Cathedral Mountain, east end.
44 Word, lower limestone: Section 12, south of Sullivan Peak.
45 Word, lower limestone: Section 12, .40 mile southwest of 44.
46 Word, lower limestone: Section 12, .25 mile south of 44 and .2 mile east of 45.
47 Word, middle: West side of Gilliland Canyon, below hill 5939.
48 Word, middle limestone: .5 mile northeast of locality 4869, north-northwest of Iron Mountain.
49 Capitan: .5 mile north-northwest of point 6311, north of Cathedral Mountain.
50 Capitan: Altuda member, northeast part of Del Norte range south of James Ranch.
51 Word: Lower limestone, northeast of Clay slide.
52 Leonard: Section 12, bed 37, lower part; calcareous sandstone, bearing ammonoids, south of Sullivan Peak.
53 Word: Lower, section 11, beds 1 and 2, 1.5 mile southwest of Sullivan Peak.
54 Word: Lower, section 11, bed 3, 1.5 mile southwest of Sullivan Peak.
55 Word: Lower, 1.1 mile south-southwest of hill 5935, at about the same horizon as locality 54.
56 Capitan: .4 mile north-northwest of hill 5935, west end of Cathedral Mountain.
57 Capitan: Altuda member, 1.5 mile northeast of Altuda.
58 Word: Lower, south side of Cathedral Mountain.
59 Word: Upper, section 10, beds 8 and 9.
60 Gilliam: .7 mile east of hill 4870 south of Gilliland Canyon.
61 Capitan: Altuda member, .25 mile east of hill 5672, at southwest end of Glass Mountains.
62 Word: Upper, from loose blocks lying on down-slumped Vidrio 7 miles southeast of Altuda.
63 Word: Upper, east slope of Sullivan Peak.
69 Wolfcamp: Lower shale, just to north of igneous plug, Hess Ranch horst.
70 Wolfcamp: Base of range about 1 mile west of Sullivan Ranch-Marathon road.
71 Wolfcamp: At base of escarpment between Sullivan Ranch-Marathon road and a point .5 mile to west.
72 Wolfcamp: At base of escarpment about .3 mile west of Sullivan Ranch-Marathon road.
73 Wolfcamp: Hill just west of Sullivan Ranch-Marathon road.
74 Wolfcamp: Between hill west of Iron Mountain and the Sullivan Ranch-Marathon road.
75 Wolfcamp: .75 mile west-northwest of the summit of Iron Mountain.
76 Wolfcamp: Upper, westernmost outcrop of Wolfcamp on Leonard Mountain; bed containing large *Schwagerina.*
77 Wolfcamp: Upper, lowest beds above basal conglomerate, about .2 mile east of locality 76.
78 Leonard: Float on south side of Leonard Mountain.
79 Wolfcamp: Northwest of the summit of Iron Mountain, .2 mile south of locality 1.
82 Wolfcamp or Leonard: Float on middle of south side of Leonard Mountain.
83 Leonard: Float at east base of Leonard Mountain.
84 Wolfcamp: *Uddenites* zone on northeast side of Leonard Mountain, near small igneous intrusion.
85 Wolfcamp: South middle part of Hess Ranch horst, west end.
86 Wolfcamp: South side of Hess Ranch horst, west end.
87 Wolfcamp: One mile west by north of Wolfcamp, Section 23, bed 12 of Wolfcamp section and above. Differentiated into two parts, low and high, the lower part being approximately equivalent to bed 13 and the upper to the higher beds of the section at Wolf Camp.
88 Wolfcamp: Section 24, *Uddenites* member, bed 1b at Wolf Camp.
89 Wolfcamp: Section 24, bed 4, at Wolf Camp; containing a few brachiopods.
90 Wolfcamp: Section 24, bed 8, at Wolf Camp; not very fossiliferous.
91 Wolfcamp: Section 24, bed 12, at Wolf Camp.
91x Wolfcamp, Hess, or Leonard: Loose pieces picked up on bed 12, section 24, the fossils of which indicate a Hess or Leonard age.
92 Wolfcamp: Section 24, bed 14, at Wolf Camp.
93 Wolfcamp: Section 24, bed 9, and float from the next few higher beds on the side of the arroyo northeast of Wolf Camp.
94 Wolfcamp: *Uddenites* bed, about .5 mile west of locality 95, below hill 4815, and northeast of Wolf Camp.
95 Wolfcamp: Section 27, bed 13, at hill 4752; *Uddenites* bed.
96 Wolfcamp: Lowest beds near Gap Tank, about .25 mile east of the edge of the Hess Canyon quadrangle.
91 Wolfcamp: Basal beds about .25 mile southeast of Gap Tank.
98 Hess: West end of Glass Mountains in Monument Spring quadrangle, about 20 feet above the Wolfcamp.
99 Hess: East end of Dugout Mountain, along the down-faulted spur.
100 Hess: West end of Dugout Mountain.
101 Hess: Upper, top of Leonard Mountain, in the line of section 17.
102 Hess: Near top of formation, section 17.
103 Hess or Leonard: Float on Wolfcamp at foot of escarpment about 1 mile west of the Marathon-Sullivan Ranch road.

104 Leonard: Northeast of Hess Ranch, on north side of the escarpment, 1.2 mile west of hill 5725.
105 Hess: .5 mile northeast of hill 5305 on west end of the Hess Ranch horst.
106 Hess: On hill 5305 from beds lower than those from which collection was made at locality 105.
107 Hess: Upper, on escarpment west of Hess Canyon fault, from upper fossiliferous horizon, immediately below a conspicuous layer of massive limestone; *Perrinites compressus* horizon.
108 Hess: Upper, same horizon as 107, between and south of hills 5767 and 5821.
109 Hess: Upper, float from the beds above the upper fossiliferous horizon, collected upon the fossiliferous bed.
110 Hess: Lower, bed 5, section 23, escarpment northwest of Wolf Camp.
111 Hess: Uppermost, south of the road and a short distance west of the Word Ranch.
112 Hess: Upper, about .5 mile south of the forks of Hess Canyon, 1.25 miles southwest of Word Ranch.
113 Hess: Middle, section 27, bed 6, on hill 4752, near top of layer of nodular limestone.
114 Hess: Middle, about 1 mile southeast of hill 5233, eastern Hess Canyon quadrangle.
115 Hess: Middle, .5 mile northwest of hill 4762 on escarpment, eastern Hess Canyon quadrangle.
117 Hess: Upper, between hills 5233 and 5035, on the east side of the long valley, eastern Hess Canyon quadrangle.
118 Hess: Upper, .5 mile northeast of hill 5233, at elevation 5000, eastern Hess Canyon quadrangle.
119 Leonard: Upper, below and to west of Clay Slide.
120 Leonard: Middle, .6 mile east of hill 4910, east of Clay Slide; lower *Perrinites* horizon.
121 Leonard: Middle, section 17, north of Leonard Mountain, bed 13 near top.
122 Hess or Leonard: Limestones below lower Leonard shale on Leonard Mountain, section 17.
123 Leonard: Section 17, bed 14; richly fossiliferous horizon near middle of Leonard formation.
124 Leonard: Lower, hill south of forks of Hess Canyon, south of road to Word Ranch.
125 Leonard: Upper, about .5 mile south of hill 5611, south of Hess Canyon.
126 Leonard: Above conglomerate bed near the Word Ranch house.
127 Leonard: Directly above conglomerate bed southwest of Split Tank, 1.5 mile northeast of Word Ranch house.
128 Leonard: .2 to .3 mile northeast of Split Tank, 1.5 mile northeast of Word Ranch house; also from the same horizon about a mile east-northeast of Split Tank; the Tank is on the line of section 26.
129 Leonard: Upper, north of hill 4627, northeast corner of Hess Canyon quadrangle.
130 Word: Middle, Del Norte Mountains, near the "I" in "Mountains" as represented on the topographic sheet, Monument Spring quadrangle; yellow limestone between lower and middle limestones.
131 Word: Lower limestone, south side of Altuda Mountain.
132 Word: First limestone, section 17, bed 1.
133 Word: First limestone, section 17, upper part of bed 1.
134 Word: Lower, section 17, bed 3.
135 Word: Third limestone, section 17, bed 7c, mountain north of Leonard Mountain.
136 Word: Third limestone, Section 17, bed 7f, mountain north of Leonard Mountain.
137 Word: Third limestone, Section 17, mountain north of Leonard Mountain.
138 Word: Third limestone, Section 17, top of hill south of junction of Road and Gilliland Canyons.
139 Word: Float at junction of Road and Gilliland canyons.
140 Word: First limestone, .5 mile south of hill 5874, west side of Gilliland Canyon.
141 Word: Lower limestone, above Clay slide, section 14; same locality as number 6.
142 Word: Fourth limestone, about .5 mile northeast of Willis Ranch.
143 Word: Fourth limestone, east and west of hill 5578, Hess Canyon.
144 Word: Second limestone, .5 mile north of hill 5611, Hess Canyon.
145 Word: Second limestone, 1.5 mile northwest of Word Ranch house, .5 mile west of hill 5507, Hess Canyon.
146 Word: Third limestone, south and west of south part of Comanche outlier north of Word Ranch house.
147 Word: First limestone, in channel of Hess Canyon near Leonard-Word contact.
148 Word: Fourth limestone, northeast of Word Ranch house.
149 Word: Fourth limestone, northeast of Word Ranch and east of 148.
150 Word: Fourth limestone, east of Comanche outlier north of Word Ranch house; collections extend for about a mile along the strike.
151 Leonard: Near Split Tank, collected by McGonagill family, same as 128.
152 Word: Upper, several miles east-northeast of Word Ranch house.
153 Word: First limestone, south side of hill 5611, west side of Hess Canyon, section 23.
154 Word: Upper, east from hill 5360 to big fault 5 miles northeast of Word Ranch.
155 Word: Upper, east of big fault 5 miles northeast of Word Ranch, as far as hill 4902; mainly collected from west side of latter hill. Large flat gastropods present at this locality could not be collected.
156 Word: Upper, across valley from hill 5461; Hess Canyon quadrangle.
157 Word: Upper, large *Fusulina* from east side of big fault.
158 Word: Upper, chert on hill 4732, Hess Canyon quadrangle.
159 Word: Upper, chert east of hill 4800, northeast part of Hess Canyon quadrangle.
160 Delaware Mountain formation: West of Guadalupe Point in hills just to north of highway from Van Horn to Carlsbad.
161 Capitan: Altuda member, south side of Altuda Mountain.
162 Word: Upper, cherty limestone east of Comanchean outcrop north of Word Ranch, approximately the same as 150.
163 Capitan: Middle of Altuda member, bed 5, section 16, at south end of Old Blue Mountain.
164 Capitan: Gilliam member; lower 300 feet in Gilliland Canyon just north of Igneous plug.
165 Capitan: Gilliam member; upper part 1 mile east-southeast of B. M. 3948, and .75 mile northwest of hill 4870.
168 Wolfcamp: Section 24, Gray Limestone member at Wolf Camp.
169 Wolfcamp: About 250 yards south of locality 84, the ammonoid locality on the east side of Leonard Mountain.
169a Wolfcamp: Just above Gray Limestone member, section 24, Wolf Camp.
170 Word: Upper, thick prominent limestone 700 feet below top north of Dugout Mountain.
171 Word: Lower limestone, northwest of Dugout Mountain.
173 Word: Lower limestone, capping hill between B. M. 4873 and 4869, in Gilliland Canyon.
174 Leonard: Section 27, .25 mile east of hill 5157, in arroyo.
175 Wolfcamp: Below Gray Limestone member, northeast of locality 88.

175a Wolfcamp: Yellow-brown limestone in shale underlying Gray Limestone member northeast of locality 88.
176 Word: Middle, west side of Gilliland Canyon, west of Road Canyon.
179 Capitan: Gilliam member, 2.1 miles east of Easterwood Ranch, on top of ridge.
180 Word: Float in northern Hess Canyon.
181 Wolfcamp: Range east of Wolf Camp hills, and southeast of hill 4815.
182 Wolfcamp: Wolf Camp section, section 24, shale of bed 5.
183 Leonard: Section south of Altuda Mountain, section 5, bed 8.
184 Capitan: Gilliam member?; south of old Beatty Place, from a thick bed crowded with *Fusulina.*
185 Capitan: Gilliam member; .75 mile north of head of Spring Canyon.
186 Capitan: Altuda member; northern Altuda Mountain, 1.5 mile north of locality 41.
190 Wolfcamp: Northeast of Gap Tank, from shale containing *Schwagerina,* directly below Hess conglomerate.
191 Hess: Northeast of hill 4402, Van Horn quadrangle.
192 Word: Fourth limestone; north of junction of Road and Gilliland Canyons, section 17.
193 Wolfcamp: Upper, south of high point on Dugout Mountain.
194 Wolfcamp: Upper, perhaps including some basal Hess, from float on south side of high point of Dugout Mountain.
195 Wolfcamp: Lower shale; .5 mile southwest of hill 5816, Hess Ranch horst.
196 Wolfcamp: Upper; .5 mile northeast of hill 5305, Hess Ranch horst.
198 Wolfcamp: Upper fossiliferous bed in the graben near the middle of the Hess Ranch horst, and the same bed to the west of the graben.
199 Wolfcamp: *Uddenites* member; .35 mile northeast of hill 5060, east of Wolf Camp; basal brown limestone about 15 feet above Gaptank limestone.
200 Wolfcamp: Gray Limestone member, lower part, .35 mile southwest of hill 4952, northeast of Wolf Camp.
201 Wolfcamp: Brown limestone near base of hill, .3 mile southwest of hill 4815, 4 miles northeast of Wolf Camp.
202 Wolfcamp: Directly below base of Hess, .8 mile west of east end of Hess Canyon quadrangle.
203 Wolfcamp: Beds below Gray Limestone member, on range of foothills at east edge of Hess Canyon sheet, within the quadrangle.
204 Wolfcamp: .5 mile south of Allison and Gilbert ranch.
205 Hess: At foot of cliff of Dugout Mountain, 1 mile southeast of summit.
206 Hess: Uppermost, 1 mile northeast of Lenox.
207 Hess: Upper, west side of fault on spur north of high point of Leonard Mountain.
208 Hess: .5 mile north of Hess Ranch, at west end of limestone ridge.
209 Hess: 150-200 feet below top, northeast end of Leonard Mountain, directly below Leonard outlier on east side of fault, below and south of locality 207.
210 Hess: White limestone at top of section on Hess Ranch horst, north of the northeast end of igneous intrusion.
211 Hess: .75 mile north-northeast of hill 5305, on Hess Ranch horst.
212 Hess: Upper fossiliferous horizon, the same as that of localities 107 and 108, .6 mile west-southwest of hill 5725, northwest of Wolf Camp.
213 Hess: Middle part, from dolomite layer about halfway up scarp south of hill 5725, 3.5 miles east-northeast of Hess Ranch.
214 Hess: Section 26, on Meeks Ranch, southeast of hill 5567 on face of escarpment, beds 11, 12, and 13.
215 Hess: Upper fossiliferous horizon, .5 mile east-southeast of hill 5652, at top of section 27.
216 Hess: Middle part, 4.25 miles east-northeast of Gap Tank.
217 Hess: Middle part, about 4 miles west of east edge of Hess Canyon quadrangle; layer containing *Fusulina.*
218 Hess: Middle part, 1.5 mile east-northeast by east of Allison and Gilbert Ranch, along old washed-out road.
219 Hess: Basal layers at easternmost outcrops 3.5 miles east of Allison and Gilbert ranch, from layers of sandstone.
220 Hess: Upper part on cuesta capped by Hess limestone west of the fault bounding the west side of Dugout Mountain.
221 Leonard: Bone Canyon member, near contact with Delaware Mountain formation near Bone Spring, Guadalupe Mountains.
222 Hess: Upper fossil horizon, same as that of localities 107, 108, and 212, on scarp east of head of east fork of Hess Canyon about .25 mile below and southeast of hill 5767.
223 Hess: Uppermost, 1.1 mile southwest of Word Ranch house.
224 Leonard: First limestone member, or slightly below, at west end of Dugout Mountain.
225 Leonard: Just below base of Word at old Payne Ranch, from highest limestone layer of the Leonard.
226 Leonard: First Limestone member, in central part of Dugout Mountain.
227 Leonard: Second Limestone member on Dugout Mountain.
228 Leonard: Horizon of First Limestone, east of fault at east end of Dugout Mountain.
229 Leonard: Lower 200 feet, west end of range north of Lenox.
230 Leonard: First Limestone member, at top, 2 miles northeast of Lenox.
231 Leonard or Uppermost Hess: Limestone containing chert pebbles directly below Leonard shale on south face of Leonard Mountain; same as locality 122.
232 Leonard: Lower limestone on top of Leonard Mountain, above first bed of siliceous shale.
233 Leonard: Basal, on spur north of high point of Leonard Mountain, on east side of fault at east end of the Mountain.
234 Leonard: .6 mile west-northwest of hill 5726, south of Hess Ranch horst.
235 Leonard: Upper part, 1 mile west of Word Ranch house, section 24.
236 Leonard: Uppermost, .3 mile southeast of hill 5674, north of Leonard Mountain.
237 Word: Lower limestone near latitude 30°10′, Del Norte Mountains.
238 Word: Middle limestone, .5 mile south of south side of big basin in northern Del Norte Mountains.
239 Word: Third Limestone member, on south side of Road Canyon, west of divide separating the drainage of Gilliland and Hess canyons.
240 Word: Third Limestone member, capping mountain north of Leonard Mountain along the line of section 18, southeast of hill 5453.
241 Word: First limestone member on mountain north of Leonard Mountain, southeast of hill 5453.
242 Word: Third Limestone member, from bed below uppermost white limestone at east end of range north of Leonard Mountain, on the north slope of hill 5453.
243 Word: Third Limestone member, .5 mile southeast of hill 5803, north side of Road Canyon.
244 Word: Fourth Limestone member, north of Willis Ranch.

245 Leonard: Downfaulted block south of Hess Ranch horst, .6 mile west-northwest of hill 5726, from bituminous limestone; same as 234?
246 Word: Fourth Limestone member, north side of Hess Canyon, east of hill 5543.
247 Word: Fourth Limestone member, east side of Hess Canyon, near its angle.
248 Word: Fourth Limestone member, on east side of Hess Canyon, near northernmost outcrop of the formation.
249 Word: Basal dolomite, 1 mile west of Word Ranch.
250 Word: Second Limestone member, section 23, east of Hess Ranch horst; same as 264.
251 Word: First Limestone member, .8 mile west of Word Ranch on section 24.
252 Word: Fourth Limestone member, on line of section 24 west of Comanche outlier north of Word Ranch.
253 Word: Upper part of Fourth Limestone, north of Word Ranch, east and west of Comanche outlier for a short distance.
254 Word: Upper part of Fourth Limestone, 1 mile northeast of Comanche outlier north of Word Ranch.
256 Word or Leonard: Lower part of hill lying in the middle of a broad valley in the northeasternmost corner of the Hess Canyon quadrangle.
257 Word: Middle and upper beds on hill in middle of broad valley in the northeasternmost corner of Hess Canyon quadrangle.
258 Hess: Near summit of Sierra Madera.
259 Word: .35 mile southeast of hill 4108, north-central part of Sierra Madera.
260 Word: .6 mile west of hill 4054, east-central Sierra Madera.
261 Word: .5 mile west-northwest of point 3663, northeast of Sierra Madera; from float.
262 Word: .3 mile south of hill 4600, the high point of Sierra Madera.
263 Word: About .5 mile northeast of point 4588, Sierra Madera.
264 Word: Second Limestone member east of Hess Ranch horst, west side of Hess Canyon, same as 250.
265 Word: .8 mile northwest of hill 5079, northwestern Hess Canyon quadrangle, float lying on the surface of the upper Vidrio.
266 Capitan: Tessey member, .75 mile north of point where many pelecypods were collected (locality 267) north of Hess Canyon quadrangle.
267 Capitan: Tessey member, 5.1 miles west of west side Sierra Madera quadrangle, and 1.8 mile north of north side of Hess Canyon quadrangle, about .07 mile east of north end of a Comanche mesa lying on the east side of the road to Sanderson Cabin. From a bed a foot thick, containing a great abundance of *Pleurophorus*, above a layer of anhydrite which outcrops .5 mile to the east on the west side of a fault.
268 Bissett: Section 24, bed 5, near highest exposures of formation 3 miles north of Warren Ranch, on west side of Hess Canyon.
269 Word: Float .5 mile east of Skinner's gate on the Marathon-Fort Stockton highway.
270 Leonard: Northeast of summit of Dugout Mountain, on Hess cuesta.
301 Leonard: Mid-part of Clay Slide, same as locality 6.
303 Delaware Mountain formation: Limestone in lower part of formation, below Bone Spring, Guadalupe Mountains.
376 Lowest Gym above Canyon-Cisco limestone 3.3 miles west of Helms Peak.
377a Lower Gym: Section west of Powwow Canyon, bed 1.
377b Lower Gym: Section west of Powwow Canyon, bed 2.
378 Lower Gym: Sand-mantled hills 6 miles west-northwest of Helms' West Well.
379 Lower Gym: Basal beds on hill 5 miles N 80° W of the summit of Helms Peak (north of Carlsbad road).
380 Uppermost lower Gym: 5.5 miles west-southwest of Hueco Tanks.
381 Lower Gym: Section west-southwest of Hueco Canyon, bed 1.
382 Lower Gym: Section west-southwest of Hueco Canyon, bed 2.
383 Lower Gym: South of Hueco Tanks road on northwest side of the Hueco anticline, on the east side of the hills.
384 Lower Gym: East end of hills north of Hueco Tanks road, west of Hueco Tanks.
385 Lower Gym: Slopes of Juan Peak.
386 Lower Gym: Section on Juan Peak, bed 9.
387 Lower Gym: Marl underlying the bed capping Juan Peak.
388 Lower Gym: Beds capping Juan Peak.
389 Lower Gym: Ridge east of Juan Peak, from beds stratigraphically above that capping Juan Peak.
390 Upper part of lower Gym: Southern part of Lefthand Canyon.
391 Lower Gym: 1.3 miles north 10° east of hill 5345, south of Hueco Tanks road.
392 Lower Gym: Section just south of the entrance to Hueco Canyon, bed 2.
393 Lower Gym: Limestone inlier in igneous sill .7 mile notrh of hill 5345 El Paso quadrangle, due east of Hueco Tanks.
394 Lower Gym: .8 mile north of hill 5345, south of the Hueco Tanks road, collected directly above the igneous sheet.
395 Lowest Gym: West of hill 5345, El Paso quadrangle south of Hueco Tanks road.
396 Lower Gym: South end of hill 5345, section southeast of Hueco Tanks, bed 1.
397 Lower Gym: Section southeast of Hueco Tanks, bed 2.
398 Lower Gym: Section southeast of Hueco Tanks, bed 5.
399 Lower Gym: Section southeast of Hueco Tanks, bed 8.
400 Basal lower Gym: Southwest corner of Neville Mountain.
401 Lower Gym: 1.2 mile south-southwest of hill 5345, El Paso quadrangle.
402 Lower Gym: Top of hill 1.9 mile south of hill 5345.
403 Lower Gym: 2 miles south-southwest of hill 5345, El Paso quadrangle.
404 Lower Gym: Second range of hills north of Powwow Canyon, 3 miles south of hill 5345, El Paso quadrangle.
405 Basal lower Gym: .8 mile west of point halfway between "O" and "U" of "Mountains," El Paso quadrangle.
406 Lower Gym: North side of Powwow Canyon.
407 Lowest Gym: East wall of upper Powwow Canyon.
408 Lower Gym: 3.8 miles northwest of hill 5436, Cerro Alto quadrangle.
409 Lower Gym: .5 mile northeast of hill 5426, Cerro Alto quadrangle, north of place where section was measured.
410 Lowest Gym: Coyote Tanks, southeast end of Hueco Mountains.
411 Lowest Gym: Outlier on Strawn .4 mile east of west end of Cerro Alto and 1.7 mile south of 31°50′ lat. line.
412 Lower Gym: 2.2 miles south-southeast of b. m. 4523, southwestern Cerro Alto quadrangle.
413 Lower Gym: Summit 4659, south of Padre Mine Canyon.
414 Middle Gym: Summit of highest hill in mountains west of Hueco Tanks, 6 miles west-southwest of Hueco Tanks.
415 Middle Gym: 3.4 miles west and a little south of Hueco Tanks.
416 Middle Gym: Section west-southwest of Hueco Canyon, bed 12.
417 Middle Gym: Lower middle part, 2.2 miles northwest of the summit of Cerro Alto.

418 Lower middle Gym: Above sill, metamorphosed limestone 2 miles south-southwest of southeast corner of Cerro Alto.
419 Middle Gym: Limestone in marly beds above metamorphosed limestone 2 miles southwest of the southwest corner of Cerro Alto.
420 Middle Gym: Southwest foot of Cerro Alto.
421 Middle Gym: Northwest Cerro Alto quadrangle.
422 Middle Gym: 1.4 mile south of summit of Cerro Alto, below *Pugnoides* horizon.
423 Middle Gym: 2 miles south of summit of Cerro Alto, not far below the Upper Gym.
424 Middle Gym: 2.6 miles south 5° east of summit of Cerro Alto, about 75 feet below the Upper Gym.
425 Middle Gym: 2 miles northwest of hill 5700 near west border of Cerro Alto quadrangle, from black limestone near the same horizon as beds just above the sill to the east.
426 Middle Gym: 2 miles north of hill 5700, near west border of Cerro Alto quadrangle.
427 Middle Gym: Just above sill on line of section south of Cerro Alto in basin.
428 Middle Gym?: Southwest of Neville Mountain; possibly in part from Upper Gym.
429 Middle Gym: 1.2 mile east of east summit of Neville Mountain, northwestern Cerro Alto quadrangle.
430 Middle Gym: North of Powwow Canyon near line of section.
431 Middle Gym: Section north of Powwow Canyon, bed 1 of Middle Gym.
432 Middle Gym: Section north of Powwow Canyon, bed 6, directly below Upper Gym.
433 Middle Gym: 1.4 mile west-southwest of b. m. 5149, southwest central Cerro Alto quadrangle.
434 Lower part of Middle Gym: 1.9 mile southwest of b. m. 5149, northwest center of Cerro Alto quadrangle.
435 Upper Gym: 3 miles north of entrance to Hueco Canyon.
436a Upper Gym: Highest beds on section on south side of Hueco Canyon, easternmost Hueco Canyon exposure near Lincoln Tank.
436b Lower Upper Gym: West of Daily Mountain (on east side of road to Bassett Ranch), 1.6 mile west of the summit.
437a Lower upper Gym—about 1.5 miles south of summit of Cerro Alto.
437b Basal upper Gym: South side of Daily Mountain.
438 Upper Gym: 2 miles south of the summit of Cerro Alto, above the red beds.
439 Upper Gym: 1.7 mile south of summit of Cerro Alto.
440a Upper Gym: Summit of Deer Mountain, northwestern Cerro Alto quadrangle .
440b Upper Gym: Limestone capping hill 5700, northwestern Cerro Alto quadrangle.
441 Lower Upper Gym: Below red beds south of Deer Mountain.
442 Gym: 2 miles north-northwest of Dagger Tank, Cerro Alto quadrangle.
443 Lower upper Gym?: 2 miles east of b. m. 4984, 2 miles northeast of summit of Rancheria Mountain.
444 Lower upper Gym?: 2 miles due east of b. m. 4984, 2 miles northeast of summit of Rancheria Mountain, from a level 40 feet above that of 443.
445 Gym: 1.8 mile north of Big Tank (west end of Buckhorn Draw), Cerro Alto quadrangle.
446 Gym: 1.5 mile north of central part of Buckhorn Draw, Cerro Alto quadrangle.
447 Gym: 2.6 miles east-southeast of Panther Tank, Cerro Alto quadrangle.
448 Gym: Hills south of Borrego Tank.
449 Gym: Hills north of tank halfway between Borrego and Shakespeare Tanks.
450 Gym: .2 mile north of first "d" in "Abandoned Tanks," Cerro Alto quadrangle.
451 Gym: Cuesta above sill, west side of Sierra Tinaja Pinta, near old Miller Ranch.
452 Gym: Hills 6 miles south-southwest of the southwest corner of Sierra Tinaja Pinta.
453 Upper Gym: 1 mile southeast of Deer Mountain above red beds.
454 Lower Gym: *Schwagerina* from beds west of fault on west side of Franklin Mountains.
455 Middle Gym: Dark limestone on west side of Franklin Mountains west of main western fault.
456 Upper Wolfcamp: .5 mile southeast of diabase hill 5039, Van Horn quadrangle.
457 Upper Wolfcamp: South of Marble Quarry Canyon.
458 Upper Wolfcamp: Above Strawn limestone southeast of Marble Quarry, bed 12.
459 Upper Wolfcamp: South side of entrance to Victorio Canyon.
460 Wolfcamp: South of Victorio Peak, above Millican.
461 Hess?: Southeast of Apache Peak, arroyo north of hill 4520, float.
462 Hess: Southeast of Apache Peak, halfway up hill 4520.
463 Hess: Southeast of Apache Peak, limestone at east foot of hill 4520.
464 Hess: .3 mile southwest of hill 4520, east of Apache Peak, on east side of fault.
465 Bone Canyon: 1 mile northeast of summit 6630, south of Apache Peak.
466 Hess: Lower cliff, 1.5 mile east of summit 6630, near Marble Quarry.
467 Hess?: Float, 1 mile east of Marble Quarry.
468 Hess: Lower, base of section south of Marble Quarry, float.
469 Hess: Section south of Marble Quarry, bed 14.
470 Hess?: Float, entrance to Victorio Canyon.
471 Lower Hess: Victorio Peak section, bed 13.
472 Hess: Victorio Peak section, bed 14.
473 Hess: Victorio Peak section, bed 15.
474 Hess: Victorio Peak section, bed 16.
475 Hess: Victorio Peak section, bed 18.
476 Hess: Victorio Peak section, beds 20–21.
477 Hess: Victorio Peak section, beds 23–24.
478 Hess: Lower two fossiliferous layers in upper part of Hess, 1.5 mile east of b. m. 6140, Sierra Diablo south of Victorio Peak.
479 Hess: Upper fossiliferous layer in upper part of Hess, 1.5 mile east of b. m. 6140, Sierra Diablo south of Victorio Peak.
480 Hess: Upper part of Hess 1.3 mile south of b. m. 6140, cherty horizon.
481 Hess: Float, 1 mile southeast of b. m. 5560, Baylor Mountains.
482 Hess: Below summit 5560, southeastern Baylor Mountains.
483 Bone Canyon: Apache Peak section; *Fusulina* from the lower part of the member and gastropods from bed 6, below the upper limestone of Apache Peak.
484 Bone Canyon: Shale northeast of summit 6345 (southwest of Victorio Peak) and underlying the limestone which is exposed on that summit.
485 Bone Canyon: Lower part of lower shale above Hess limestone, section south of Victorio Peak.
486 Bone Canyon: Upper shale, section south of Victorio Peak.
487 Bone Canyon: Victorio Peak section, bed 25.
488 Bone Canyon: Black limestone below the shale underlying hill 6345, south of Victorio Peak.
489 Bone Canyon: Conglomerate, about 150 above base, .8 mile southwest of b. m. 6140, southwest of Victorio Peak.
490 Bone Canyon: Section in Delaware Mountains north of Van Horn quadrangle, bed 2.
491 Bone Canyon: Section in Delaware Mountains north of Van Horn quadrangle, bed 5.
492 Victorio Peak: 8.5 miles south of Dos Alamos.

493 Victorio Peak: Upper beds, below Delaware Mountain section 11.5 miles south of Dos Alamos.
494 Victorio Peak: .5 mile west of east edge of Salt Basin quadrangle, in beds dipping from escarpment east into the flat.
495 Victorio Peak: White limestone just east of Salt Basin sheet in beds dipping into flat from the escarpment.
496 Victorio Peak: Victorio Peak section, 150 feet above base of bed 30.
497 Victorio Peak: .6 mile northeast of summit 6630.
498 Victorio Peak: Upper grey limestone at top of section south of Marble Quarry.
499 Victorio Peak: Victorio Peak section, bed 29.
500 Victorio Peak: Same as 496.
501 Victorio Peak: Victorio Peak section, about 459 feet above base of bed 30.
502 Leonard: Section on Baylor Mountains, beds 5–6, mostly bed 5.
503 Leonard: Section on Baylor Mountains, beds 8–9, mostly bed 9.
504 Delaware Mountain: 6 miles south of Dos Alamos.
505 Delaware Mountain: About 30 feet above its base, 8.5 miles south of Dos Alamos.
506 Delaware Mountain: Section 11.5 miles south of Dos Alamos, bed 3.
507 Gym: Section at west side of Wylie Mountains, lower part.
508 Gym: Section at west side of Wylie Mountains, upper part.
509 Gym: Wylie Mountains 3 miles south of Wildhorse.
510 Gym: Lower beds of the Permian 3 miles east of Dalberg, Carrizo Mountains.
511 Hess: Conglomerate bed, Finlay Dome, south of "Fossil Hill."
512 Leonard: Shales just below ammonoid bed, "Fossil Hill," northwestern Finlay Dome.
513 Leonard: "Fossil Hill," Finlay Dome.
514 Leonard: Limestone beds in dark shale near Ross Mine, Shafter quadrangle.
515 Leonard: Limestone in upper beds near divide east of Ross Mine.
516 Leonard: Lower part of section northwest of Shafter Mine.
517 Leonard: Second main limestone northwest of Shafter Mine, on line of section.
518 Leonard: North of Shafter silver mine, probably including some fossils from the basal Word limestone.
519 Leonard: 1.5 mile northwest of Ojo Bonito.
520 Chupadera: 3.5 miles south-southeast of McVeigh Ranch, northeastern Salt Basin quadrangle (collected by Mr. Shapleigh Gray).

LOCALITIES IN UNIVERSITY OF TEXAS COLLECTIONS*

Ta Word: "Between stations 60 and 62, Green Canyon," Glass Mountains.
Tb Leonard: North side of top of Leonard Mountain, "near stations 80 and 81"; north face of Leonard Mountain, "thin-bedded ledges just below station 81 and above heavy ledge, interbedded with sandstone."
Tba Leonard: North base of Leonard Mountain.
Tc Word: Middle limestone in Hess Canyon, "upper half of of section D, Hess Tank"; "stations 1 to 2 in section northeast of camp at Hess Tank"; "hill below beginning of section D, Hess Tank"; "stations 3 and 4 in section northeast of camp at Hess Tank"; "samples from end of section, after station 7, taken northeast of camp at Hess Tank." Probably collected .5 mile south of hill 5578; as identified by Beede some of these fossils are listed in Udden's section 6, bed 1.

*Where a number is suffixed (as T9) the number corresponds approximately to the locality listed under that number in the foregoing list.

Td Leonard: Horizon in "Cibolo" just above brecciated zone of Cibolo Ranch, hill just east of Cibolo Creek, associated with *Lyttonia.*
Te Gym: Upper beds on 3 Mile Mountain near Van Horn.
Tf Leonard: "Cieneguita beds" 10 miles north-northwest of Shafter.
Tg Leonard: "Cieneguita beds," Shafter, collections 56, 57, and 62.
Th Leonard: Transition beds of "Cibolo," 6 miles north-northwest of Shafter.
Ti Leonard: Above transition beds of "Cibolo," 5 miles northwest of Shafter.
Tj Word: Thin-bedded zone of "Cibolo," 4–5 miles north-northwest of Shafter.
Tk Word: Thin-bedded zone of "Cibolo," 4–5 miles north-northwest of Shafter.
Tl Leonard: Brecciated zone of "Cibolo," 4 miles north-northwest of Shafter.
Tm Leonard: "Cibolo limestone," 4–6 miles northwest of Shafter.
Tn Leonard: "Cibolo limestone," 6–10 miles northwest of Shafter.
To Leonard: "Chinati series" north of Chinati Mountains.
Tp Word: Yellow limestone of "Cibolo limestone," 3 miles north-northwest of Shafter.
Tp Leonard: Transition beds of "Cibolo limestone," 3–4 miles northwest of Shafter.
Tr Leonard?: 10 miles west of Decie (Wedin) Ranch.
Ts Lower Hess: Dugout Mountain.
Tt Hess: About two-thirds mile north of Gap Tank.
Tu Word?: "Numbers 33 and 34."
Tv Hess?: "About the same horizon as the first hogback north of Leonard Mountain."
Tx Word: Middle Word limestone in Hess Canyon, fossils etched free.
T9 Leonard: "Top of ridge 2½ miles northeast of Wedin's oil derrick," "about 3 miles north 20° east of Wedin's oil derrick," "north side of Round Point ridge, 3 miles north of Wedin's oil derrick," "base of hill 2 miles north 20° east of Wedin's oil derrick," "about halfway between first day's section and Wedin's land."
T9a Leonard: 3 miles west of Iron Mountain "above 200 feet of shale, station 3, upper part," "top of bluff, section of October 27, station 3, 1½ mile east (?) of Iron Mountain."
T15 Lower Leonard: 1 mile west of Iron Mountain.
T15a Lower Leonard: "Basal part of section ¾ mile west-southwest of Skinner's West Ranch," top ledge of first ridge west of Iron Mountain.
T41 Leonard: "Near Bird Mine, 200–400 feet below base of dolomite cliff."
T82 Wolfcamp or Hess: Just above the conglomerate "at station 85," south side of Leonard Mountain.
T82a Leonard?: South face of Leonard Mountain.
T85 Wolfcamp?: 1½ mile east-southeast of Hess Tank, uplift northeast of Hess Ranch.
T88 Wolfcamp: *Uddenites* zone at Wolf Camp.
T88a Wolfcamp: Base of *Uddenites* zone.
T90 Middle Wolfcamp: Just below T93.
T91 Wolfcamp: "1 mile northwest of station 3, sheet 2; layer of limestone in shale"; "grey limestone of very fine texture containing shells of ostracods"; "stations 21 and 22."
T93 Middle Wolfcamp: On stream bank northeast of Wolf Camp.
T107 Hess: 2½ miles north 65° west of Wolf Camp.
T108 Upper Hess: Fossiliferous horizon about 150 feet stratigraphically below the top of the cuesta north of Wolf Camp.
T119 Leonard: Shale slide 4 miles northeast of Decie Ranch.

T120 Upper Leonard: Hill east of shale slide "about midway between first day's section and Wedin (Decie) land."
T128 Leonard: Near Word Ranch.
T141 Word: Limestone above shale slide.
T144 Word: Mostly below middle Word ammonoid horizon, Bowman's section 2.5 miles up valley from Hess Tank.
T144a Word: Ravine 3 miles east of Hess Tank.
T148 Word: Tank ½ mile north of Word Ranch and beds above tank.
Tx148 Word: Near the tank ¼ mile north of Word Ranch.
T183 Leonard: South side of Altuda Mountain, near granite hill.
T205 Hess: Basal, 2(?) miles west-northwest of Old Payne Ranch House, Dugout Mountain.
T226 Middle Leonard: Dugout Mountain, "Payne Ranch."
T232 Leonard: Top of Leonard Mountain.
T233 Leonard: South side of Leonard Mountain, "station 83."
T238 Word limestone: Southern part of Permian outcrop on Del Norte range.
T239 Middle Word: ½ mile southeast of junction of Road and Gilliland Canyons.
T240 Middle Word: Mountain 1½ miles north 55° west of old Hess Ranch House, "number 24, section 1," collected by Beede, Bybee, and Christner.
T240a Middle Word: Top of the first mountain north of Leonard Mountain "sta. 74"; "middle of the yellow sandstone between stations 74 and 75."
T243 Middle Word: Road Canyon, "stations 70 and 70-71."
T251 Lower Word: ¼ mile southwest of Word Ranch on road to Leonard Mountain.
Taa Victorio Peak: Brackett Draw.
Tzz, aa Gym: Western Wiley Mountains.
Tmm Wolfcamp: Top of Beede's section K, 4.5 miles south of Hueco Tanks.

LOCALITIES IN DELO COLLECTION

The exact localities of this collection are not known. D1 is from the Leonard on Leonard Mountain; D2, D3, D4, D5, D7, D8, D9, D10, D11, D12, D13, D14, D15, D16, D17, D18, D19, and D21 are from various localities in the Leonard formation in the western part of the Glass Mountains; D6 is from the Hess formation; and D239 and part of D3 are from the Word formation. None of these numbers has any relation at all to the numbers in the remainder of the collection, except D239, which is the junction of Road and Gilliland Canyons, middle Word limestone, corresponding to localities 239 and T239.

LOCALITIES IN SCHUCHERT COLLECTION

The localities in this collection have been numbered to correspond with the numbers in the King and The University of Texas collections. The more important localities are:

23S Middle Leonard: South of Sullivan Peak.
26S Middle Leonard: South of Sullivan Peak.
88S Wolfcamp: *Uddenites* zone at Wolf Camp.
93S Middle Wolfcamp: Stream bank northeast of Wolf Camp.

LOCALITIES IN R. F. BAKER COLLECTION

This small collection was made from several localities, particularly 88, 93, the hills southwest of Hueco Tanks, the Gym in Hueco Canyon, and locality 520.

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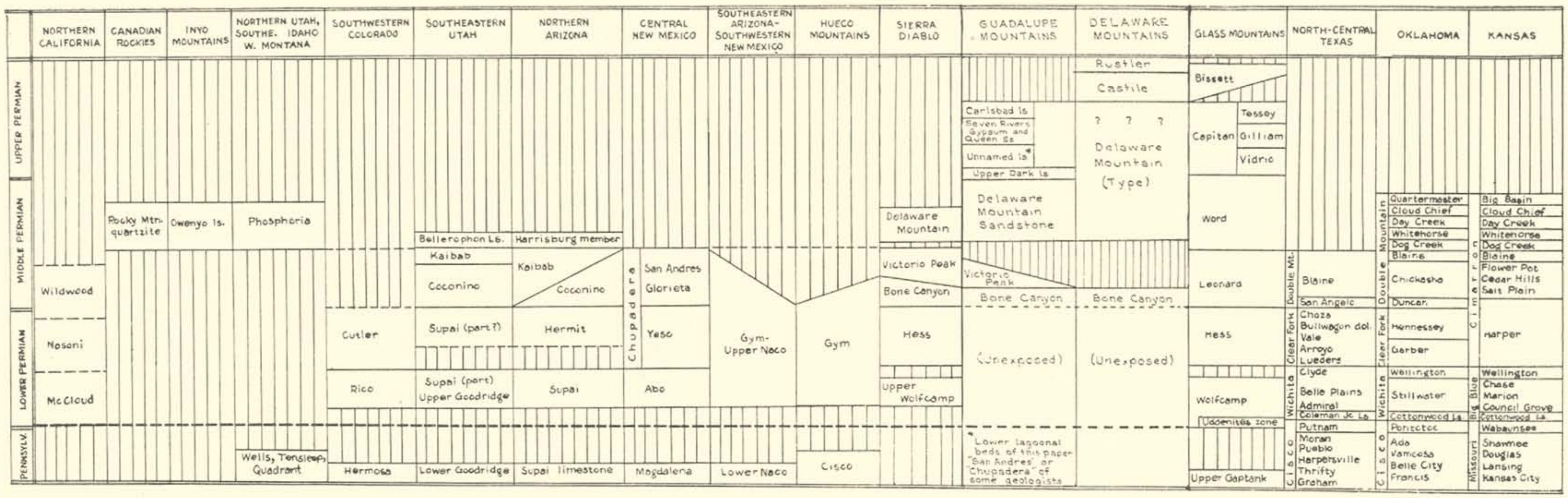

FIG. 1. CORRELATION CHART.

LEGEND

REALM: *A*-Descended from American Pennsylvanian species; *B*-Descended from American Permian species; *C*-Tethyan; *D*-Andean; *E*-Arctic

RELATIVE ABUNDANCE: A-Abundant; C-Common; X-Sporadically common; R-Rare; ?-Questionable; G-Listed by Girty where not found by King

Species	Wolfcamp: Uddenites Zone-Glass Mts.	Wolfcamp: Middle & Upper Wc-Glass Mts.	Wolfcamp: Upper Wc-Sierra Diablo	Gym: Hueco Mountains: Lower	Gym: Hueco Mountains: Middle	Gym: Hueco Mountains: Upper	Gym: Diablo Plateau	Gym: Wylie Mountains	Gym: Carrizo Mountains	Hess: Glass Mountains	Hess: Sierra Diablo	Hess: Finlay Mountains	Leonard: Glass Mountains	Leonard: Sierra Diablo: Bone Canyon Member	Leonard: Sierra Diablo: Victorio Peak Member	Leonard: Bone C. Member-Guadalupe Mt.	Leonard: Baylor Mountains	Leonard: Finlay Mountains	Leonard: Shafter Area	Word and Delaware Mtn.: Glass Mountains	Word and Delaware Mtn.: Sierra Diablo	Word and Delaware Mtn.: Delaware-Guadalupe Mts.	Word and Delaware Mtn.: Shafter Area	Capitan: Glass Mountains: Altuda Member	Capitan: Glass Mountains: Gilliam Member	Capitan: Glass Mountains: Tessey Member	Capitan: Guadalupe Mountains	Bissett Formation	Las Delicias: Limestone of Cerro Capella	Las Delicias: Wadgenoceras Horizon	Las Delicias: Limestone of Pichagua	New Mexico: Abo Formation	New Mexico: Yeso Formation	New Mexico: San Andres Formation	Kaibab (Arizona)	Phosphoria (Idaho, Utah, etc.)	Pennsylvanian System	Realm	Related foreign species	Girty's name (Prof. P. 58)
Orbiculoidea missouriensis (Shumard)																													R						X	X	*A*		
Crania sp.																				R							G												*Crania* sp.
Rhipidomella carbonaria (Swallow)	X	X																																			X	*A*	*R. cora* (d'Orbigny)	
R. hessensis King										C	X																											*E*	*R. subquadrata* (Fliegel)	
R. leonardensis King													R							?																		*B*		
R. mesoplatys King													X							R																		*B*		
R. mesoplatys baylorensis King														R			R																					*B*		
R. transversa King										R			R																									*B*		
Orthotichia kozlowskii King	R	R	R	?									R																									*C*	*O. derbi* (Waagen)	
Enteletes dumblei Girty		?		X		?				C	X			X					X	C																		*B?*	*E. andii* (d'Orbigny)	*Enteletes dumblei* n. sp. *Enteletes angulatus* n. sp.
E. leonardensis King													X																									*B*		
E. liumbonus King				X						X			?			G																						*B*		*Enteletes* sp. c
E. plummeri King										R			C																									*E*	*E. oehlerti* Gemmelaro	
E. wordensis King																				X	R	G																*B*		*Enteletes* sp. a, sp. b, sp. d
Parenteletes cooperi King	C																																				X	*A, E*	*P. suessi* (Schellwien)	
P. globosus Girty																				G?																				*Enteletes globosus* n. sp.
Streptorhynchus gregarium Girty																											G											*B?*		*Streptorhynchus gregarium* n. sp.
S. lamellatus King		X								X			X																									?		
S. pygmaeum Girty						R					R		R							R		G																*B?*		*Streptorhynchus pygmaeum* n. sp.
S. perattenuatum Girty																						G																*B?*		*Streptorhynchus perattenuatum* n. sp.
S. pyramidalis King		X															?	R											?									*E*	*S. pelargonatus* (Schlotheim)	
S.? undulatus King										X																												*E*	*S. opeculatus* Waagen	
Orthotetes guadalupensis Girty																						G					G													*Orthotetes guadalupensis* n. sp.
O. declivis Girty																											G													*Orthotetes declivis* n. sp.
O. distortus Girty																				G							G													*Orthotetes distortus* n. sp.
Orthotetella wolfcampensis King	X	C		?	?																																	*A?*		
Orthothetina sp. (cf. *Orthotetes mutabilis* G.)		R																																			X	*A*	*O. circularis* (Fliegel)	
Meekella attenuata Girty		?								X	C		A		X	X	X			A									X									*B*		
M. difficilis Girty													A	X		G	X		X										?									*B*		*Meekella difficilis* n. sp. *M. multilirata* n. sp.
M. globosa King													X																									*B*		
M. grandis King		?								R			R		R				R																			*B*		
M. irregularis texanus King	C	X																																				*E*	*M. irregularis* Schellwien	
M. mexicana Girty		?	?		A	X				X																							G	G				*B*		
M. hessensis King										X																												*B*		
M. skenoides Girty																				A	X	G																*B*		*Meekella skenoides* n. sp.
M. striatocostata (Cox)		R																														G					X	*A*		
Geyerella americana Girty		?								R																	G											*E*	*G. distorta* Schellwien	*Geyerella americana* n. sp. *Orthotetes distortus campanulatus* n. var.
Derbya buchi (d'Orbigny)		X			X	X																																*C*	*D. regularis* Waagen	
D. crenulata Girty											G?									?		G																*B*		*Derbya? crenulata* n. sp.
D. cymbula H. and C.		?																																			X	*A*		
D. elevata King																				R		G					G		R									*B*		*Derbya* sp. b
D. nasuta Girty										?	X		X	X					X	X											R							*E*	*D. grandis* Waagen	*Derbya nasuta* n. sp.
Chonetes biplicatus King		R									R																											*B?*		
C. deliciasensis King																													A									*E?*	?*C. moelleri* Tschernyschew	
C. granulifer Owen	X	X																																			X	*A*		
C. hessensis King										R																												*E*	*C. molengraafi* Broili	
C. hillanus Girty																				R		G					G											*B*		*Chonetes hillanus* n. sp.
C. molengraafi Broili?																																						*E*	*C. molengraafi* Broili	
C. ostiolatus Girty																							R													X		*D*	*C. capitolinus* Toula	
C. permianus Shumard			?							?			X	X	X		X			X		G													X			*B*	*C. ambiensis* Waagen	*Chonetes permianus* Shumard; *Chonetes* sp.
C. quadratus King																				X															X			?		
C. spinoliratus King	R	R																																				?		
C. spinoliratus diabloensis King											R																											*B*		
C. subliratus Girty										?	X		A	X	X			X		A				X																*Chonetes subliratus* n. sp.
C. vernevilianus N. and R.	X		X																										?								X	*A*		
Isogramma millepunctata M. & W.	R		X																																		X	*A*		

FIG. 2. TABLE OF FOSSILS

Species	Wolfcamp			Gym						Hess			Leonard							Wood and Delaware Mtn.				Capitan					Las Delicias			New Mexico						Realm	Legend	
				Hueco Mountains										Sierra Diablo										Glass Mountains															Realm: A Descended from American Pennsylvanian species; B Descended from American Permian species; C-Tethyan; D-Andean; E-Arctic	Relative abundance: A-Abundant; C-Common; X-Sporadically common; R-Rare; ?-Questionable; G-Listed by Girty where not found by King
	Uddenites Zone-Glass Mts.	Middle & Upper Wc. Glass Mts.	Upper Wc. Sierra Diablo	Lower	Middle	Upper	Diablo Plateau	Wylie Mountains	Carrizo Mountains	Glass Mountains	Sierra Diablo	Finlay Mountains	Glass Mountains	Bone Canyon Member	Victorio Peak Member	Bone C. Member-Guadalupe Mts.	Baylor Mountains	Finley Mountains	Shafter Area	Glass Mountains	Sierra Diablo	Delaware Guadalupe Mts.	Shafter Area	Altuda Member	Gilliam Member	Tessey Member	Guadalupe Mountains	Bissett Formation	Limestone of Cerro Cabalo	Waagenoceras Horizon	Limestone of Pichagua	Abo Formation	Yeso Formation	San Andres Formation	Kaibab (Arizona)	Phosphoria (Idaho, Utah, etc.)	Pennsylvanian System	Realm	Related foreign species	Girty's name (Prof. Pap. 58)
Productus arcticus Whitfield																				X																		D		
P. capitanensis Girty																						G?			R		G											B		Productus semireticulatus var. capitanensis n. var.
P. comancheanus Girty																				R																		B		Productus guadalupensis var. comancheanus n. sp.
P. dartoni King			R	R		R					R				R																							B?		
P. dartoni sullivanensis King																				R			R															B?		
P. guadalupensis Girty																				C		G																D	P. mammatus Keyserling	Productus guadalupensis n. sp.
P. hessensis King				X				C	C	X																												B		
P. huecoensis King		X	C	X																																		B		
P. inca d'Orbigny					A	A		?																										G				C		
P. indicus Waagen											?		X						R	C			?															E	P. indicus Waagen	
P. ivesi Newberry								?		C	C		A	C	C		C	X	C	?													G	G	A			E	P. spiralis Waagen	
P. leonardensis King										R			A			X				R																		B		
P. gratiosus occidentalis Schellwien		X																																			X	E	P. gratiosus Waagen	
P. multistriatus Meek																				X									X							X		D	P. weyprechti Toula	
P. occidentalis Newberry							X						X	X	X					X							G								A			E	P. grandicostatus Chao	Productus occidentalis Newberry
P. schucherti King										X			A							?			R						X									B	P. boliviensis d'Orbigny	Productus sp. c
?P. semireticulatus hermosanus Girty	X	X																																			X	A		
P. semistriatus Meek	X	X	X	X		X																																D?	P. chandlessi Derby	
P. wolfcampensis King		X	C	X																																		B		
P. mexicanus Shumard																											G							G?				B		Productus mexicanus Shumard
P. indentatus Girty																						G																?		Productus indentatus n. sp.
P.? pileolus Shumard																						G					G											?		Productus? pileolus Shumard
P. limbatus Girty																						G																?		Productus limbatus n. sp.
Linoproductus cora (d'Orbigny)	C	C	C	X	C						X																					G					X	A		
L. cora angustus King					R					R			?				R	R																				B		
L. girtyi King													R							R																		B		
L. nasutus King													X							C																		B?	L. simensis (Tschernyschew)	
L. waagenianus (Girty)										X			A	X					X	A	X	G					G					G?				X		D,E	L. angard (Toula)	Productus waagenianus n. sp.; P. waagenianus var.
L. phosphaticus (Girty)													X						R	X																X		D	L. cancriniformis (Tschernyschew)	
L. villiersi (d'Orbigny)	X	X			C																																?	A	L. koninckianus (Verneuil)	
Striatifera pinniformis (Girty)										X			X	X						R							G		R									E	S. compressa (Waagen)	Productus pinniformis n. sp.
Pustula semipunctata (Shepard)	X	X								R																											X	A	P. punctata (Martin)	
Buxtonia occidentalis King		X																														G?					X	A	Juresania juresanensis (Tschernyschew)	
B. peruviana (d'Orbigny)				X							X																								?			C	B. porrecta (Kutorga)	
B. victorioensis King													R		R					?																		B		
Waagenoconcha leonardensis King										R			X																									E	W. abichi (Waagen)	
W. montpelierensis Girty	R			G									X		X					X									R						X	X		C,D	W. irginae (Stuckenberg)	
?Overtonia cristato-tuberculata (Kozlowski)	X																																				X	C	O. fimbriata (Sow.)	
Avonia boulei (Kozlowski)	X	C		C						R																												C	A. tuberculata (Moeller)	
A.? incurvata King																				R																		B		Productus latidor
A. latidorsata (Girty)																				?							G											B		Productus latidorsatus n. sp.
A. meekana (Girty)																				R		G																E	A. pustulata (Keyserling)	Productus meekanus n. sp.
A. signata (Girty)																				A	X	G																E	A. opuntia (Waagen)	Productus signatus n. sp.; P. signatus var.; P. sp. a
A. subhorrida (Meek)																				R																X		D		
A. subhorrida rugatula (Girty)						R							X							C		G							X									B		Productus subhorridus var. rugatulus n. var.
A. walcottiana (Girty)																				C		G																B		Productus walcottianus n. sp. (part)
A. walcottiana costata King																				X		G							X									B		Productus walcottianus n. sp. (part)
Horridonia texana King																				R																		E	H. timanica (Stuckenberg)	
Marginifera capaci (d'Orbigny)	C	C		C		X																															?	C		
M. cristobalensis Girty					?					X			A	X		G																		?				E	M. spinosocostata (Abich)	Productus latidorsatus var.
M. dugoutensis King	?	X	?																																			B		
M. lasallensis (Worthen)	X																																					A		
M. manzanica Girty										X	X		A	X	X		X		X															?				E	M. ingrata	
M. opimus Girty																				A	X	G		X														B		Productus popei var. opimus n. var.
M. popei (Shumard)													X							A		G		X			G											B		
M. popei minor King																													X									B		
M. reticulata King										?			A						X																			B		
M. reticulata angusta King										R			C		X																							B		
M. sublaevis King										R	X		A	X			X	X	X	X																		B		
M.? texana (Girty)																				X																		B		Productus texanus n. sp.
M. wabashensis (N. and P.)	A	X											?																								X	A		
M.? whitei King						?				X	C		R						R															?				B		
M.? wordensis King																				X																		B		

FIG. 3. TABLE OF FOSSILS.

LEGEND

REALM: A-Descended from American Pennsylvanian species. B-Descended from American Permian Species. C-Tethyan. D-Andean. E-Arctic.

RELATIVE ABUNDANCE: A-Abundant. C-Common. X-Sporadically common. R-Rare. ?-Questionable. G-Listed by Girty where not found by King.

SPECIES	Wolfcamp: Uddenites Zone-Glass Mts.	Wolfcamp: Middle & Upper Wc.-Glass Mts.	Wolfcamp: Upper Wc.-Sierra Diablo	Gym: Hueco Mountains: Lower	Gym: Hueco Mountains: Middle	Gym: Hueco Mountains: Upper	Gym: Diablo Plateau	Gym: Wylie Mountains	Gym: Carrizo Mountains	Hess: Glass Mountains	Hess: Sierra Diablo	Hess: Finlay Mountains	Leonard: Glass Mountains	Leonard: Sierra Diablo: Bone Canyon Member	Leonard: Sierra Diablo: Victorio Peak Member	Leonard: Bone C. Member-Guadalupe Mts.	Leonard: Baylor Mountains	Leonard: Finlay Mountains	Leonard: Shafter Area
Scacchinella gigantea SCHELLWIEN	X	R								C									
Aulosteges beedei KING													X						
A. guadalupensis SHUMARD																			
A. magnicostatus GIRTY										X			C	X					
A. medlicottianus WAAGEN		R								A			A						
A. subcostatus KING													X						
A. trigonalis KING										R			C	?			X		
A. tuberculatus KING																			
A. wolfcampensis KING	C	A																	
Strophalosia hystricula GIRTY		X									X		X	X					
Teguliferina bösei KING	?	C																	
Prorichthofenia likharewi KING										C	C		A	X			X		X
P. permiana (SHUMARD)																			
P. teguliferoides KING										C	C	C							
P. uddeni (BÖSE)													C	X					X
Parakeyserlingina frederiksi KING		X								?			?						
Lyttonia nobilis americanus (GIRTY)										C	C		A	X	X				
L. hortoni KING										R			R						
Liorhynchus bisulcata (SHUMARD)													R						
L. weeksi nobilis (GIRTY)																			
Pugnoides bidentatus (GIRTY)													X			X			
P. elegans (GIRTY)										X	X		X						
P. pinguis (GIRTY)										X			X						
P. shumardianus (GIRTY)													R						
P. swallowianus (SHUMARD)																			
P. texanus (SHUMARD)				R	C	A				X			R	?		G			
P. transversus KING										C									
Rhynchopora illinoisensis WORTHEN	R	R																	
R. taylori GIRTY																			
Camarophoria deloi KING				R															
C. thevenini KOZLOWSKI		R		R									R						
C. venusta GIRTY		R								C			A	X		X	X		X
C.? indentata (SHUMARD)																			
C.? longaeva (GIRTY)																G?			
Uncinuloides guadalupensis (SHUMARD)		R								R			C						

SPECIES	Word and Delaware Mts.: Glass Mountains	Word and Delaware Mts.: Sierra Diablo	Word and Delaware Mts.: Delaware-Guadalupe Mts.	Word and Delaware Mts.: Shafter Area	Capitan: Glass Mountains: Altuda Member	Capitan: Glass Mountains: Gilliam Member	Capitan: Glass Mountains: Tessey Member	Capitan: Guadalupe Mountains	Bissett Formation	Las Delicias: Limestone of Cerro Casella	Las Delicias: Waagenoceras Horizon	Las Delicias: Limestone of Pichagua	New Mexico: Abo Formation	New Mexico: Yeso Formation	New Mexico: San Andres Formation	Kaibab (Arizona)	Phosphoria (Idaho, Utah, etc.)	Pennsylvanian System	REALM	RELATED FOREIGN SPECIES	GIRTY'S NAME (PROF. PAP. 58)
Scacchinella gigantea SCHELLWIEN																			E	*S. variabilis* GEMMELLARO	
Aulosteges beedei KING	R																		B		
A. guadalupensis SHUMARD	A	X	G					G											E	*A. dalhousi* DAVIDSON	*Aulosteges guadalupensis* SHUMARD
A. magnicostatus GIRTY	R																		B		*Aulosteges magnicostatus* n. sp.
A. medlicottianus WAAGEN	X																		E		
A. subcostatus KING																			B?		
A. trigonalis KING	X																		B		
A. tuberculatus KING	C	X																	B		
A. wolfcampensis KING																			A?		
Strophalosia hystricula GIRTY	X																		A?		*Strophalosia hystricula* n. sp.
Teguliferina bösei KING																			E	*T. deformis* SCHELLWIEN	
Prorichthofenia likharewi KING												X							B		
P. permiana (SHUMARD)	A		G					G		?									B		
P. teguliferoides KING																			B		
P. uddeni (BÖSE)	X																		B		
Parakeyserlingina frederiksi KING																			E	*P. dervasica* (TSCHERNYSCHEW)	
Lyttonia nobilis americanus (GIRTY)	A	X	G		X			G		X									E	*L. nobilis* WAAGEN	*Leptodus americanus* n. sp. *L. guadalupensis* n. sp.
L. hortoni KING	R																		B		
Liorhynchus bisulcata (SHUMARD)			G					G			A								D		*Pugnax bisulcata* SHUMARD; vars. *gratiosa* & *seminuloides*
L. weeksi nobilis (GIRTY)	X																X		D		
Pugnoides bidentatus (GIRTY)			G																B		*Pugnax bidentata* n. sp.
P. elegans (GIRTY)	X							G											B		*Pugnax elegans* n. sp.
P. pinguis (GIRTY)	R		G																B		*Pugnax pinguis* n. sp.
P. shumardianus (GIRTY)								G											B		*Pugnax shumardiana* n. sp.
P. swallowianus (SHUMARD)	X		G					G									X		D		*Pugnax swallowiana* SHUMARD
P. texanus (SHUMARD)			G?											?					B		*Pugnax osagensis* SWALLOW *Rhynchonella? texana* SHUM
P. transversus KING																			B		
Rhynchopora illinoisensis WORTHEN																		X	A, C	*R. nikitini* TSCHERNYSCHEW	
R. taylori GIRTY	X									X							X		D		
Camarophoria deloi KING	R																		B		
C. thevenini KOZLOWSKI																			C		
C. venusta GIRTY	C	X			X			G											E	*C. purdoni* DAVIDSON	*Camarophoria venusta* n. sp.
C.? indentata (SHUMARD)	?		G		?			G		?									B		*Rhynchonella? indentata* SHUMARD
C.? longaeva (GIRTY)								G											B		*Rhynchonella? longaeva* n. sp.
Uncinuloides guadalupensis (SHUMARD)	X							G											E	*U. jabiensis* WAAGEN	*Rhynchonella? guadalupae* SHUMARD

FIG. 4. TABLE OF FOSSILS.

Species	Wolfcamp: Uddenites Zone-Glass Mts	Wolfcamp: Middle & Upper Wc-Glass Mts	Wolfcamp: Upper Wc-Sierra Diablo	Gym: Hueco Mountains, Lower	Gym: Hueco Mountains, Middle	Gym: Hueco Mountains, Upper	Gym: Diablo Plateau	Gym: Wylie Mountains	Gym: Cerrizo Mountains	Hess: Glass Mountains	Hess: Sierra Diablo	Hess: Finlay Mountains	Leonard: Glass Mountains	Leonard: Sierra Diablo, Bone Canyon Member	Leonard: Sierra Diablo, Victorio Peak Member	Leonard: Bone C. Member-Guadalupe M.	Leonard: Baylor Mountains	Leonard: Finlay Mountains	Leonard: Shafter Area	Word and Delaware Mts: Glass Mountains	Word and Delaware Mts: Sierra Diablo	Word and Delaware Mts: Delaware-Guadalupe Mts.	Word and Delaware Mts: Shafter Area	Capitan: Glass Mountains, Altuda Member	Capitan: Glass Mountains, Gilliam Member	Capitan: Glass Mountains, Tessey Member	Capitan: Guadalupe Mountains	Bissett Formation	Las Delicias: Limestone of Cerro Caballo	Las Delicias: Waagenoceras Horizon	Las Delicias: Limestone of Pichagua	New Mexico: Abo Formation	New Mexico: Yeso Formation	New Mexico: San Andres Formation	Kaibab (Arizona)	Phosphoria (Idaho, Utah, etc.)	Pennsylvanian System	Realm	Related Foreign Species	Girty's Name (Prof. Pap. 58)
Spirifer condor D'ORBIGNY	X	X		C																																		C		
S. marcoui infraplica KING													X	X	X			X	X																			E	S. marcoui WAAGEN	
S. (Neospirifer) bakeri KING													R							X																		E	S. niger WAAGEN	
S. (Neospirifer) costella KING													R																									E	S. fasciger KEYSERLING	
S. (Neospirifer) huecoensis KING				X						X																												B?		
S. (Neospirifer) mexicanus SHUMARD																						G					G											E	S. oldhamianus WAAGEN	Spirifer mexicanus SHUMARD
S. (Neospirifer) mexicanus compactus GIRTY																											G											E?		Spirifer mexicanus var. compactus n. var.
S. (Neospirifer) latus KING										R			X	X																								E		
S. (Neospirifer) pseudocameratus GIRTY													A	X	X		X		X	A	X	G					G		C							X		D		Spirifer sp. b
S. (Neospirifer) texanus MEEK	X	X																																			X	A		
S. (Neospirifer) triplicatus HALL	C	C																																			X	A		
S. (Elivina) sulcifer SHUMARD																				A		G					G											E	S. rajah SALTER	Spirifer sulcifer SHUM. Spirifer sp. a
Squamularia guadalupensis (SHUMARD)		X								C			C	X	X				C	C		G	X	A			G						?	?				B,E	S. indica WAAGEN	Squamularia guadalupensis SHUMARD
S. perplexa (MC CHESNEY)	X	?																																			X	A		
Ambocoelia guadalupensis GIRTY					X								X			X			X	X		G					G									X		B,D		Ambocoelia planoconvexa var. guadalupensis n. var.
A. planoconvexa (SHUMARD)	C	?																																			X	A		
Martinia rhomboidalis GIRTY													X		X	X				X		G		A			G											E	M. variabilis GEMELLARO	Martinia rhomboidalis n. var.
M. wolfcampensis KING	A	C																																				E	M. triquetra TSCHERNESCHEW (non GEMMELLARO)	
Spiriferina angulata KING										X	X																											B?		
S. hilli GIRTY										X			X						X												X							E	S. multiplicata (SOWERBY)	Spiriferina hilli n. sp.
S. laxa GIRTY																				X		G		X			G				X							E	S. cristata (SCHLOTHEIM)	Spiriferina laxa n. sp. S. welleri n. sp.
S. pyramidalis GIRTY																				R		G					G											B		Spiriferina pyramidalis n. sp.
Punctospirifer billingsi (SHUMARD)																				X		G		X			G											E	P. ornata (WAAGEN)	Spiriferina billingsi SHUMARD
P. kentuckyensis (SHUMARD)	R	R																																			X	A		
Hustedia bipartita GIRTY													R									G																B		Hustedia bipartita n. sp.
H. hessensis KING										X	X																											B		
H. huecoensis KING						X																																B		
H. meekana (SHUMARD)										X			A		X	X	X		X	A	X	G		X			G		X		X							E	Hustedia indica (WAAGEN)	Hustedia meekana SHUMARD
H. mormoni (MARCOU)	C	A		C																																	X	A		
H. mormoni papillata (SHUMARD)													X			G				C		G					G											B		Hustedia papillata SHUMARD
H. pusilla (GIRTY)		?								X						G				X									X		X							B?		Pugnax ? pusilla n. sp.
Composita emarginata GIRTY																						G					G											B		Composita emarginata n. sp.
C. emarginata affinis GIRTY																				A	X	G		X			G		X									B,E	C. xetra (DIENER)	Composita emarginata var. affinis n. var.
C. mexicana (HALL)				X	C	A	X			X	X		X		X	G			X														X	X				B		Composita mexicana HALL. C. mex. var. guadalupensis n. var.
C. mira (GIRTY)			?							X			C			X	X		X	C	X								X							X		B,D		
C. persinuata (MEEK)																				R																X		D		
C. subtilita (HALL)	C	X		C				X		A	X		A	X	X		X		X														X	X			X	A,C,E		
C. subtilita angusta KING	X	X	A										?																									B		
Dielasma bovidens (MORTON)	X	X		X																																	X	A,C		
D. problematicum wordense KING																				R											X							E	D. problematicum (DAVIDSON)	
D. shafterense KING																			R																			B		
D. spatulatum GIRTY													?							X		G	X				G											E	D. truncatum (WAAGEN)	Dielasma spatulatum n. sp. D. cordatum n. sp.
D. prolongatum GIRTY																						G					G											B		Dielasma prolongatum n. sp.
D. schucherti minor KING																				X																		E	D. biplex WAAGEN	
Dielasmina guadalupensis GIRTY										R												G					G											E		Dielasmina guadalupensis n. sp.
Notothyris schucherti GIRTY																						G					G											E		Notothyris schuchertensis n. sp.; N. sch. var. ovata Gir.
Heterelasma shumardianum GIRTY																						G					G											B?		Heterelasma shumardianum n. sp.

LEGEND

REALM
- A-Descended from American Pennsylvanian species
- B-Descended from American Permian species
- C-Tethyan
- D-Andean
- E-Arctic

RELATIVE ABUNDANCE
- A-Abundant
- C-Common
- X-Sporadically common
- R-Rare
- ?-Questionable
- G-Listed by Girty where not found by King

PLATES I TO XLIV

Except where otherwise indicated, all figures on these plates are natural size.

PLATE I

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10–11.	*Rhipidomella mesoplatys*, n. sp.	44
10a–c.	Posterior, pedicle, and brachial (×2) views of the holotype, from loc. 123. Y.P.M. 12680.	
11a–b.	Lateral and brachial (×2) views of a somewhat distorted specimen from loc. 256. T. 10551. Leonard and Word (?) formations, Glass Mountains.	
12–13.	*Rhipidomella transversa*, n. sp.	44
12a–c.	Pedicle, lateral, and brachial (×3) views of the holotype, from loc. 123. Y.P.M. 12650.	
13a–c.	Brachial, posterior, and pedicle (×3) views of a specimen from loc. T15a. Leonard formation, Glass Mountains.	
14–15.	*Orthotichia kozlowskii*, n. sp.	45
14a–b.	Brachial and pedicle views of the holotype, from loc. 92. Y.P.M. 12651. Wolfcamp formation, Glass Mountains.	
15a–b.	Brachial and pedicle views of a somewhat crushed specimen from loc. 456. Wolfcamp formation, Sierra Diablo.	
16–20.	*Parenteletes cooperi*, n. gen., n. sp.	41
16.	Pedicle valve of a cotype from loc. 273, in which the posterior part has been ground away, showing the arrangement of the internal plates. Gaptank formation. Y.P.M. 12678.	
17a–d.	Brachial, pedicle, lateral, and posterior views of a cotype from loc. 199. Y.P.M. 12679.	
18.	Interior of the pedicle valve of a cotype from loc. 95S, showing arrangement of internal plates. Y.P.M. S1494.	
19a–b.	Pedicle and posterior views of a broken cotype from loc. 199. Y.P.M. 12679.	
20.	Posterior view of a cotype from loc. Tba. Wolfcamp formation, *Uddenites* zone, Glass Mountains.	

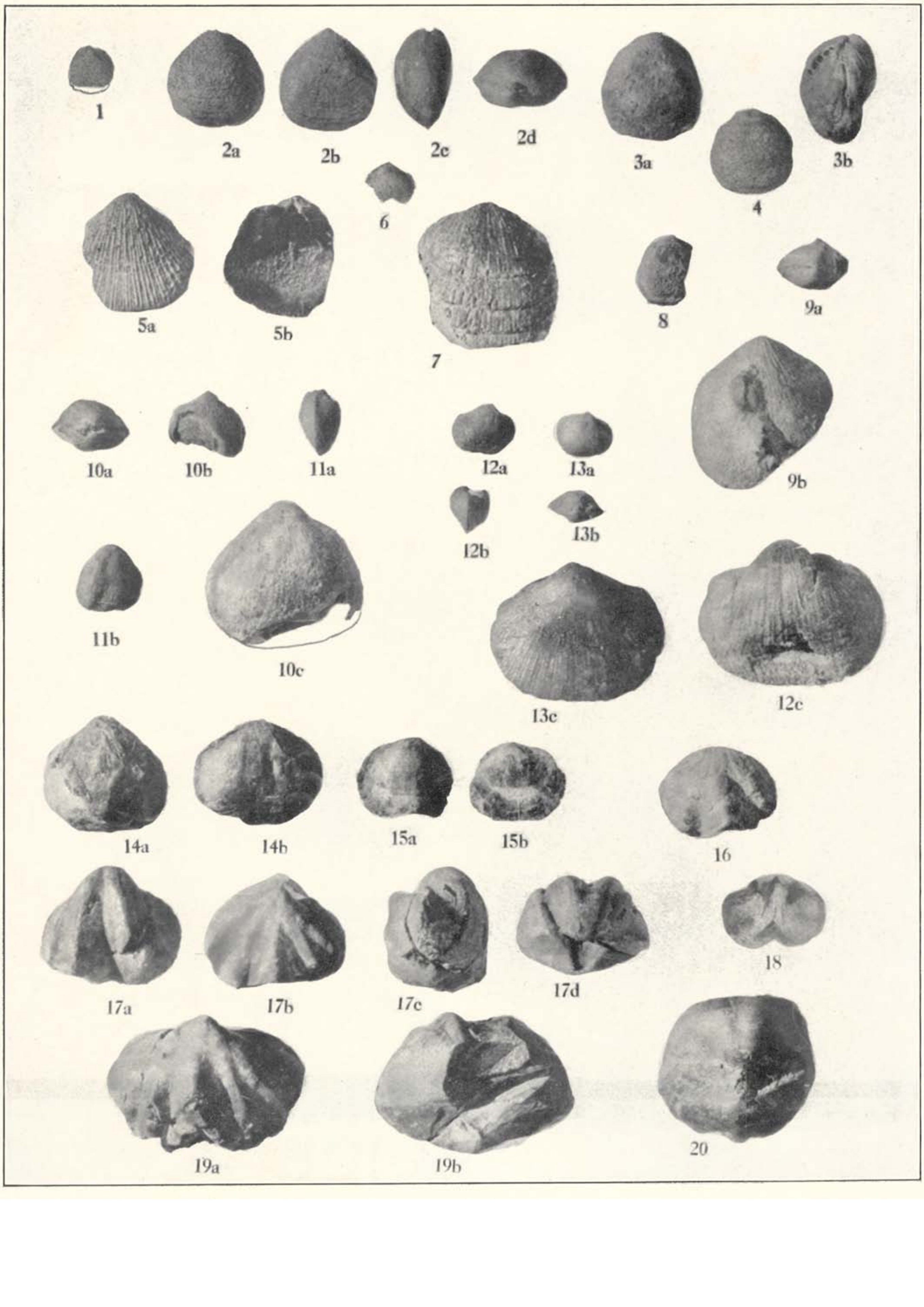
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PLATE II

Figure— PAGE

1–3. *Parenteletes cooperi*, n. gen., n. sp. 49

1a–c. Brachial, pedicle, and lateral views of a specimen from loc. T. 65.

2. Brachial view of a specimen from loc. 273. Y.P.M. 12678.

3a–d. Lateral, anterior, posterior, and antero-ventral views of a specimen from loc. T. 65. Gaptank formation, Marathon basin.

4–8. *Enteletes dumblei* Girty 45

4. Brachial interior view of a specimen from loc. Tx. T. 11047.

5. Pedicle interior view of a specimen from loc. Tx. T. 11047.

6a–c. Pedicle exterior views, and oblique lateral view of pedicle interior, of a specimen from loc. Tx. T. 11047. Word formation, Glass Mountains.

7a–c. Brachial, lateral, and posterior views of a specimen from loc. 222. Y.P.M. 12674.

8a–d. Brachial, ventral, lateral, and posterior views of a specimen from loc. 222. Y.P.M. 12674. Upper Hess formation, Glass Mountains.

9–11. *Enteletes liumbonus*, n. sp. 46

9. Pedicle view of a paratype from loc. 17. Y.P.M. 12668.

10a–c. Lateral, brachial, and posterior views of a paratype from loc. T. 15a. Hess formation, Glass Mountains.

11a–b. Pedicle and lateral views of a paratype from loc. 381. Y.P.M. 12669. Gym formation, Hueco Mountains.

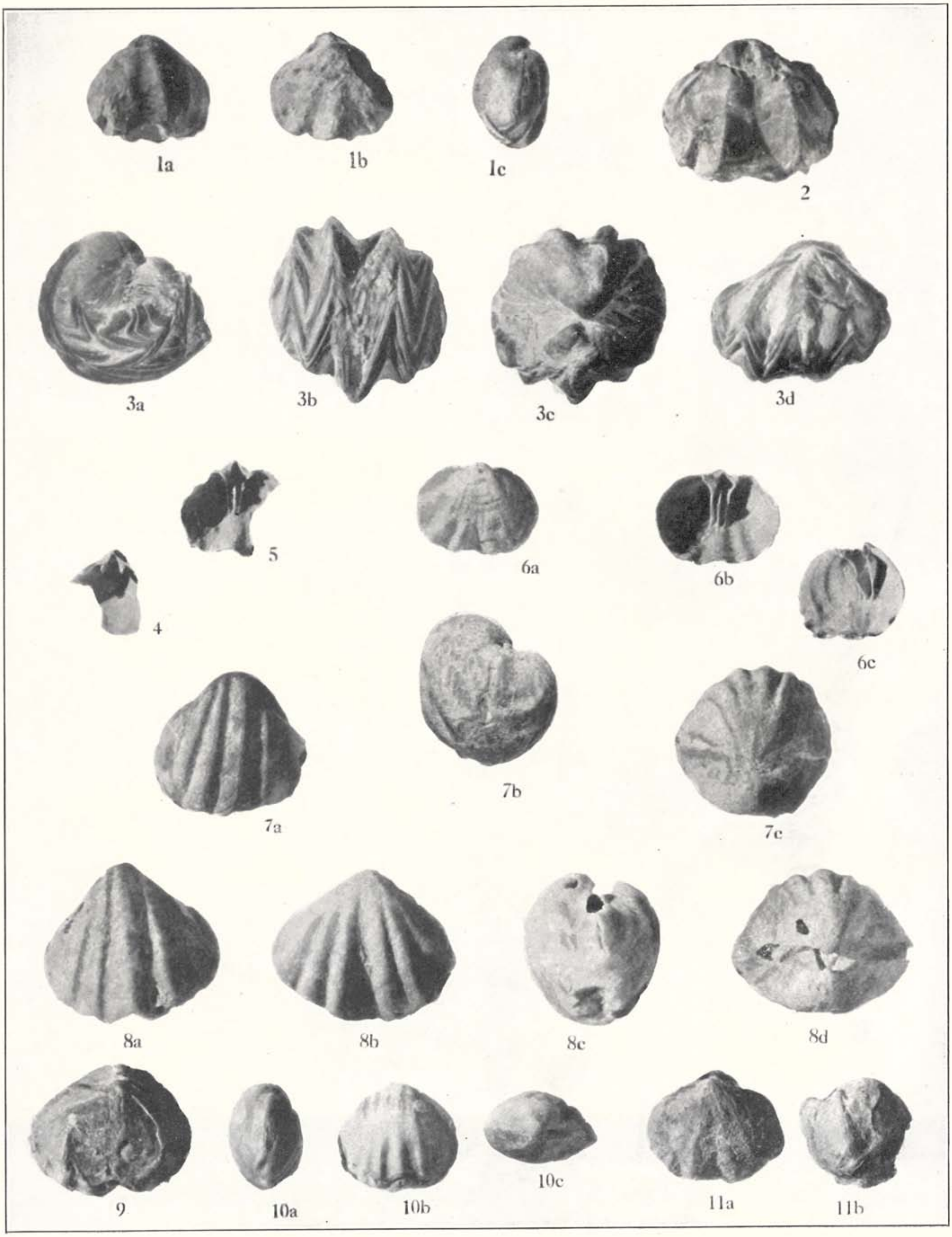
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PLATE III

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1–2. *Enteletes liumbonus*, n. sp. . . . 46

1a–d. Brachial, pedicle, lateral, and posterior views of a paratype from loc. 17. Y.P.M. 12668. Hess formation, Glass Mountains.

2a–c. Brachial, pedicle, and lateral views of the holotype from loc. 467. Y.P.M. 12670. Hess formation, Sierra Diablo.

3–8. *Enteletes plummeri*, n. sp. . . . 47

3a–b. Brachial and lateral views of a specimen from loc. T. 15. Lower Leonard formation, Glass Mountains. T. 10410.

4a–c. Brachial, pedicle, and lateral views of a specimen from loc. T. 8. T. 10410. Upper Hess formation, Glass Mountains.

5a–b. Brachial and lateral views of a specimen from loc. T. 9.

6a–b. Brachial and pedicle views of a cotype from loc. 282. Y.P.M. 12666.

7. Posterior view of a cotype from loc. 104. Y.P.M. 12667.

8. Lateral view of a specimen from loc. T. 15. Lower Leonard formation, Glass Mountains.

9. *Enteletes wolfcampensis*, n. sp. . . . 47

9a–c. Pedicle, brachial, and lateral views of the holotype, from loc. 196. Y.P.M. 12645. Wolfcamp formation, Glass Mountains.

10–12. *Enteletes leonardensis*, n. sp. . . . 46

10a–c. Brachial, pedicle, and posterior views of a specimen from loc. 28. Y.P.M. 12671.

11a–c. Lateral, posterior, and brachial views of the holotype. from loc. 128. Y.P.M. 12673.

12a–b. Brachial and posterior views of a specimen from loc. 37. T. 11031. Leonard formation, Glass Mountains.

13–15. *Enteletes wordensis*, n. sp. . . . 47–48

13a–d. Brachial, pedicle, lateral, and posterior views of the holotype, from loc. 264. Y.P.M. 12656.

14a–b. Brachial and lateral views of a brachial valve from loc. 255. Y.P.M. 12655.

15a–c. Brachial, posterior, and lateral views of a brachial valve from loc. 255. T. 10550. Word formation, Glass Mountains.

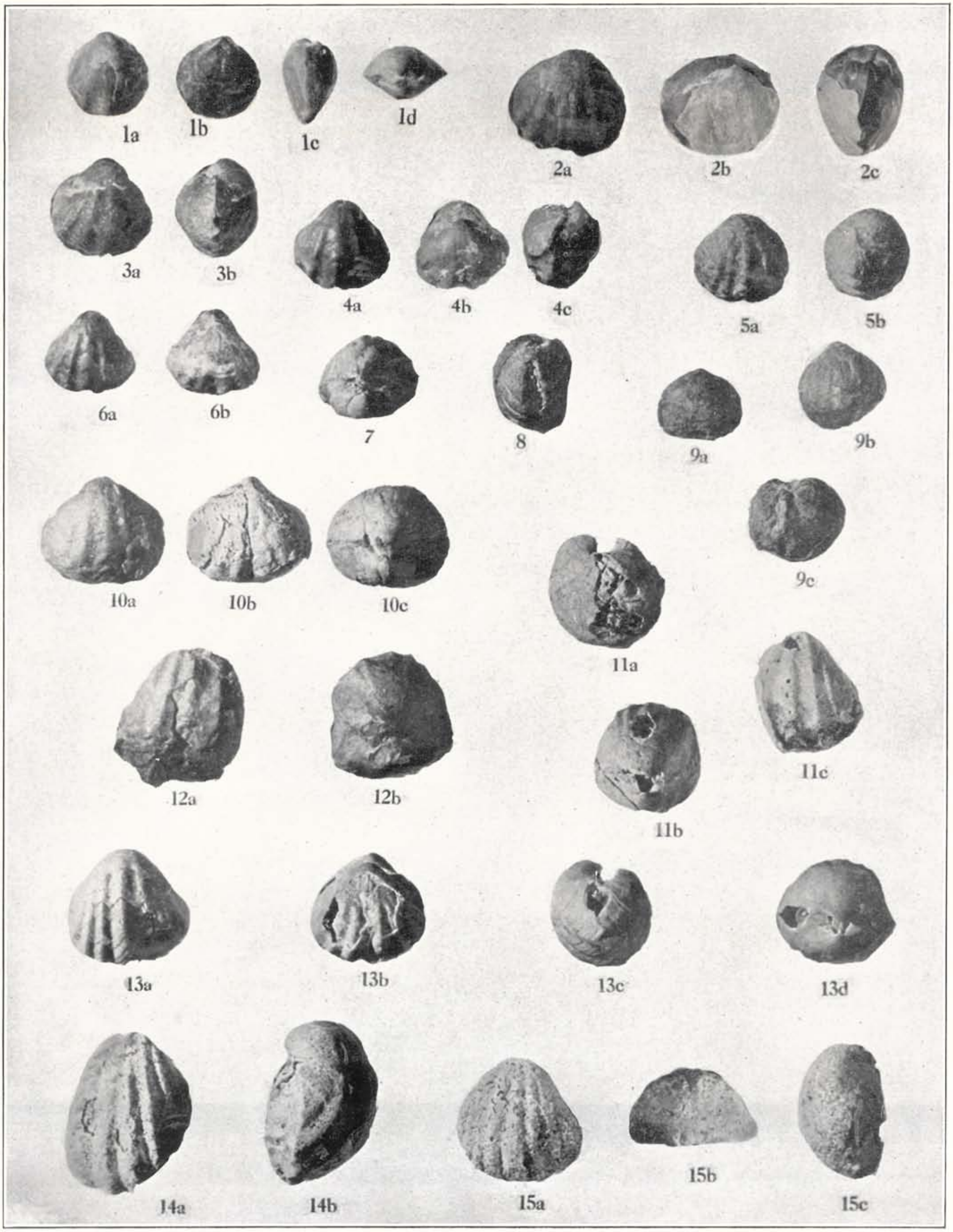
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PLATE IV

Figure— PAGE

1-3. *Streptorhynchus lamellatum*, n. sp. ... 49

1a-c. Brachial, lateral, and posterior views of the holotype, from loc. 245. In 1c the pedicle valve is up. Note dorsal cardinal area. Y.P.M. 11399. Leonard formation, Glass Mountains.

2. Brachial view of a specimen from loc. 105. Y.P.M. 11398. Hess formation, Glass Mountains.

3. Brachial view of a specimen from loc. T. 93. T. 10684. Wolfcamp formation, Glass Mountains.

4-6. *Streptorhynchus pygmaeum* Girty ... 49-50

4. Brachial view of a specimen from loc. T. 240. T. 10573. Word formation, Glass Mountains.

5a-c. Pedicle, brachial, and posterior views of a specimen from loc. 268. Y.P.M. 11387. Leonard formation, Glass Mountains.

6a-b. Pedicle and lateral views of a large specimen from loc. T. 148. T. 10578. Word formation, Glass Mountains.

7-10. *Streptorhynchus pyramidale*, n. sp. ... 50-51

7a-c. Exterior, interior, and lateral views of a brachial valve of a cotype from loc. 93. Y.P.M. 11392.

8a-c. Pedicle, cardinal, and lateral views of a pedicle valve of a cotype from loc. 93; the apical part has been ground off. Y.P.M. 11392.

9. Brachial view of a cotype from loc. 93. Y.P.M. 11392.

10. Brachial view of a cotype from loc. 93. T. 10581. Wolfcamp formation, Glass Mountains.

11-13. *Streptorhynchus? undulatum*, n. sp. ... 51

11a-d. Brachial, pedicle, posterior, and lateral views of the holotype, from loc. 211. In 11d the pedicle valve is up, the brachial down. Y.P.M. 11406.

12a-b. Pedicle and posterior views of a specimen from loc. T. 9. In 12b the pedicle valve is up, the brachial down. T. 10661.

13. Posterior view of a specimen from loc. T. 9, with the cardinal area exfoliated. T. 10661. Hess formation, Glass Mountains.

14-15. *Orthothetina* sp. (cf. *Orthothetes mutabilis* Girty) ... 52

14a-b. Brachial and lateral views of a specimen from loc. 91. Y.P.M. 11420. Wolfcamp formation, Glass Mountains.

15a-b. Brachial and posterior views of a specimen from loc. 354. Y.P.M. 11424. Limestone of Strawn age, Hueco Mountains.

16-17. *Meekella difficilis* Girty ... 53-54

16a-d. Pedicle, brachial, lateral, and posterior views of a specimen from loc. D. 1. In 16d the pedicle valve is up, the brachial down.

17. Pedicle valve from loc. 235. Y.P.M. 10897. Leonard formation. Glass Mountains.

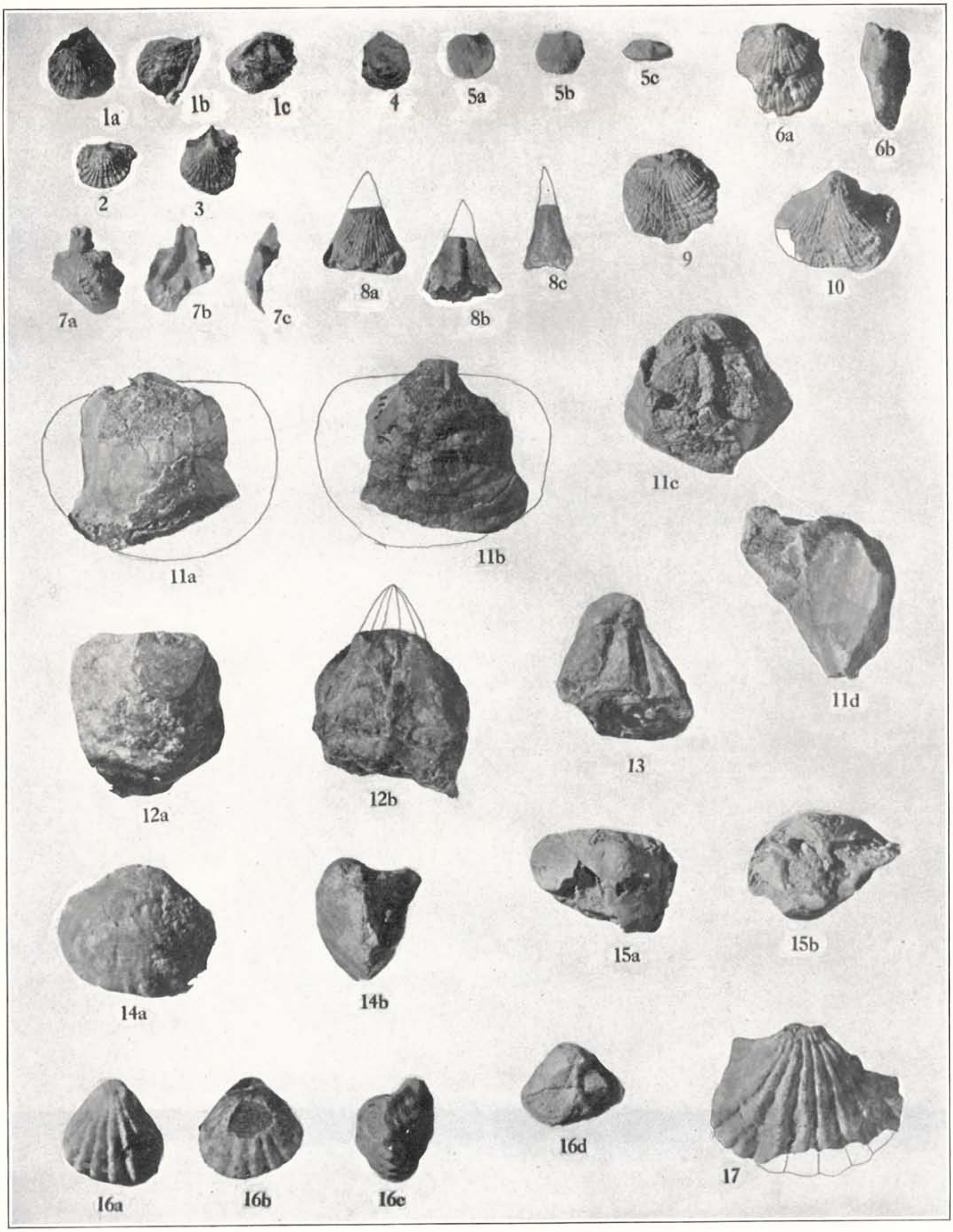
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PLATE V

Figure— PAGE

1. *Meekella difficilis* Girty ... 53
   - 1a–b. Brachial and posterior views of a brachial valve from loc. 268. Y.P.M. 10992.

2–7. *Meekella attenuata* Girty ... 52–53
   - 2a–b. Exterior and interior views of a pedicle valve from loc. Tx. T. 11028. Word formation, Glass Mountains.
   - 3a–b. Lateral and cardinal views of a specimen from loc. 123. In 3b the pedicle valve is up, the brachial down. This specimen is exceptionally small and finely plicated, and the cardinal area is unusually high. Y.P.M. 10908. Leonard formation, Glass Mountains.
   - 4a–d. Pedicle, brachial, lateral, and posterior views of a specimen from loc. 242. In 4d the pedicle valve is up, the brachial down. Y.P.M. 10921.
   - 5a–d. Brachial, pedicle, lateral, and posterior views of a specimen from loc. T. 240a. In 5d the pedicle valve is up, the brachial down. T. 10700.
   - 6a–c. Lateral, posterior, and anterior views of a large cardinal process from loc. Tx, of undetermined relationships, perhaps belonging to a *Meekella*.
   - 7a–d. Pedicle, brachial, lateral, and posterior views of a specimen from loc. Tx. 148. In 7d the pedicle valve is up, the brachial down. T. 10709. Word formation, Glass Mountains.

8–9. *Meekella hessensis*, n. sp. ... 56
   - 8a–d. Pedicle, brachial, lateral, and posterior views of the holotype, from loc. 122. Y.P.M. 10950.
   - 9a–b. Lateral and pedicle views of a specimen from loc. 222, more coarsely plicate than the holotype. Hess formation, Glass Mountains.

10–12. *Meekella globosa*, n. sp. ... 54
   - 10. Pedicle valve of a large specimen from loc. 128. T. 10609.
   - 11a–c. Pedicle, lateral, and posterior views of a cardinal process from loc. 128. Y.P.M. 10945.
   - 12a–c. Brachial, lateral, and posterior views of the holotype, from loc. 151. Y.P.M. 10944. Leonard formation, Glass Mountains.

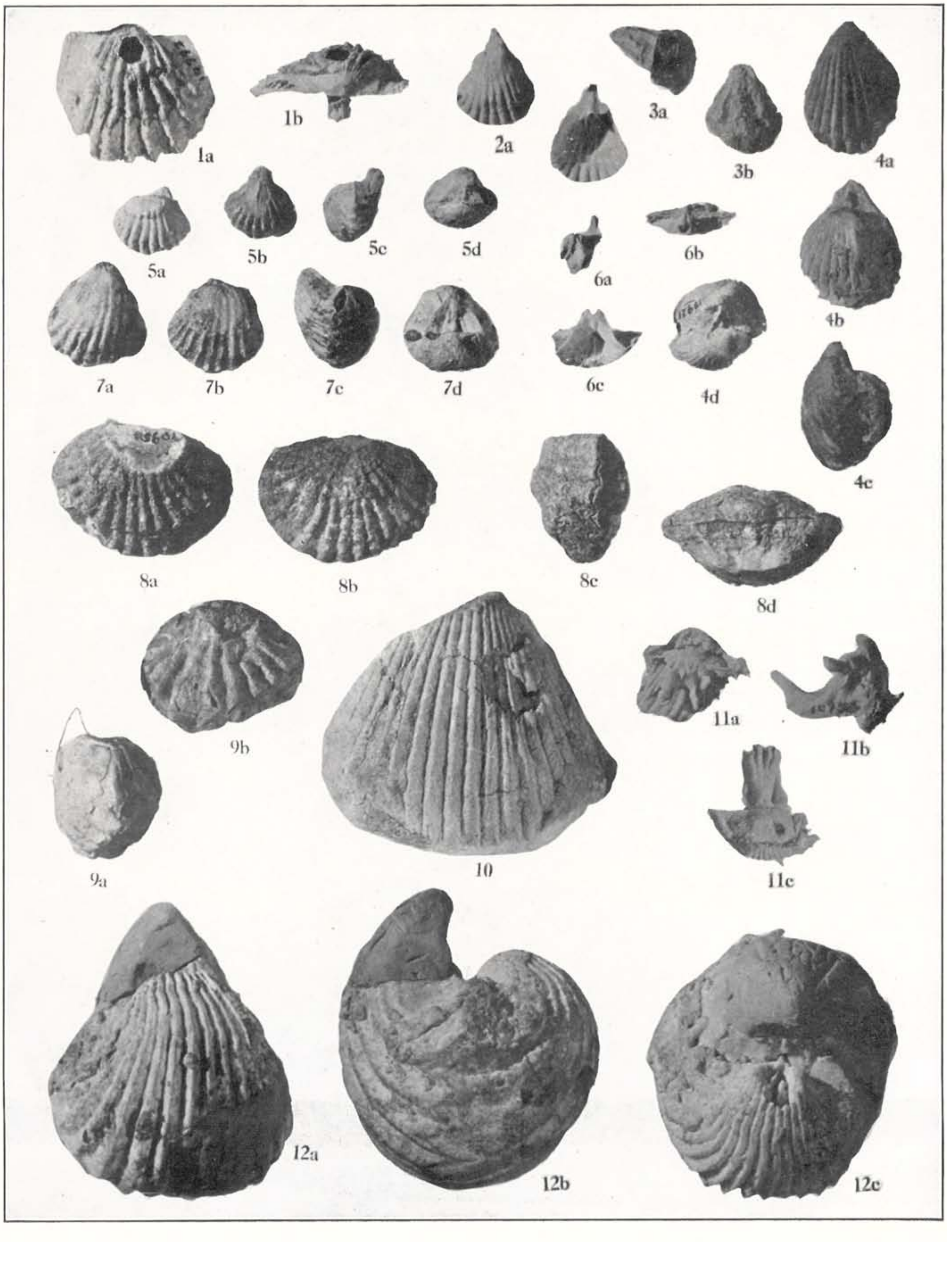
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PLATE VI

Figure— PAGE

1–4. *Meekella irregularis texana,* n. var. 55

1a–c. Pedicle, lateral, and posterior views of a pedicle valve from loc. 70.

2a–c. Pedicle, lateral, and posterior views of a pedicle valve from loc. 199, the holotype. Y.P.M. 10966.

3. Brachial valve of a specimen from loc. 95. Y.P.M. 10967.

4a–b. Pedicle and lateral views of a pedicle valve from loc. 88S. Y.P.M. 10968. Wolfcamp formation, Glass Mountains.

5–7. *Meekella grandis,* n. sp. 54–55

5a–c. Lateral, brachial, and posterior views of the holotype, from loc. 174. In 5c the pedicle valve is up, the brachial down. Y.P.M. 10589. Leonard formation, Glass Mountains.

6a–d. Ventral, posterior, inverted, anterior, and lateral views of a cardinal process from loc. 105. Y.P.M. 10890. Hess formation, Glass Mountains.

7. Brachial valve of a specimen from loc. Tg. Leonard formation, Shafter.

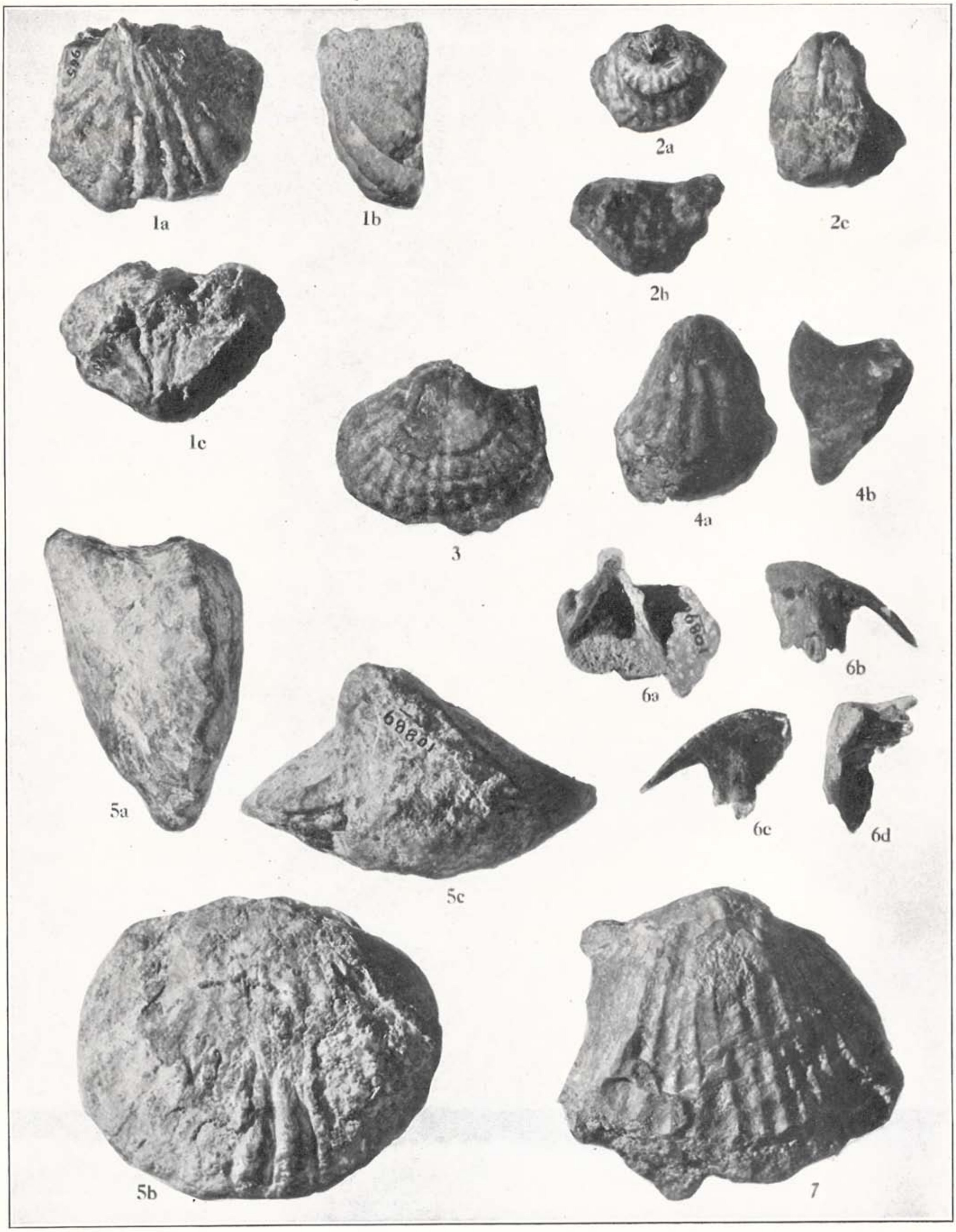
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PLATE VII

Figure— PAGE

1–5. *Meekella mexicana* Girty 55

1a–d. Pedicle, brachial, lateral, and posterior views of a specimen from loc. 434. In 1d the pedicle valve is up, the brachial down. Y.P.M. 10943.

2a–c. Lateral, pedicle, and brachial views of a specimen from loc. 434. Y.P.M. 10943.

3a–b. Brachial and posterior views of a specimen from loc. 434.

4. Posterior view of a specimen from loc. 434.

5. Posterior view of a specimen from loc. 434. Y.P.M. 10943. Middle Gym formation, Glass Mountains.

6–8. *Meekella skenoides* Girty 56

6a–d. Pedicle, brachial, lateral, and posterior views of a specimen from loc. 192. Y.P.M. 11000.

7a–d. Pedicle, lateral, brachial, and posterior views of a specimen from loc. 192. The apical part of the pedicle valve has been reconstructed with clay. In 7d the pedicle valve is up, the brachial down. T. 10748.

8. Fragmentary pedicle valve from loc. 44–46. Y.P.M. 11331. Word formation, Glass Mountains.

9. *Meekella striatocostata* (Cox), *Strophalosia hystricula* Girty, *and Streptorhynchus* sp. 56–57; 96

9a–c. Pedicle, interior, and lateral views of a pedicle valve from loc. 93S. Y.P.M. 11911. Wolfcamp formation, Glass Mountains.

10–13. *Geyerella americana* Girty 57

10a–b. Lateral and pedicle views of a pedicle valve from loc. 85, which appears to belong to this genus but is not typical of the species. Y.P.M. 10999.

11a–b. Lateral and posterior views of a specimen from loc. 35. In 11b the cardinal area is twisted to the left; it is not sharply defined, and therefore not easily distinguishable. Y.P.M. 10995.

12a–b. Lateral view of a large specimen from loc. T. 15, and longitudinal section of same, showing the median septum below, with one of the dental lamellae above joining it at an angle. Apices of both valves broken.

13. Pedicle view of a shell from loc. 17. Y.P.M. 10997. Hess (or possibly Wolfcamp) formation, Glass Mountains.

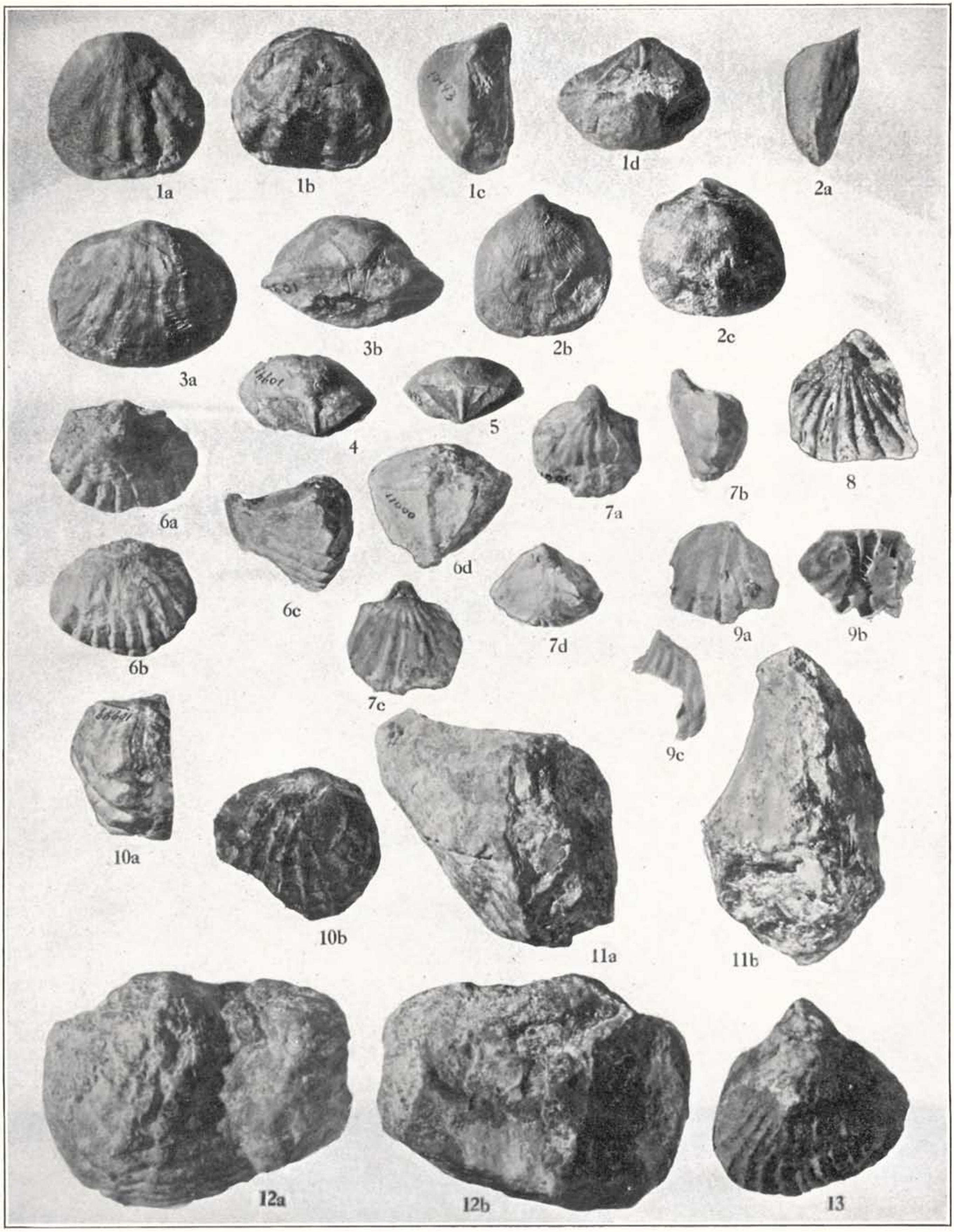
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PLATE VIII

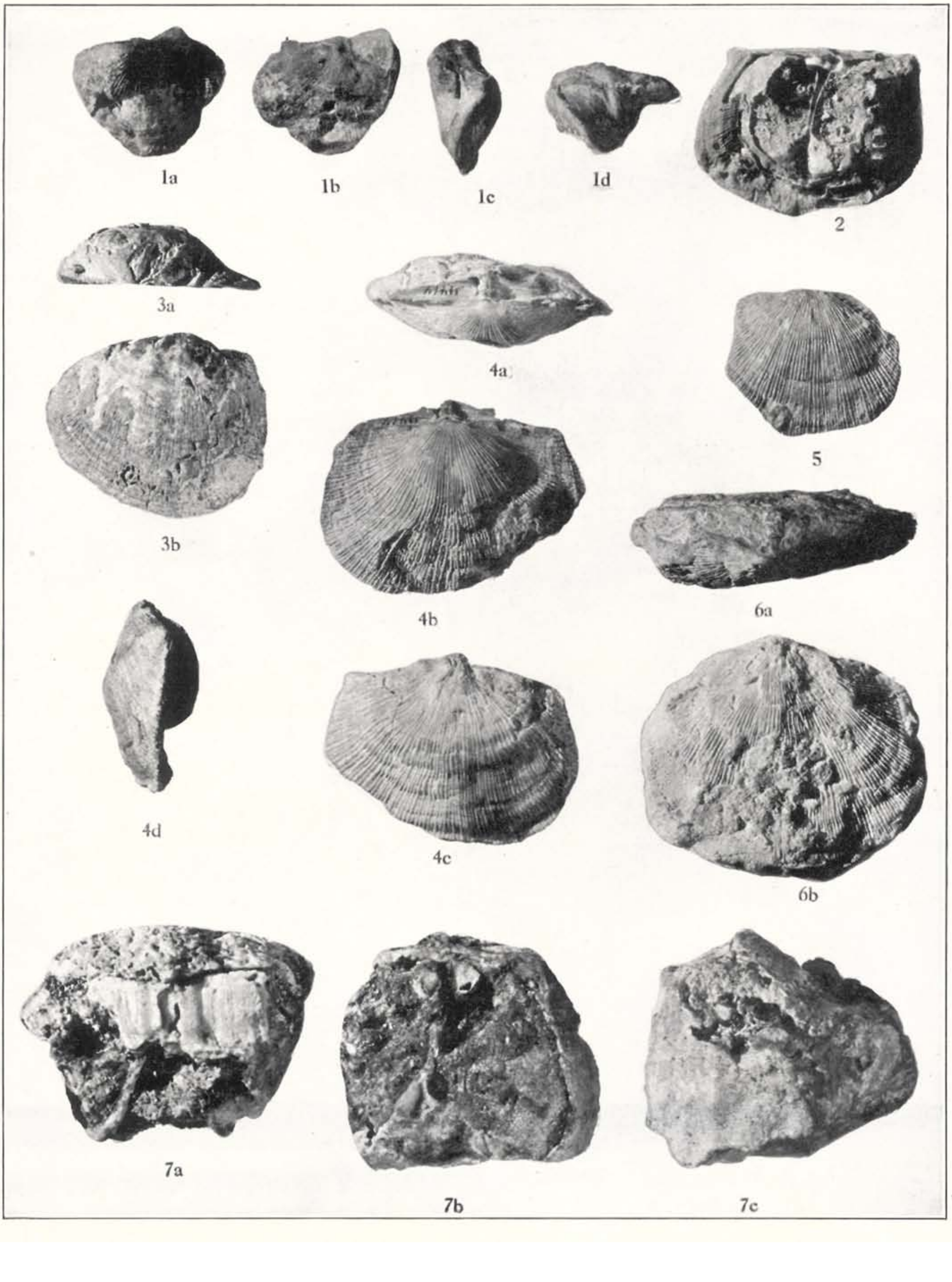
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PLATE IX

Figure— PAGE

1-4. *Chonetes permianus* Shumard 62–63

1a-b. Exterior and interior brachial views of a specimen from loc. 6. Y.P.M. 10811.

2a-b. Exterior and interior pedicle views of a specimen from loc. 6. Y.P.M. 10811. Word formation (basal limestone), Glass Mountains.

3. Pedicle view of a specimen from loc. 484. Y.P.M. 10817. Bone Canyon limestone, Sierra Diablo.

4. Pedicle view of a specimen from loc. 128. T. 10615. Leonard formation, Glass Mountains.

5. *Chonetes verneuilianus* Norwood and Pratten 64

5a-b. Pedicle and brachial views of a specimen from loc. 75. Y.P.M. 10792. Wolfcamp formation, Glass Mountains.

6. *Chonetes hillanus* Girty 61

6a-b. Internal mould of a pedicle valve, from loc. 248, and posterior view of the same. Word formation (upper limestone), Glass Mountains. Y.P.M. 10818.

7-11. *Chonetes quadratus*, n. sp. 63

7. Pedicle view of a specimen from loc. 246. Word formation, Glass Mountains. T. 10660.

8. Posterior view of a paratype from Bass Ranch, Grand Canyon. Y.P.M. 10830.

9. Pedicle view of the holotype from Bass Ranch, Kaibab formation, Grand Canyon. Y.P.M. 10830.

10. Pedicle view of a paratype from loc. 247. Y.P.M. 10833.

11. Pedicle view of a specimen from loc. T. 148. T. 10635. Word formation, Glass Mountains.

12-13. *Chonetes biplicatus*, n. sp. 60

12a-c. Pedicle, lateral, and posterior views of the holotype from loc. 476. Y.P.M. 10824. Hess formation, Sierra Diablo.

13. Pedicle view of a specimen from loc. 193. T. 10686. Wolfcamp formation, Glass Mountains.

14. *Chonetes granulifer* Owen 60

Pedicle view of a specimen from loc. 88. Y.P.M. 10796. Word formation, *Uddenites* zone, Glass Mountains.

15-16. *Chonetes spinoliratus*, n. sp. 63

15a-c. Lateral, pedicle (×3), and posterior (×3) views of the holotype, from loc. 91a. Y.P.M. 10825.

16a-b. Pedicle and brachial views of a specimen from loc. 92. T. 10588. Wolfcamp formation, Glass Mountains.

17-20. *Chonetes deliciasensis*, n. sp. 60

17a-d. Pedicle, brachial, lateral, and posterior views of a cotype from section 2, bed 12. Y.P.M. 10787.

18. Pedicle view of an internal mold from section 2, bed 12. Y.P.M. 10787.

19a-c. Posterior, pedicle, and brachial views of a cotype from section 2, bed 12. Y.P.M. 10787.

20. Exterior of pedicle valve of a cotype from section 1, bed 11. Y.P.M. 10789. Limestone of Cerro Caballo, near Las Delicias.

21-22. *Chonetes hessensis*, n. sp. 61

21a-c. Pedicle, brachial, and posterior views of a cotype from loc. 107. T. 10589.

22a-c. Lateral, pedicle (×3), and brachial (×3) views of a cotype from loc. 107. Y.P.M. 10820. Hess formation, Glass Mountains.

23. *Chonetes spinoliratus diabloensis*, n. var. 63

23a-b. Brachial and pedicle views of the holotype, from loc. 479. Y.P.M. 10829. Hess formation, Sierra Diablo.

24. *Chonetes ostiolatus* Girty 62

Pedicle view of a specimen from loc. Tn. T. 10590. Cibolo limestone.

25. *Chonetes subliratus* Girty 63-64

25a-b. Pedicle and posterior views of a pedicle valve of rather large size from loc. T. 239. T. 10730. Word formation, Glass Mountains.

26. *Chonetes molengraaffi* Broili? 61

Pedicle fragment from loc. 512. Y.P.M. 10819. Leonard formation, Finlay Mountains.

27-28. *Orthotetella wolfcampensis*, n. gen. n. sp. 51-52

27a-b. Pedicle and posterior views of a pedicle valve from loc. 93. T. 10446.

28a-c. Posterior, pedicle, and pedicle interior views of the holotype, from loc. 93. Y.P.M. 11366. Wolfcamp formation, Glass Mountains.

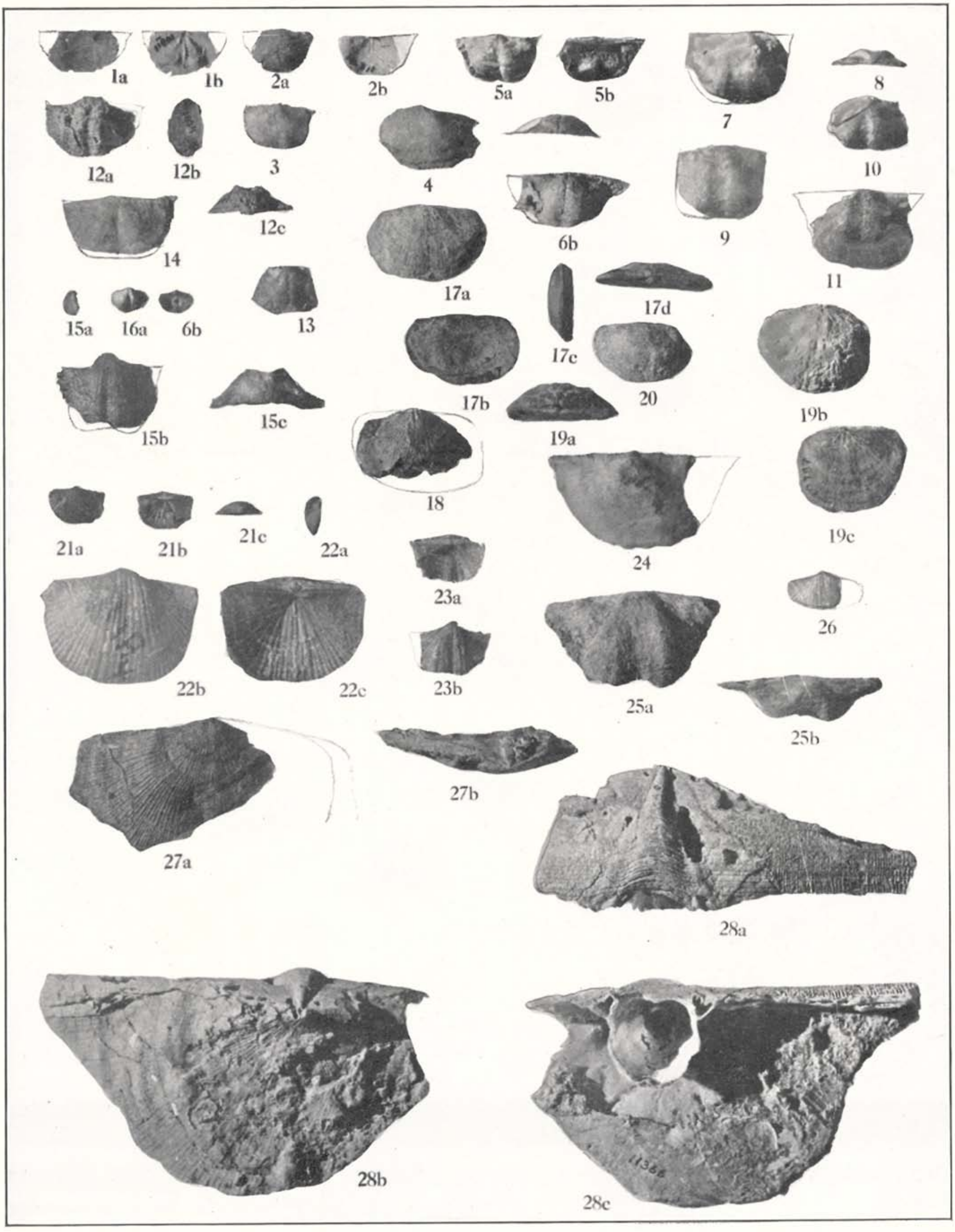
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PLATE X

Figure PAGE

1–7. *Chonetes subliratus* Girty 63–64

1a–b. Pedicle and brachial views of a shell from loc. 123, showing the inner shell surface. T. 10733.

2. Pedicle view of a small specimen from loc. 123, inner surface shown. Y.P.M. 10839. Leonard formation, Glass Mountains.

3. Interior of a pedicle valve from loc. 46, showing only the outer smooth shell layer. Y.P.M. 10856.

4a–b. Posterior and pedicle views of a specimen from loc. 250, showing outer smooth shell layer. Y.P.M. 10868.

5. Pedicle valve from loc. 253, the surface of which is formed by the outer smooth layer, showing the penetrating holes. T. 10742. Word formation, Glass Mountains.

6. Pedicle valve from loc. 512. Y.P.M. 10847. Leonard formation, Finlay Mountains.

7a–c. Pedicle, brachial, and posterior views of a specimen from loc. 123. Y.P.M. 10839. Leonard formation, Glass Mountains.

8. *Isogramma millepunctata* (Meek and Worthen) 65

Part of a pedicle valve (internal mold) from loc. 203. Y.P.M. 10837. Wolfcamp formation, Glass Mountains.

9–11. *Productus guadalupensis* Girty 67

9a–c. Pedicle, anterior, and lateral views of a specimen from loc. 246. Y.P.M. 10743.

10a–c. Pedicle, lateral, and posterior views of a specimen from loc. 246. Y.P.M. 10743.

11. Lateral view of a specimen from loc. T. 148. Upper Word formation, Glass Mountains.

12. *Productus dartoni*, n. sp. 67

12a–c. Pedicle, lateral, and posterior views of a cotype from loc. 385. Y.P.M. 10740. Lower Gym formation, Hueco Mountains.

13. *Productus dartoni*, n. sp., and *Composita mira* Girty 67, 129

13a–c. Posterior, anterior, and lateral views of a cotype from loc. 460. Y.P.M. 10739. Upper Wolfcamp formation, Sierra Diablo.

14. *Productus dartoni sullivanensis*, n. var. 67

14a–c. Pedicle, posterior, and lateral views of a specimen from loc. 46. Y.P.M. 10767. Lower Word formation, Glass Mountains.

15. *Productus capitanensis* Girty 66–67

15a–b. Pedicle and lateral views of a specimen from loc. 179. Y.P.M. 10773. Gilliam member, Glass Mountains.

16–17. *Productus arcticus* Whitfield 66

16a–c. Pedicle, lateral, and brachial views of a specimen from loc. 247. Y.P.M. 10769.

17a–c. Posterior, pedicle, and lateral views of a specimen from loc. 247. Y.P.M. 10769. Upper Word formation, Glass Mountains.

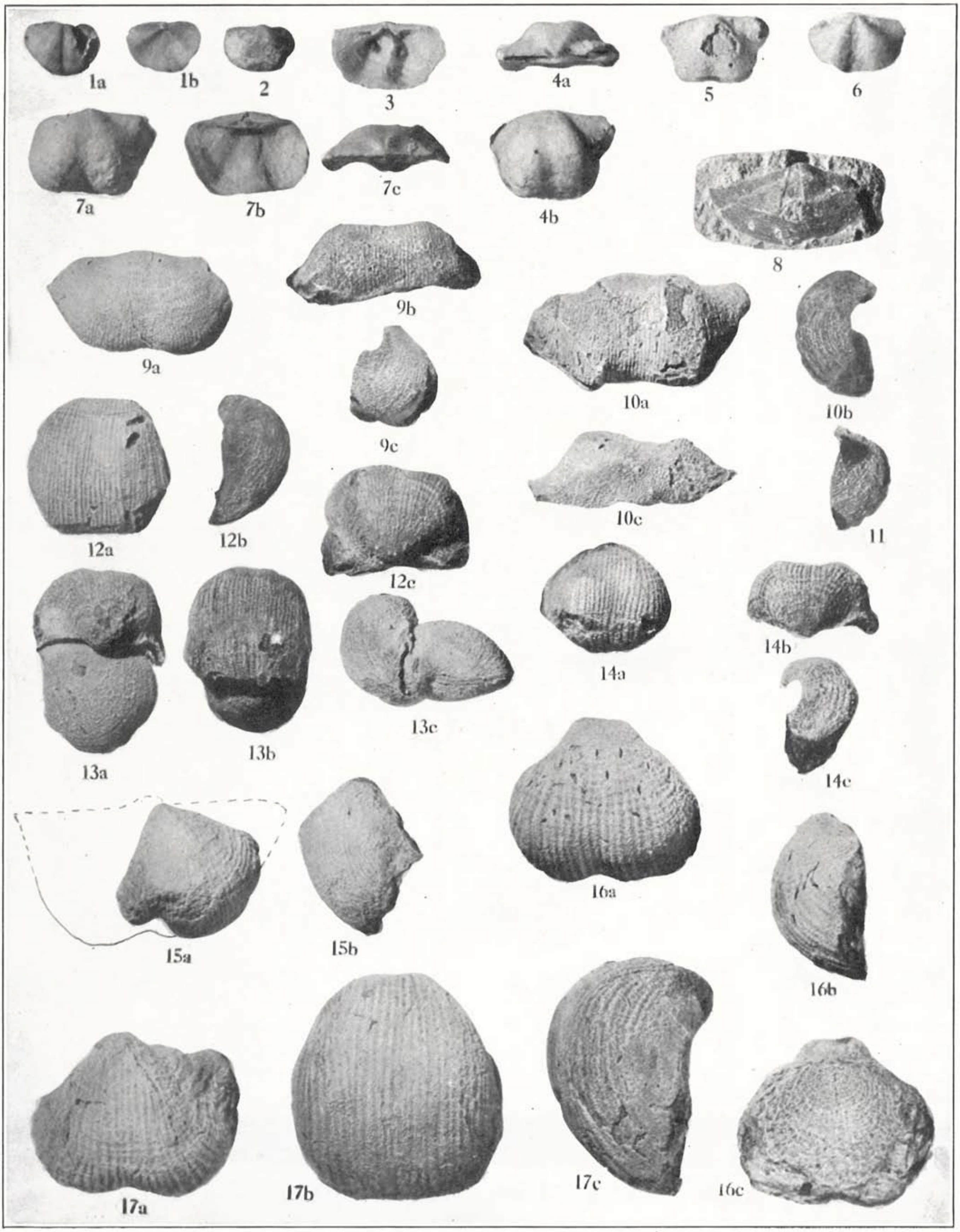
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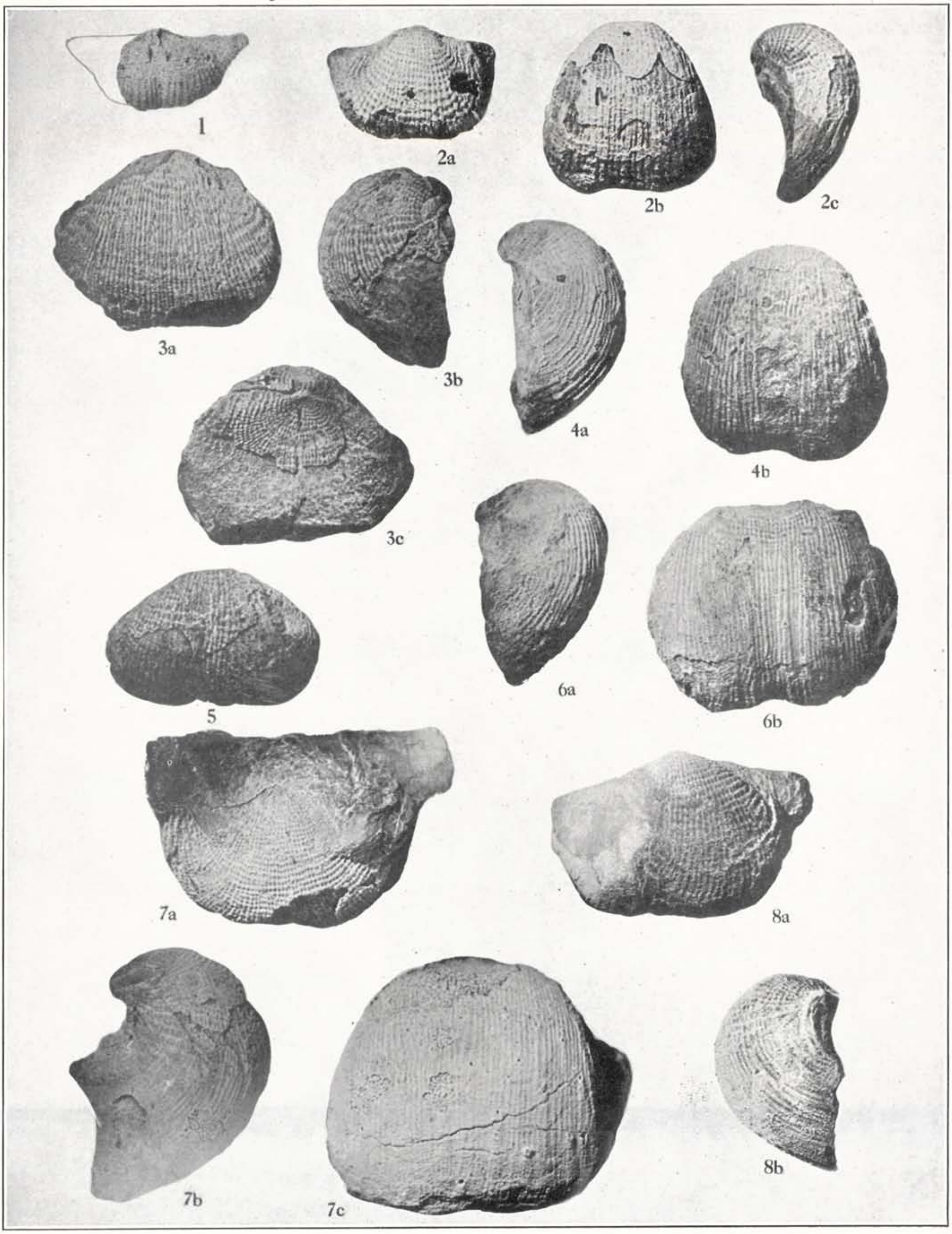
PLATE XI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1a–b. Posterior and pedicle views of a specimen from loc. 174. Y.P.M. 10608.

2. Pedicle view of a specimen from loc. 123.

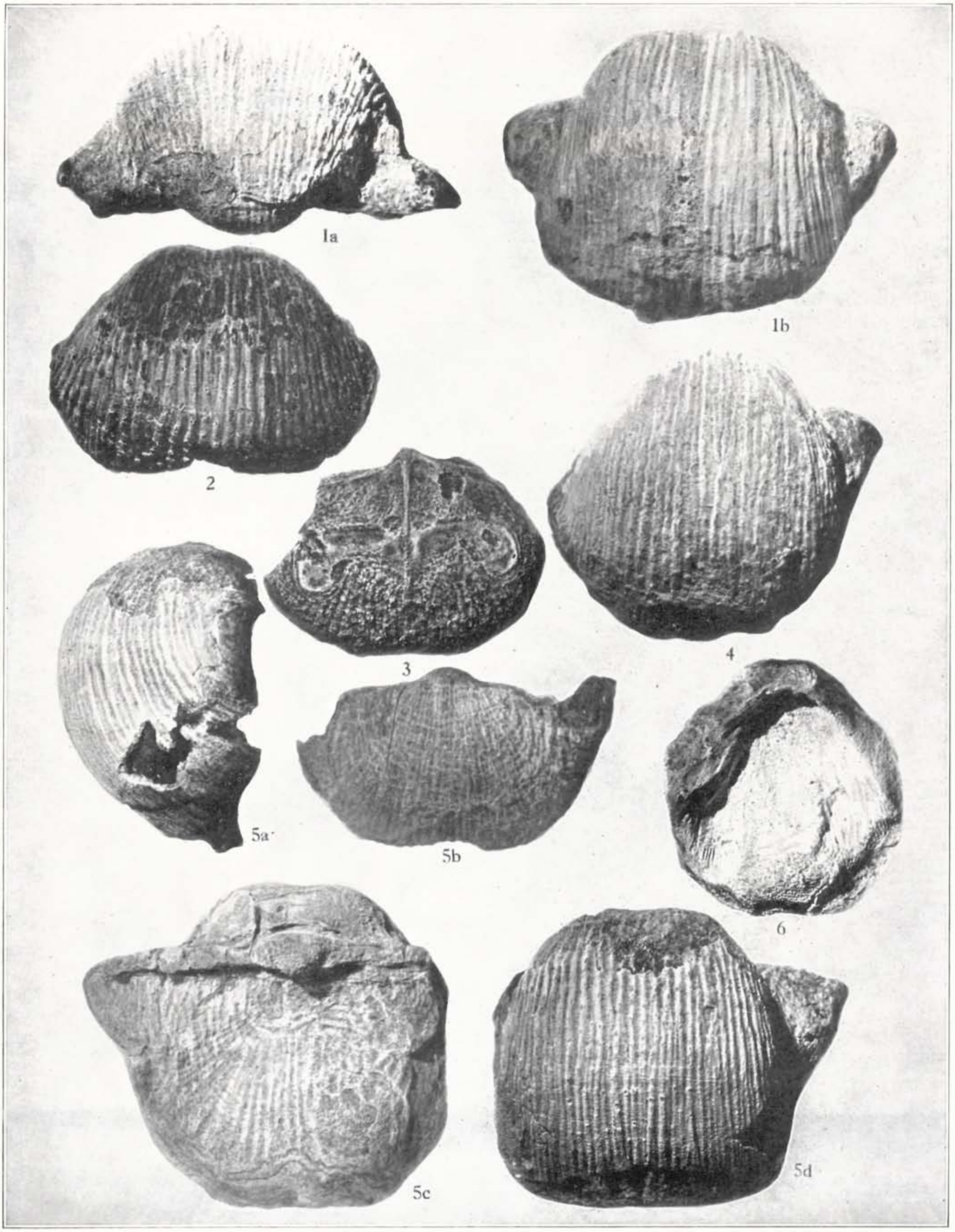
3. Interior of brachial valve from loc. T. 128. T. 9980.

4. Pedicle view of a specimen from loc. 174. T. 10049.

5a–d. a, c, d, lateral, brachial, and pedicle views of a specimen from loc. 123; b, posterior view of another specimen from the same locality. Y.P.M. 10629.

6. Interior of a very thick old pedicle valve from loc. 15. Y.P.M. 10593.

Leonard formation, Glass Mountains.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1–3. *Productus multistriatus* Meek 71

1. Pedicle view of a specimen from loc. T. 240. The anterior trail of the shell is not preserved. T. 10036.

2a–b. Lateral and pedicle views of a specimen from loc. 144. The anterior trail of the shell is not preserved. Y.P.M. 10647. Middle Word formation, Glass Mountains.

3a–c. Pedicle, lateral, and anterior views of a specimen from section 1, bed 14, showing the smaller size of the Mexican specimens. Y.P.M. 10648. Limestone of Cerro Caballo, Las Delicias, Coahuila.

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5a–c. Pedicle, lateral, and brachial views of a specimen from loc. 415. Y.P.M. 10645. Middle Gym formation, Hueco Mountains.

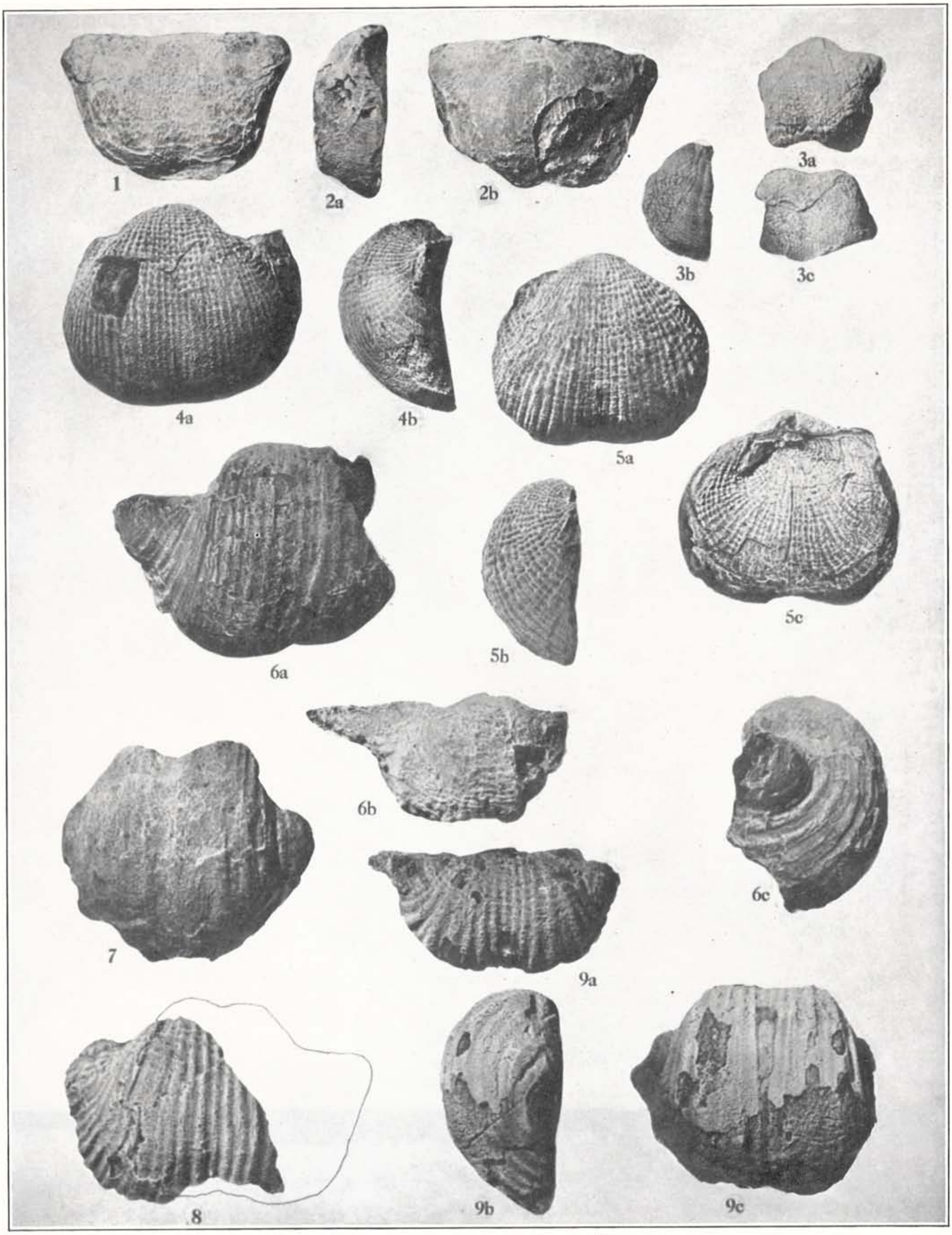
6–9. *Productus indicus* Waagen 72–73

6a–c. Pedicle, posterior, and lateral views of a specimen from loc. 46. Y.P.M. 10559. Word formation, Glass Mountains.

7. Pedicle view of a specimen from loc. 517. Y.P.M. 10562. Leonard formation, Shafter.

8. Part of pedicle valve from loc. T. 251. T. 10254.

9a–c. Posterior, lateral, and pedicle views of a specimen from loc. 46. T. 10250. Word formation, Glass Mountains.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1–3. *Productus gratiosus occidentalis* Schellwien ... 71

1a–d. Pedicle, brachial, lateral, and posterior views of a specimen from loc. 93. Y.P.M. 10768.

2. Pedicle view of a specimen from loc. 93. T. 10307. Wolfcamp formation, Glass Mountains.

3a–c. Pedicle, lateral, and posterior views of a specimen from loc. Sd. Y.P.M. 12664. Gaptank formation, Marathon Basin.

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4a–b. Brachial and pedicle views of a shell from loc. 128. Y.P.M. 10712.

5. Lateral view of a cotype from loc. 120. Y.P.M. 10706.

6a–c. Lateral, anterior, and pedicle views of a pedicle valve from loc. Tb. T. 10337.

7. External mold of a dorsal valve from loc. 10. Y.P.M. 10715.

8. Produced anterior part of a shell from loc. 128. Y.P.M. 10712.

9. Part of a pedicle valve from loc. 128, showing spines along posterior margin, and upturned marginal part of shell. Y.P.M. 10712. Leonard formation, Glass Mountains.

10–14. *Productus occidentalis* Newberry ... 72–73

10. Interior of brachial valve from loc. 123, showing brachial ridges. Y.P.M. 10566.

11. Pedicle view of a specimen from loc. 174.

12. Pedicle view of a specimen from loc. 174. Y.P.M. 10565.

13. Brachial view of a large, broad specimen from loc. 128, showing spine projecting from one of the ears. Y.P.M. 10563. Leonard formation, Glass Mountains.

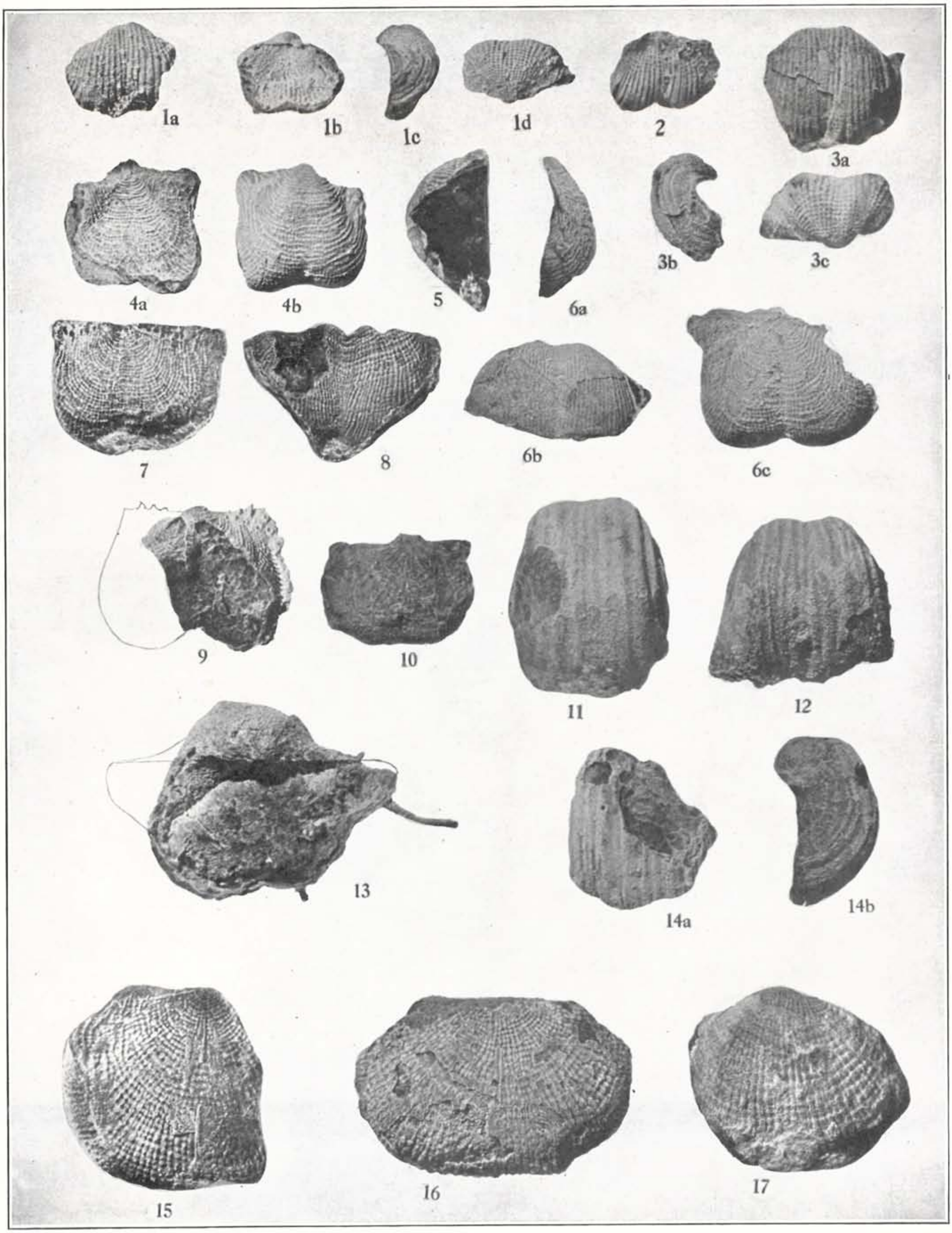
14a–b. Pedicle and lateral views of a specimen from loc. 247. T. 10319. Upper Word formation, Glass Mountains.

15–17. *Productus semireticulatus hermosanus* Girty? ... 73–74

15. Mold of brachial valve from loc. 88S. Y.P.M. 10698.

16. Part of a pedicle valve from loc. 87. T. 10288.

17. Part of a pedicle valve from loc. 195. Y.P.M. 10694. Wolfcamp formation, Glass Mountains.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1–5. *Productus schucherti*, n. sp. 73

1a–c. Posterior, lateral, and brachial views of a specimen from loc. 484. Y.P.M. 10765.

2a–c. Posterior, pedicle, and lateral views of a specimen from loc. 484. T. 10311. Bone Canyon limestone, Sierra Diablo.

3a–b. Brachial and pedicle views of a cotype from loc. 120. Y.P.M. 10763.

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5a–b. Posterior and pedicle views of a specimen from loc. D1. Leonard formation, Glass Mountains.

6–11. *Productus semistriatus* Meek 74

6a–c. Anterior, posterior, and lateral views of a specimen from loc. 92. Y.P.M. 10667. Wolfcamp formation, Glass Mountains.

7a–b. Lateral and brachial views of a specimen from loc. 376. T. 10286. Lower Gym formation, Hueco Mountains.

8a–c. Lateral, posterior, and pedicle views of an exceptionally broad specimen from loc. 88S. Y.P.M. 10675. Wolfcamp formation, *Uddenites* zone, Glass Mountains.

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10a–b. Lateral and pedicle views of a specimen from loc. 382. T. 10276. Lower Gym formation, Hueco Mountains.

11. Pedicle view of a specimen from loc. 93S. Y.P.M. 10669. Wolfcamp formation, Glass Mountains.

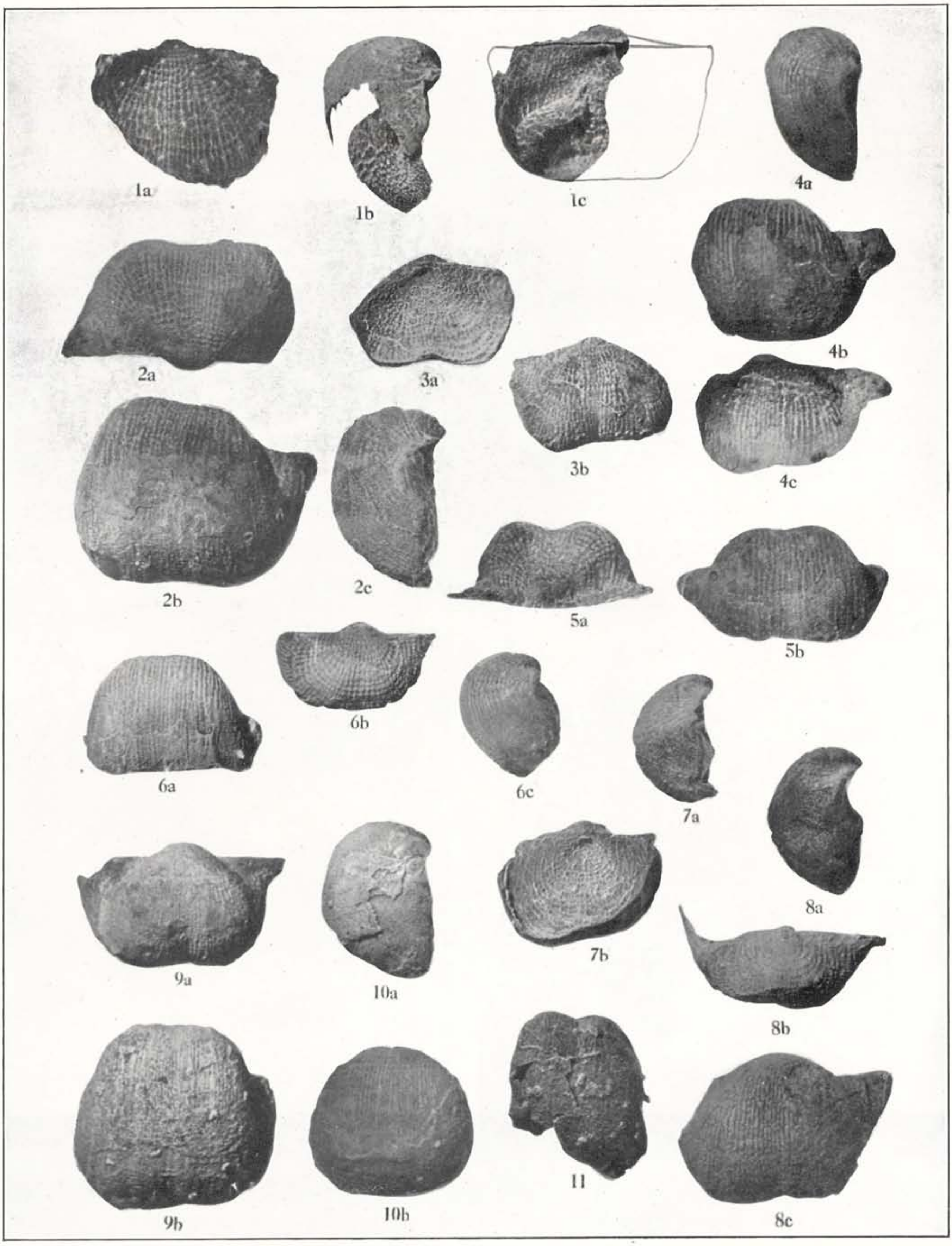
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PLATE XVI

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1–5. *Productus wolfcampensis*, n. sp. 74–75

1a–b. Pedicle and lateral views of a specimen from loc. 460. Y.P.M. 10663. Upper Wolfcamp formation, Sierra Diablo.

2a–b. Posterior and lateral views of a specimen from loc. 198. T. 10343. Wolfcamp formation, Glass Mountains.

3a–c. Pedicle, lateral, and posterior views of the holotype, from loc. Tmm. T. 10339. Lower Gym formation, Hneco Mountains.

4a–b. Pedicle and lateral views of a specimen from loc. 456. Y.P.M. 10662.

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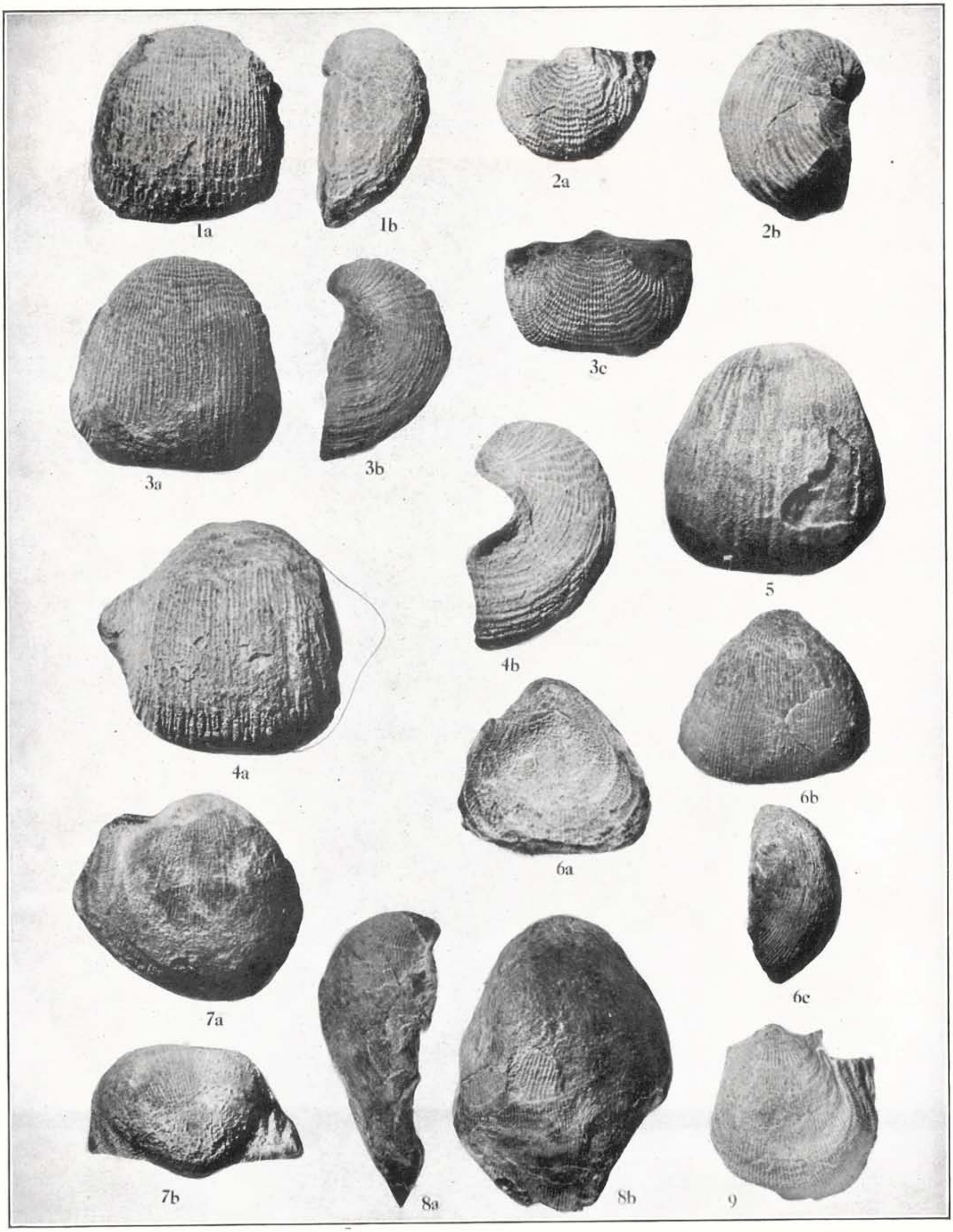
8–9. *Linoproductus cora angustus*, n. var. 76

8a–b. Lateral and pedicle views of a specimen from loc. 15. T. 10057. Leonard formation, Glass Mountains.

9. Pedicle view of a cotype from loc. 105. Y.P.M. 11519. Hess formation, Glass, Mountains.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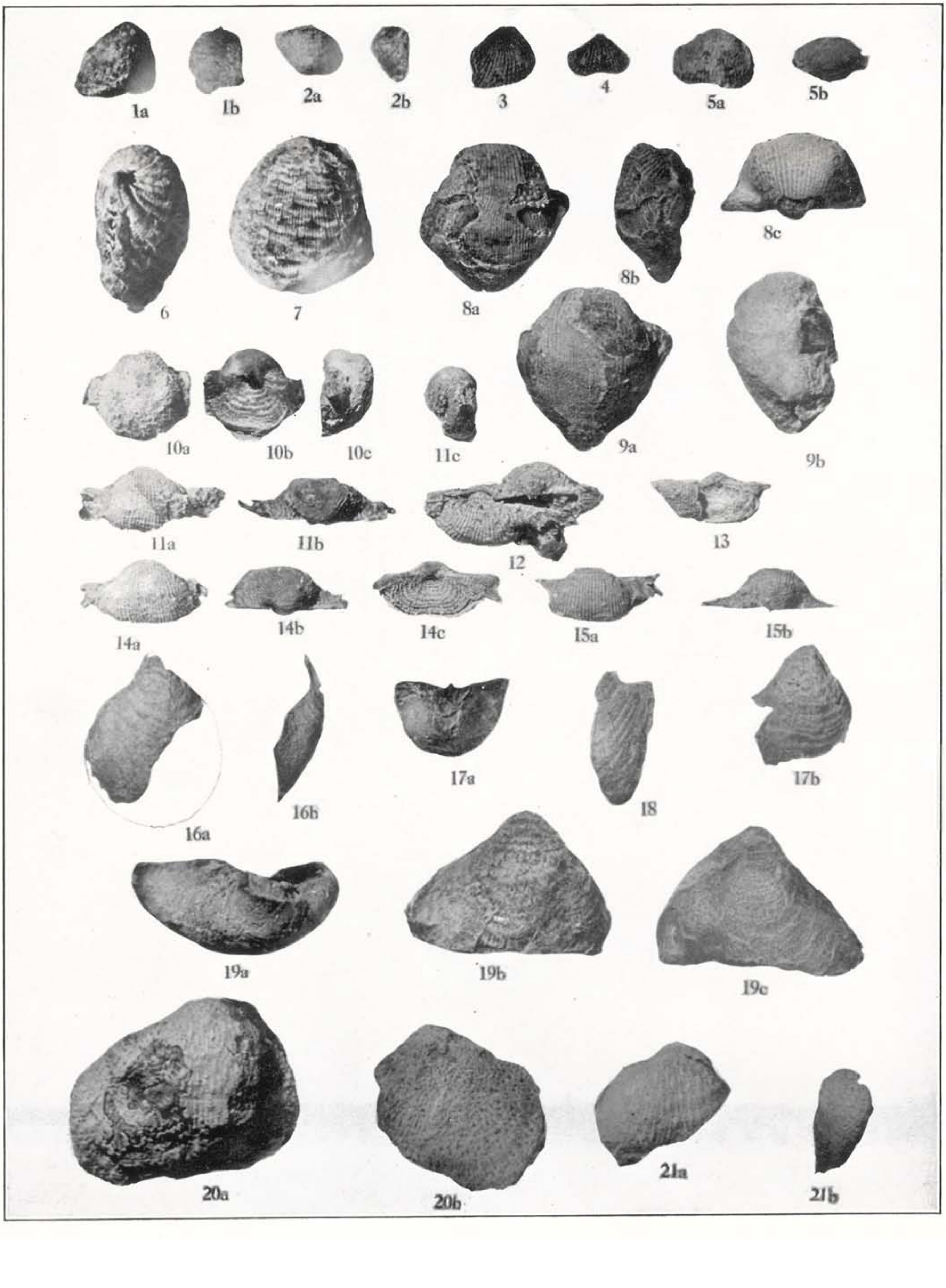
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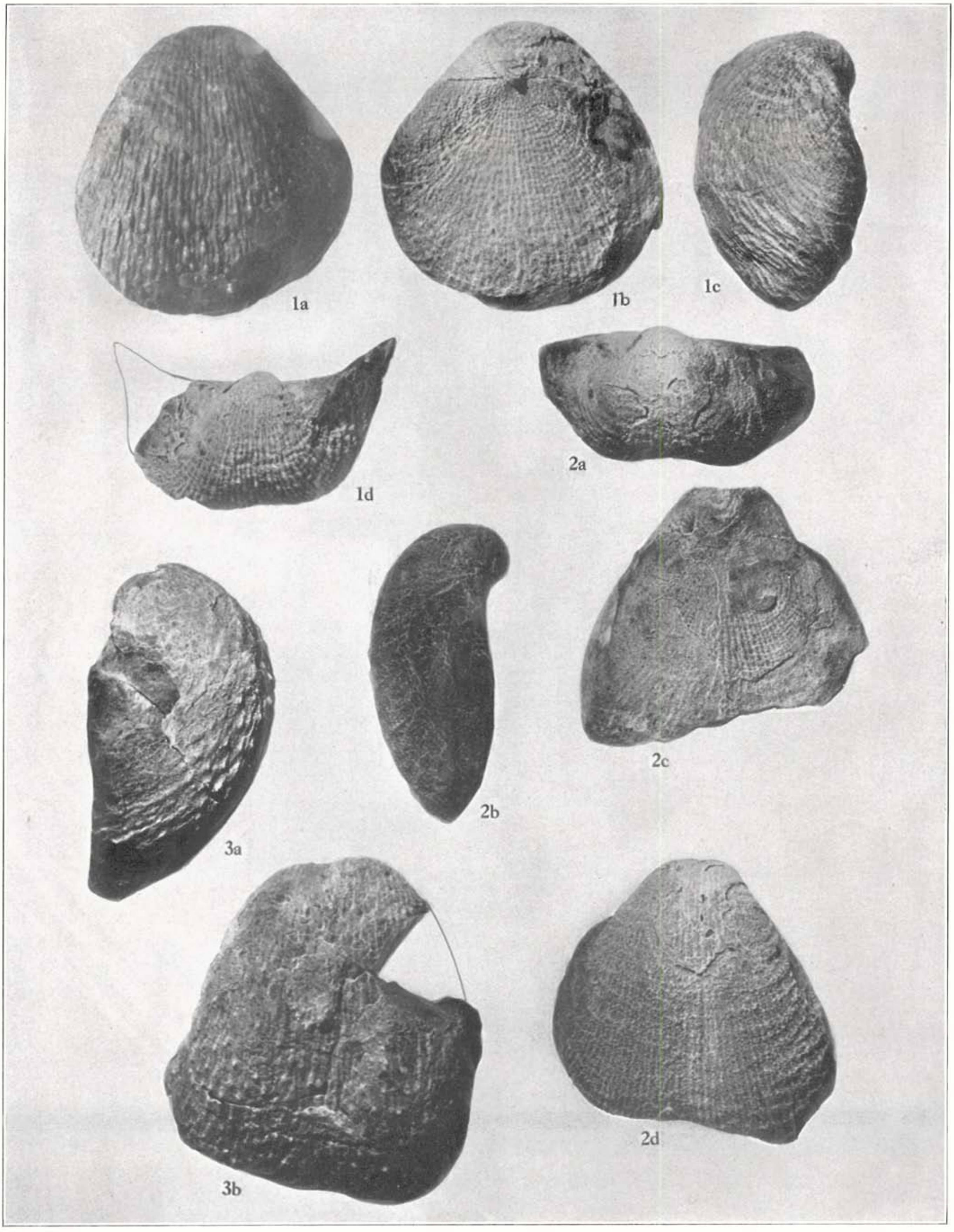
PLATE XVIII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2–4. *Waagenoconcha leonardensis*, n. sp. 80–81
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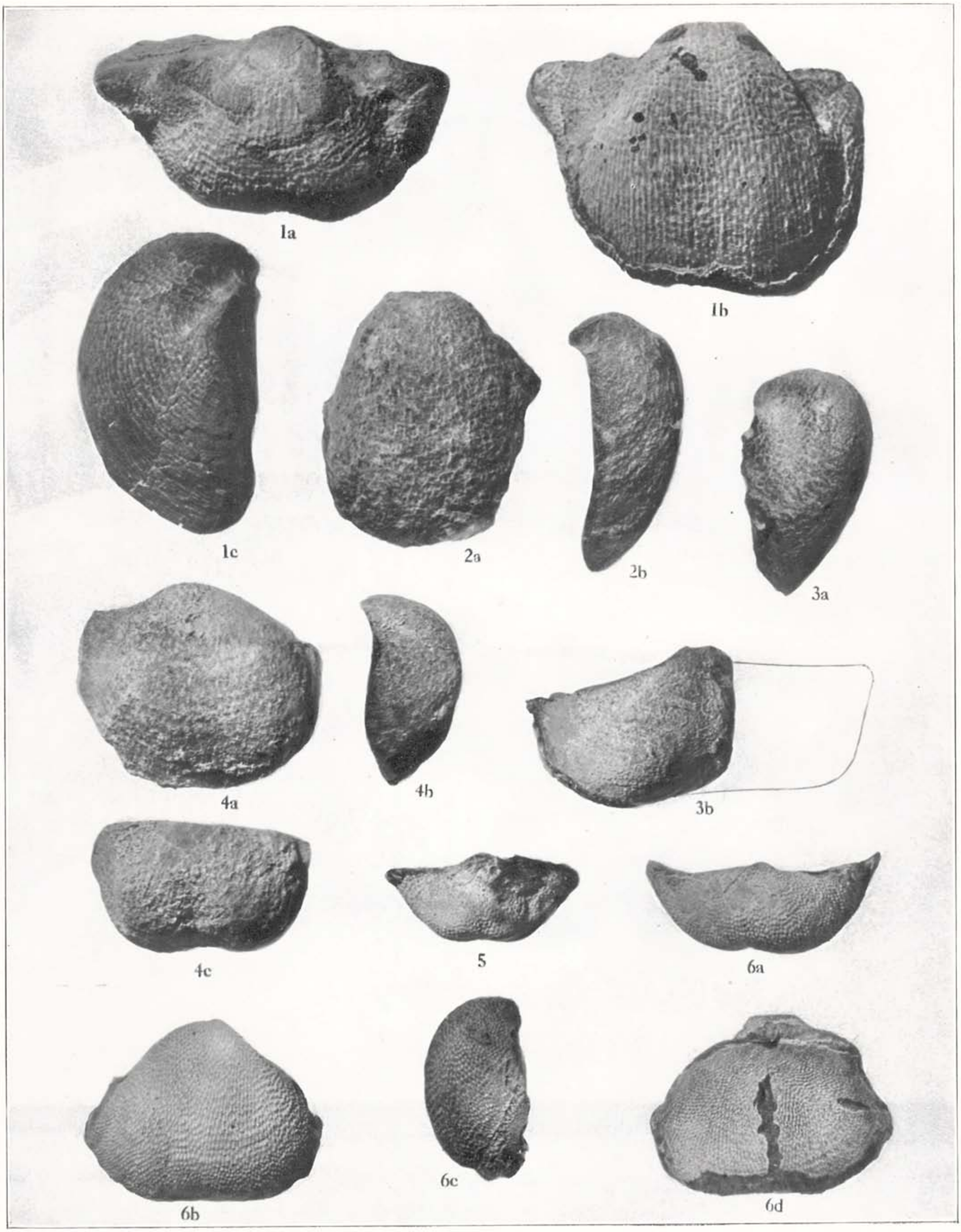
   6a–d. Posterior, pedicle, lateral, and brachial views of a specimen from loc. 146. Y.P.M. 11674. Word formation, Glass Mountains.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1–3. *Overtonia cristato-tuberculata* (Kozlowski) 82

1. Pedicle view of a specimen from loc. Tba. T. 9994.

2a–b. Pedicle and lateral views of a specimen from loc. 94. Y.P.M. 11499.

3a. Pedicle view of a specimen from loc. 94. Y.P.M. 11499. Wolfcamp formation, *Uddenites* zone, Glass Mountains.

4–5. *Avonia meekana* (Girty) 83

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6. *Avonia ? incurvata*, n. sp. 83

6a–c. Pedicle, lateral, and posterior views of the holotype, from loc. 46. Y.P.M. 11583. Lower Word formation, Glass Mountains.

7–9. *Avonia boulei* (Kozlowski) 82–83

7a–c. Pedicle, lateral, and posterior views of a specimen from loc. 193. T. 10375.

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11. Pedicle view of a specimen from loc. T. 239. T. 10255. Middle and upper Word formation, Glass Mountains.

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12a–b. Pedicle and lateral views of a specimen from loc. 440a. Y.P.M. 11608. Upper Gym formation, Hueco Mountains.

13. Lateral view of a specimen from loc. 137. T. 10256. Middle Word formation, Glass Mountains.

14. Pedicle view of a specimen from loc. 123. Y.P.M. 11607. Leonard formation, Glass Mountains.

15. Pedicle view of a specimen from loc. 137. Word formation, Glass Mountains.

16–24. *Avonia signata* (Girty) 83

16a–b. Pedicle and lateral views of a specimen from loc. 144. showing the large hollow spines on the ears. Y.P.M. 11531.

17a–b. Pedicle and lateral views of a specimen from loc. 144. T. 10235.

18. Pedicle view of a specimen from loc. 148.

19. Lateral view of a specimen from loc. 253. Y.P.M. 11545.

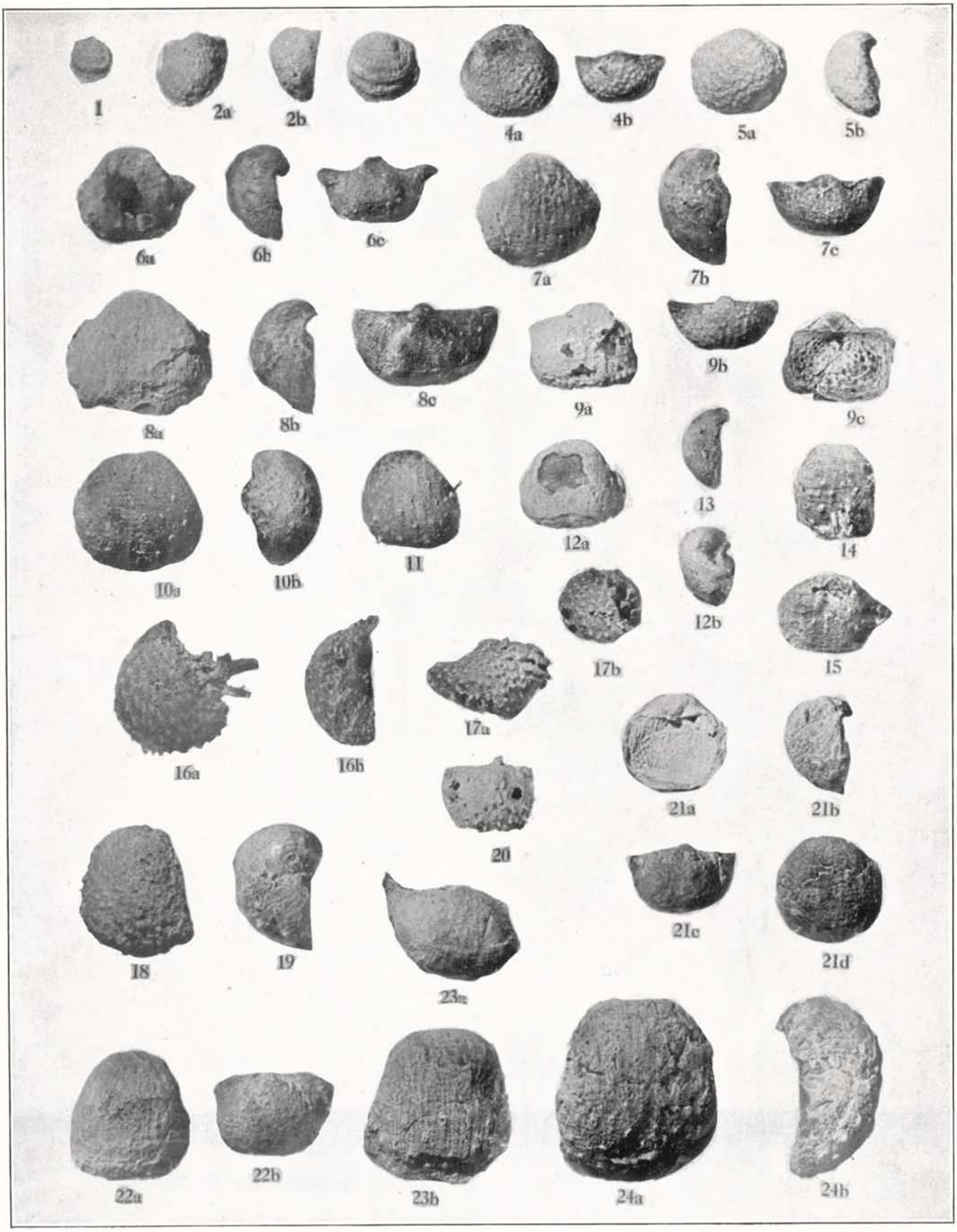
20. Interior of brachial valve from loc. Tx. T. 11070.

21a–d. Brachial, lateral, posterior, and pedicle views of a specimen from loc. 247. Y.P.M. 11543.

22a–b. Pedicle and posterior views of a specimen from loc. 247. Y.P.M. 11543.

23a–b. Posterior and pedicle views of a specimen from loc. T. 148. T. 10232.

24a–b. Pedicle and lateral views of a specimen from loc. 246. Y.P.M. 11544. Middle and upper Word formation, Glass Mountains.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1–5. *Avonia walcottiana* (Girty) ... 85
- 1. Pedicle view of a specimen from loc. x. T. 11039.
- 2a–b. Pedicle and posterior views of a specimen from loc. 248. Y.P.M. 11571.
- 3a–b. Pedicle and lateral views of a specimen from loc. 144. T. 11313.
- 4. Pedicle view of a specimen from loc. 240. Y.P.M. 11576.
- 5a–c. Pedicle, lateral, and posterior views of a specimen from loc. 144. Y.P.M. 11575. Word formation, Glass Mountains.

6–7. *Marginifera dugoutensis*, n. sp. ... 87
- 6. Pedicle view of a cotype from loc. 193. Y.P.M. 11773.
- 7a–b. Posterior and pedicle views of a cotype from loc. 193. Y.P.M. 11773. Wolfcamp formation, Glass Mountains.

8–13. *Avonia walcottiana costata*, n. var. ... 85
- 8. Pedicle view of a cotype from loc. T. 240. T. 10282.
- 9a–b. Pedicle and lateral views of a cotype from loc. T. 240. T. 10282.
- 10a–b. Pedicle and posterior views of a cotype from loc. T. 240. T. 10282.
- 11. Pedicle view of a cotype from loc. T. 240. T. 10282.
- 12a–b. Pedicle and lateral views of a cotype from loc. T. 240. T. 10282.
- 13. Lateral view of a specimen from loc. 241. Y.P.M. 11568. Word formation, Glass Mountains.

14–18. *Marginifera capaci* (d'Orbigny) ... 86
- 14a–c. Pedicle, brachial, and lateral views of a specimen from loc. 439. Y.P.M. 11772. Upper Gym formation, Hueco Mountains.
- 15a–c. Pedicle, posterior, and lateral views of a specimen from loc. 376. Y.P.M. 11770.
- 16a–b. Pedicle and posterior views of a specimen from loc. 384. Lower Gym formation, Hueco Mountains.
- 17. Pedicle view of a specimen from loc. 196. Y.P.M. 11763.
- 18a–b. Pedicle and posterior views of a specimen from loc. 88. Wolfcamp formation, Glass Mountains.

19–21. *Marginifera cristobalensis* Girty ... 86–87
- 19a–b. Lateral and posterior views of a specimen from loc. 120. T. 10188.
- 20a–c. Pedicle, lateral, and posterior views of a specimen from loc. 120. Y.P.M. 11641.
- 21. Pedicle view of a specimen from loc. 125. Y.P.M. 11662. Leonard formation, Glass Mountains.

22–24. *Marginifera manzanica* Girty ... 87
- 22a–c. Pedicle, brachial, and posterior views of a specimen from loc. 4. Y.P.M. 11687.
- 23. Posterior view of a specimen from loc. 4. Y.P.M. 11687.
- 24. Pedicle view of a specimen from loc. 4. T. 10076. Leonard formation, Glass Mountains.

25. *Horridonia texana*, n. sp., with *Agathiceras girtyi* Böse ... 85–86
- 25a–c. Pedicle, posterior, and lateral views of the holotype, which is broken in the central part, showing a specimen of *Agathiceras girtyi*. Loc. 255. Y.P.M. 11508. Middle Word formation, Glass Mountains.

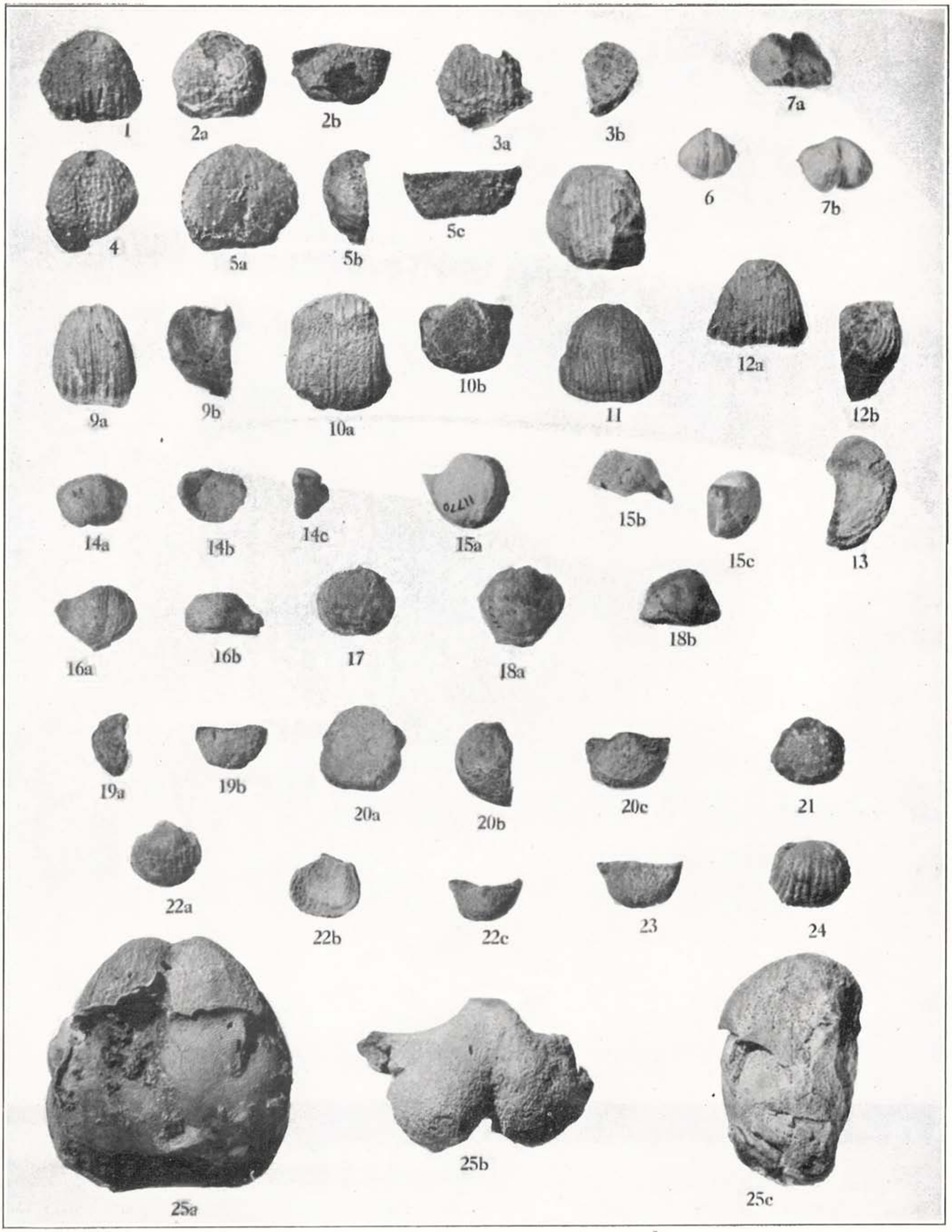
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PLATE XXII

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1–2. *Marginifera popei minor*, n. var. 88–89
- 1a–c. Pedicle, posterior, and lateral views of a cotype from section 1, bed 14. Y.P.M. 11635.
- 2. Pedicle view of a cotype from section 1, bed 14. Y.P.M. 11635. Limestone of Cerro Caballo, near Las Delicias, Coahuila.

3–10. *Marginifera reticulata*, n. sp. 89
- 3. Brachial view of a specimen from loc. 4. Y.P.M. 11724.
- 4. Pedicle view of a specimen from loc. 226. Y.P.M. 11727.
- 5a–b. Lateral and pedicle views of a specimen from loc. 228. Y.P.M. 11729.
- 6a–c. Pedicle, posterior, and lateral views of a cotype from loc. Tb. T. 10056.
- 7a–c. Lateral, pedicle, and posterior views of a specimen from loc. Tb. T. 10056.
- 8. Pedicle view of a specimen from loc. D. 4.
- 9a–b. Pedicle and lateral views of a specimen from loc. Tb. T. 10056.
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11–15. *Marginifera reticulata angusta*, n. var. 89
- 11. Pedicle view of a specimen from loc. 4. Y.P.M. 11807.
- 12. Pedicle view of a cotype from loc. 26S. Y.P.M. 11806.
- 13a–b. Pedicle and lateral views of a cotype from loc. T. 15. T. 10290.
- 14a–b. Pedicle and posterior views of a cotype from loc. 26S. Y.P.M. 11806.
- 15. Pedicle view of a specimen from loc. 15. T. 10290. Leonard formation, Glass Mountains.

16–19. *Marginifera popei* (Girty) 88
- 16. Pedicle view of a specimen from loc. 144. T. 10354.
- 17. Pedicle view of a specimen from loc. 247.
- 18. Pedicle view of a specimen from loc. 246. Y.P.M. 11753.
- 19. Pedicle view of a specimen from loc. 246. Y.P.M. 11753. Word formation, Glass Mountains.

20–25. *Marginifera opima* (Girty) 87–88
- 20. Interior view of a brachial valve from loc. Tx, showing incomplete marginal ridge. T. 11072.
- 21. Lateral view of a specimen from loc. 247. Y.P.M. 11707.
- 22a–c. Brachial, pedicle, and lateral views of a specimen from loc. 253. Y.P.M. 11718.
- 23a–c. Pedicle, lateral, and posterior views of a specimen from loc. 247.
- 24a–b. Pedicle and posterior views of a specimen from loc. 144. Y.P.M. 11706.
- 25a–b. Lateral and pedicle views of a specimen from loc. 247. Y.P.M. 11707. Word formation, Glass Mountains.

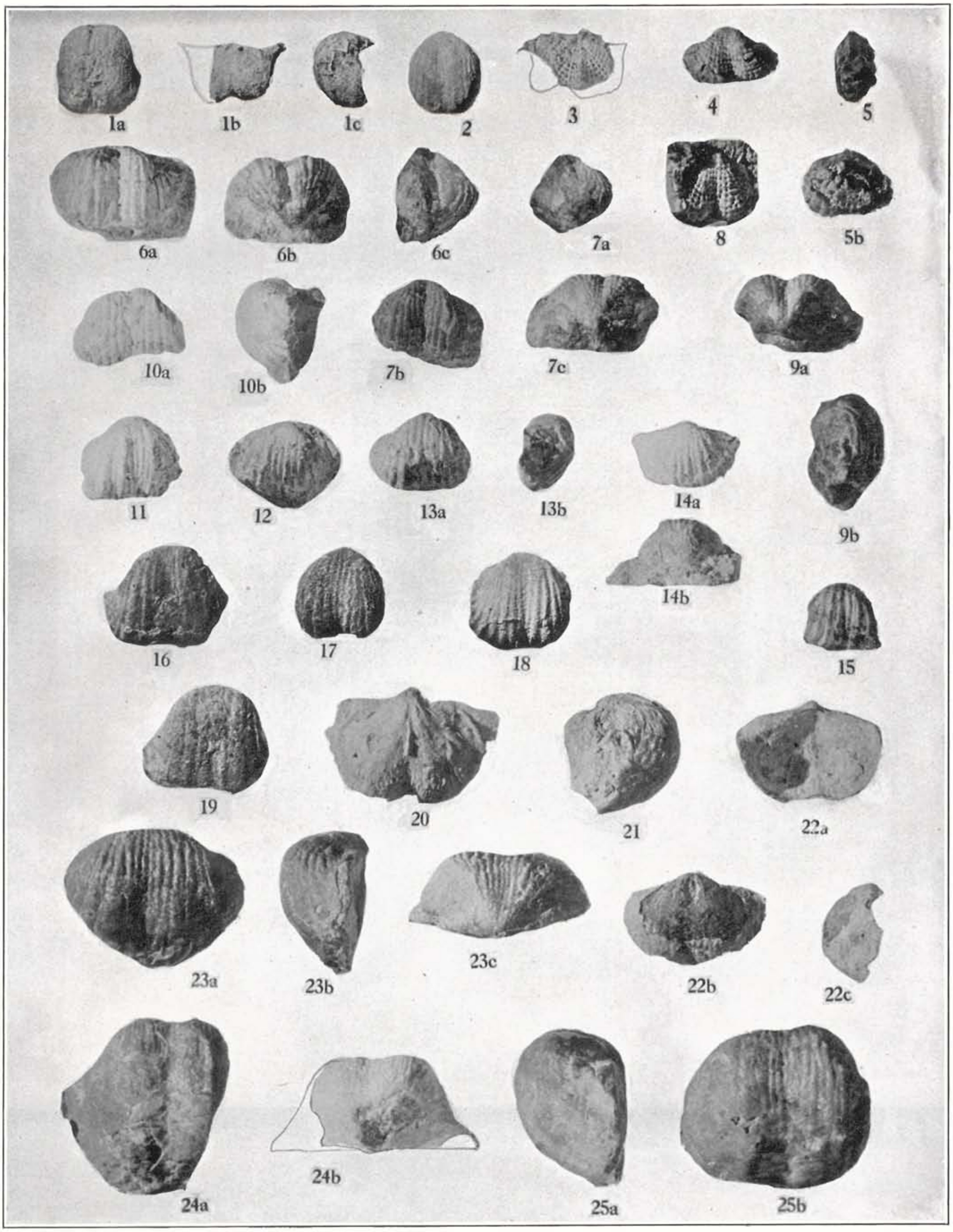
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PLATE XXIII

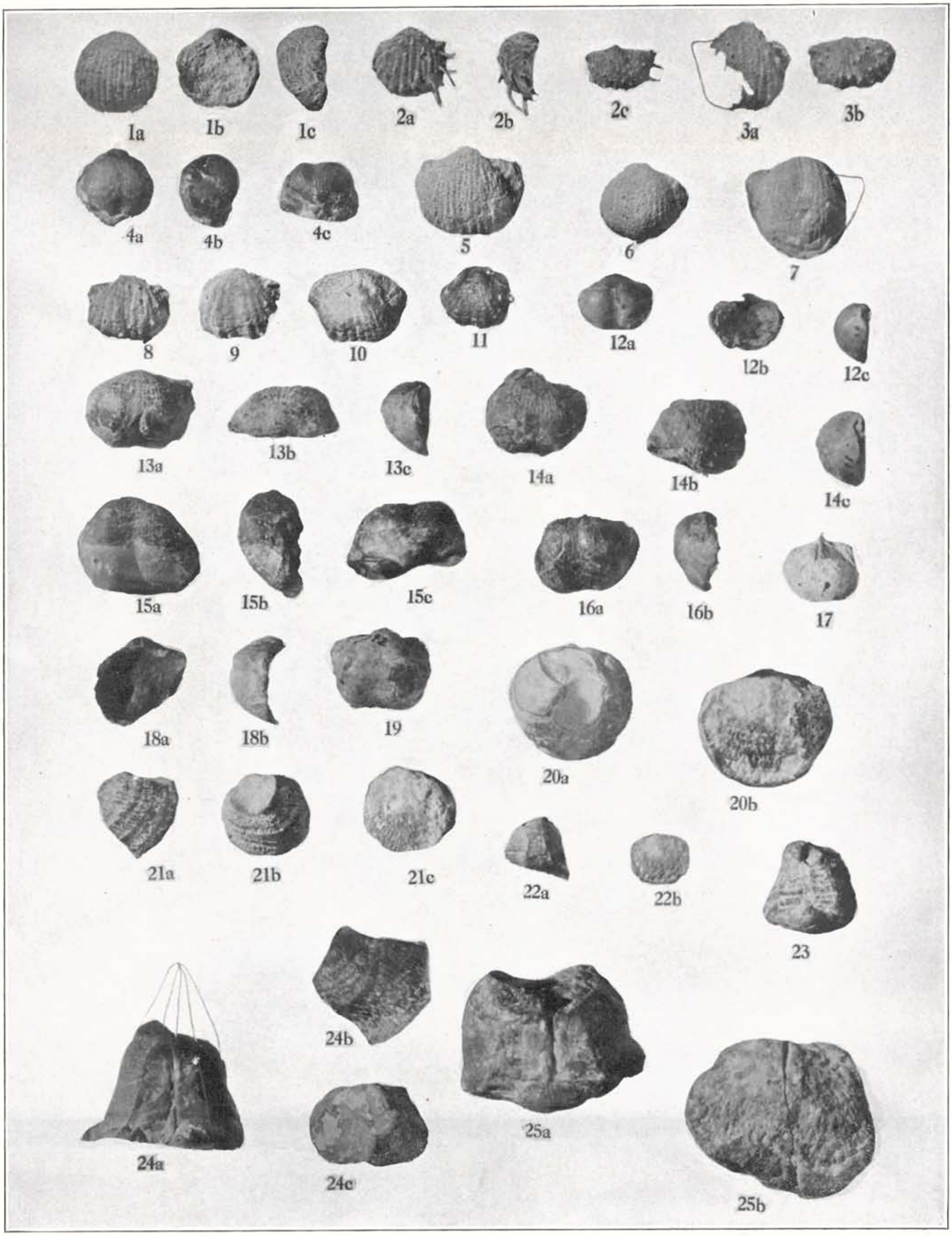
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PLATE XXIV

1a-c. Brachial, pedicle, and posterior views of a part of a long pedicle valve from loc. 35. It can be seen that the fragment is broken at both ends along the transverse partitions. Y.P.M. 12828. Hess formation, Glass Mountains.

2a-b. Posterior and brachial views of a large specimen from loc. 71, the apical part of which is not preserved. The ventral median septum may well be seen. Y.P.M. 12827. Wolfcamp formation, Glass Mountains.

3a-b. Lateral and posterior views of an elongate pedicle valve from loc. 35, showing a transverse angulation in the cardinal area. Y.P.M. 12828.

4a-b. Posterior and lateral views of a large specimen from loc. 208, showing the entire apex of the pedicle valve. Y.P.M. 12826.

5. Posterior view of a specimen from loc. 208. The apex of the pedicle valve is broken along the transverse partitions. A median depression may be seen in the cardinal area, which is due to the exfoliation of the surface of the area and excavation along the inside of the median septum. T. 10239. Hess formation, Glass Mountains.

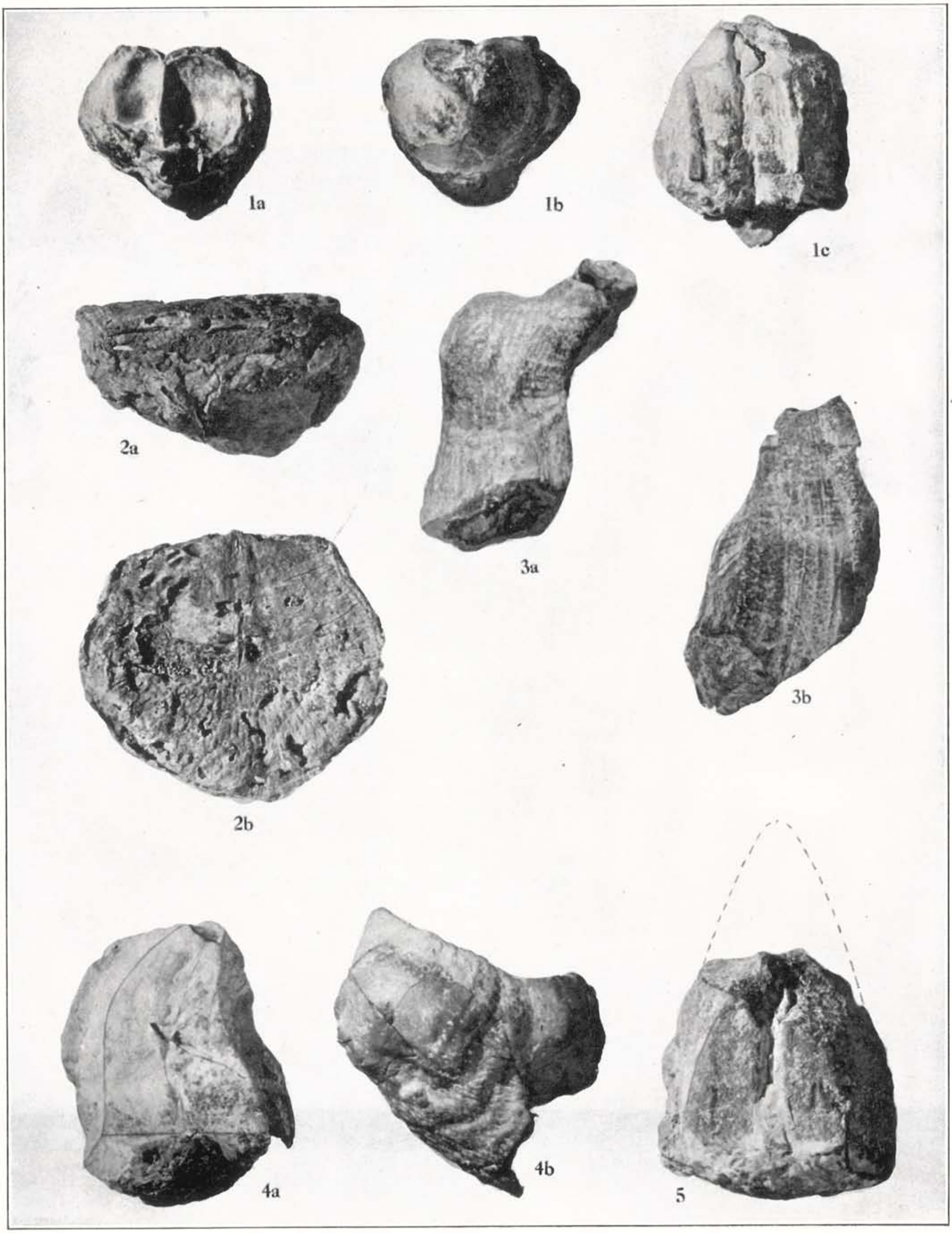
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PLATE XXV

Figure— PAGE

1–4. *Aulosteges magnicostatus* Girty 93

1a–b. Pedicle and lateral views of a specimen from loc. 123. T. 10085.

2a–b. Pedicle and lateral views of a specimen from loc. 268. Y.P.M. 11890.

3. Lateral view of a specimen from loc. 123. Y.P.M. 11902.

4a–b. Pedicle and lateral views of a specimen from loc. 228. T. 10096. Leonard formation, Glass Mountains.

5–7. *Aulosteges subcostatus*, n. sp. 94

5a–b. Exterior and interior of a pedicle valve from loc. T. 119. T. 10155.

6a–d. Pedicle, brachial, posterior, and lateral views of a specimen from loc. T. 119. T. 10155.

7a–b. Brachial and lateral views of the holotype, from loc. 123. Y.P.M. 11837. Leonard formation, Glass Mountains.

8–11. *Aulosteges guadalupensis* Shumard 93

8a–b. Pedicle and lateral views of a specimen from loc. 141. Y.P.M. 11824.

9. Pedicle valve from loc. 144. P.Y.M. 11824.

10. Pedicle valve from loc. Tx.

11. Lateral view of a pedicle valve from loc. 148. T. 10259. Word formation, Glass Mountains.

12–15. *Aulosteges beedei*, n. sp. 92–93

12a–b. Brachial and lateral views of a cotype from loc. 123. Y.P.M. 11876.

13a–c. Pedicle, brachial, and lateral views of a cotype from loc. 123. Y.P.M. 11876.

14a–c. Pedicle, brachial, and lateral views of a cotype from loc. 123. T. 10690. Leonard formation, Glass Mountains.

15a–b. Exterior and interior of a brachial valve from loc. Tx, showing the remarkable cardinal process. Word formation, Glass Mountains. T. 11045.

16–18. *Scacchinella gigantea* Schellwien 91–92

16. Part of a pedicle valve from loc. 208, which is broken along transverse partitions. Y.P.M. 12826.

17. Fragment of a brachial valve from loc. 35, showing spinose surface. T. 10241.

18a–b. Posterior and lateral views of a specimen from loc. 208, broken at the apex along transverse partitions, which show especially well in 18b. Y.P.M. 12826. Hess formation, Glass Mountains.

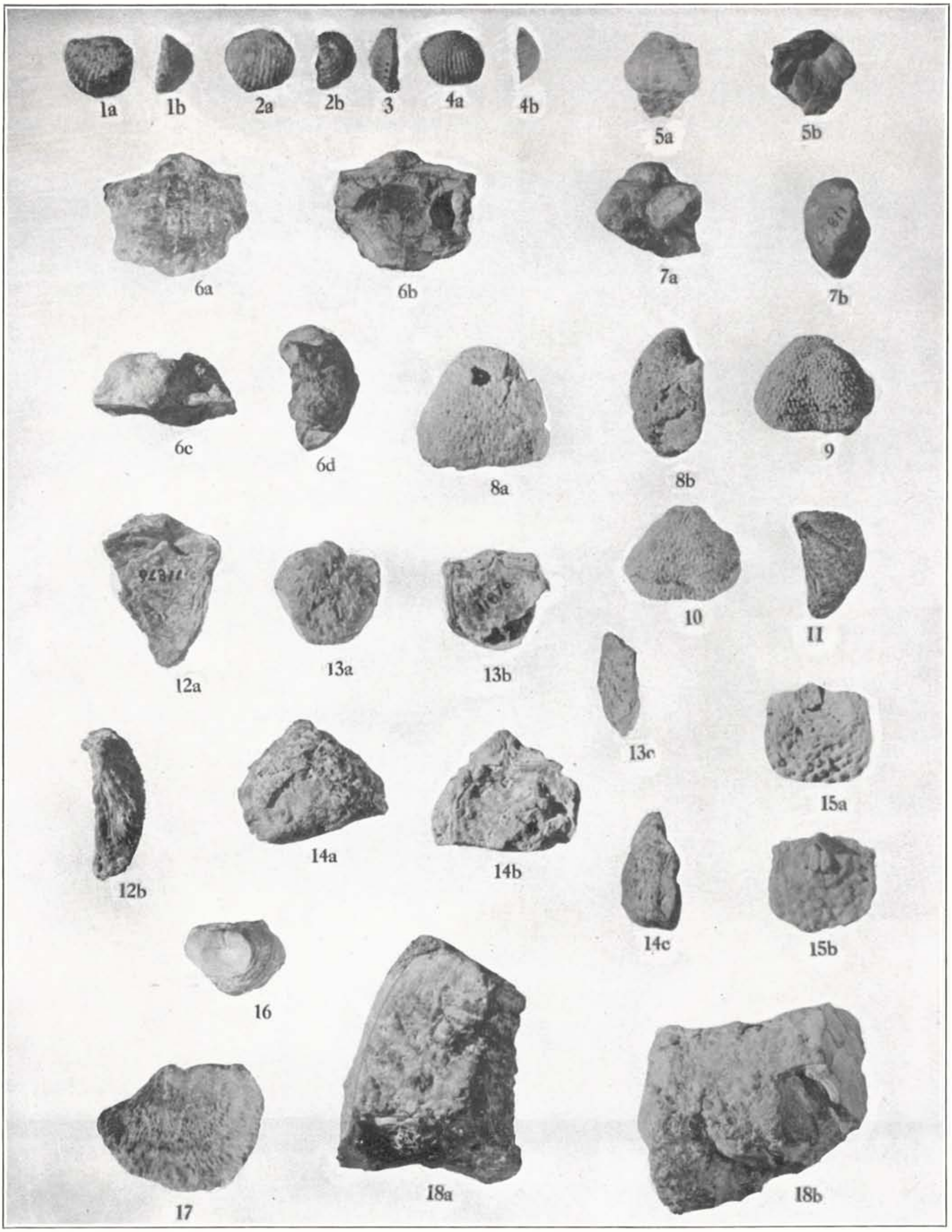
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PLATE XXVI

Figure— PAGE

1–6. *Aulosteges wolfcampensis*, n. sp. 95–96

1. Lateral view of a cotype from loc. 193. Y.P.M. 11849.
2. Mold of exterior of a brachial valve of a cotype from loc. 93. Y.P.M. 11847.
3. Interior of a brachial valve from loc. 93. Y.P.M. 11847.
4. Cardinal process of a cotype from loc. 93. T. 10158.

5a–b. Pedicle and lateral views of a cotype from loc. 88S. Y.P.M. 11839.

6a–b. Lateral and pedicle views of a cotype from loc. 93. T. 10158. Wolfcamp formation, Glass Mountains.

7–11. *Aulosteges medlicottianus* Waagen........ 93–94

7a–c. Pedicle, brachial, and lateral views of a specimen from loc. D. 3. Leonard formation, Glass Mountains.

8a–c. Lateral, pedicle, and brachial views of a specimen from loc. 108. Y.P.M. 11868. Hess formation, Glass Mountains.

9a–b. Pedicle and brachial views of a specimen from loc. 44. T. 10253. Word formation, Glass Mountains.

10. Brachial view of a specimen from loc. 121. Y.P.M. 11870.

11a–c. Pedicle, brachial, and lateral views of a specimen from loc. 124. Leonard formation, Glass Mountains. T. 11079.

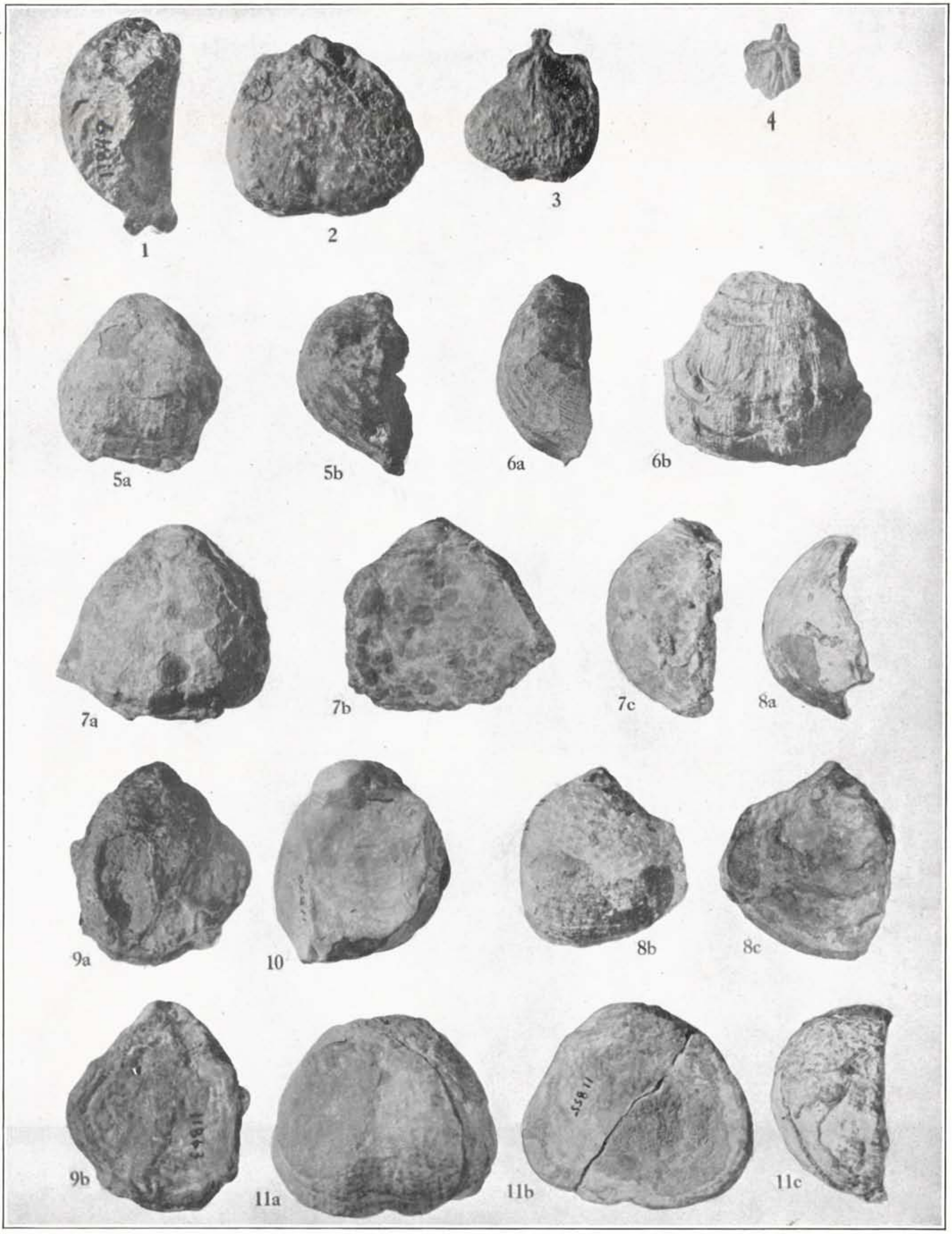
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PLATE XXVII

Figure— PAGE

1–3. *Aulosteges trigonalis*, n. sp. 94–95

1a–b. Pedicle and lateral views of the holotype, from loc. 231. Y.P.M. 11883. Leonard formation, Glass Mountains.

2a–b. Pedicle and lateral views of a specimen from loc. D. 239.

3. Pedicle view of a specimen from loc. Tx. T. 11014. Word formation, Glass Mountains.

4–7. *Aulosteges tuberculatus*, n. sp. 95

4. Part of a pedicle valve of a cotype from loc. 247. Y.P.M. 11815.

5. Brachial valve of a cotype from loc. T. 239. T. 10608.

6a–b. Lateral and pedicle views of a cotype from loc. 247. Y.P.M. 11815.

7. Pedicle valve of a cotype from loc. T. 239. T. 10608. Word formation, Glass Mountains.

8–9. *Aulosteges medlicottianus* Waagen 93–94

8. Brachial view of a specimen from loc. 124. Y.P.M. 11855. Leonard formation, Glass Mountains.

9. Lateral view of a specimen from loc. 222. Y.P.M. 11874. Hess formation, Glass Mountains.

10–13. *Strophalosia hystricula* Girty 96

10. Posterior view of a pedicle valve from loc. 128. Y.P.M. 11908.

11. Pedicle valve from loc. 128. Y.P.M. 11908.

12. Part of a pedicle valve from loc. 128. Y.P.M. 11908.

13. Part of a pedicle valve from loc. 128. Y.P.M. 11908. Leonard formation, Glass Mountains.

14–16. *Teguliferina bösei*, n. sp. 96–97

14. Large piece from loc. 93, showing many intergrown specimens attached to one another by spines. Y.P.M. 12661.

15a–c. Anterior, apertural, and brachial views of the holotype, from loc. 93. Y.P.M. 12829. In 15c the articulation of the brachial valve may be seen, with part of the pedicle valve growing over it.

16. Two intergrown specimens, showing the position of the brachial valve, Loc. 93. Y.P.M. 12661. Wolfcamp formation, Glass Mountains.

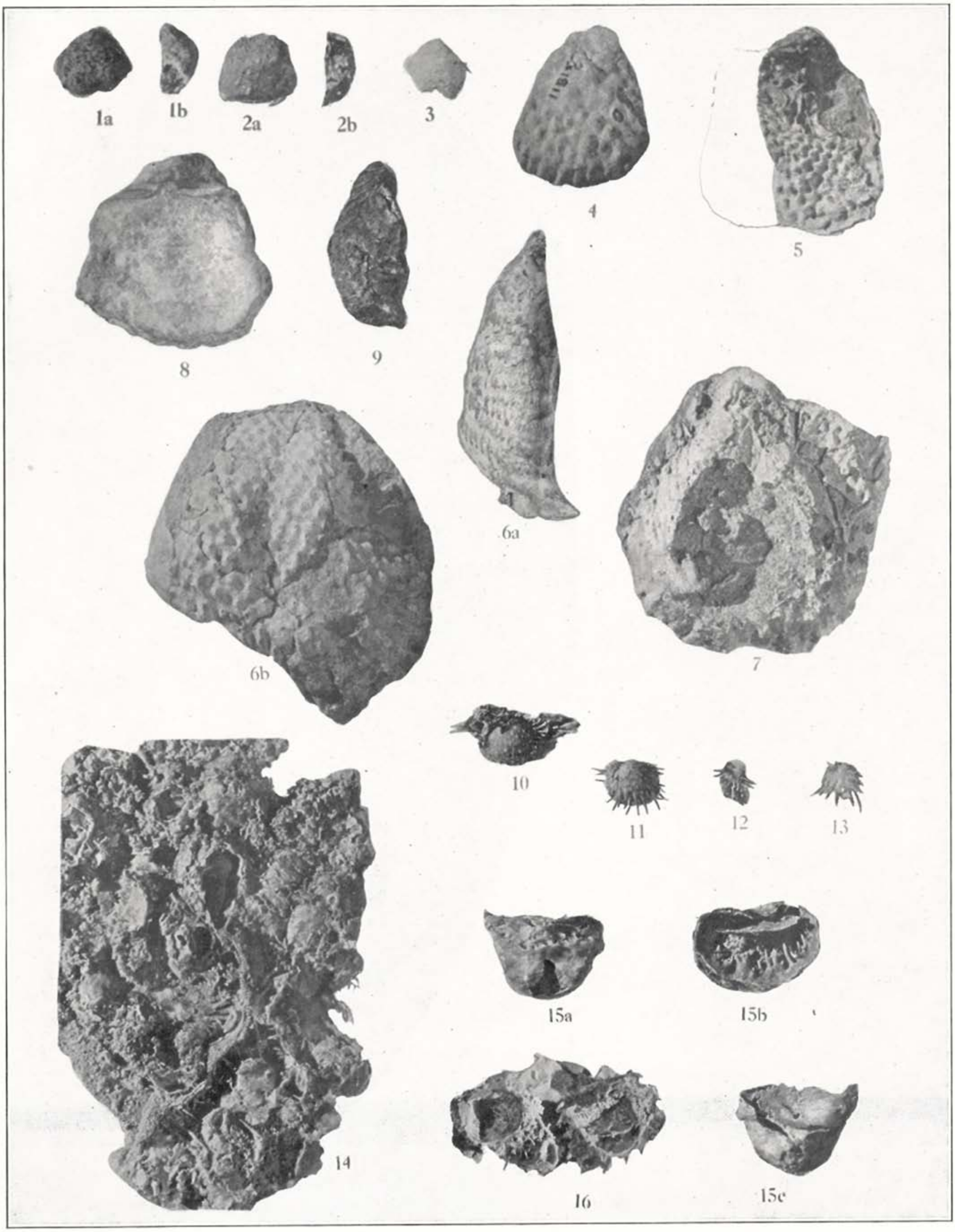
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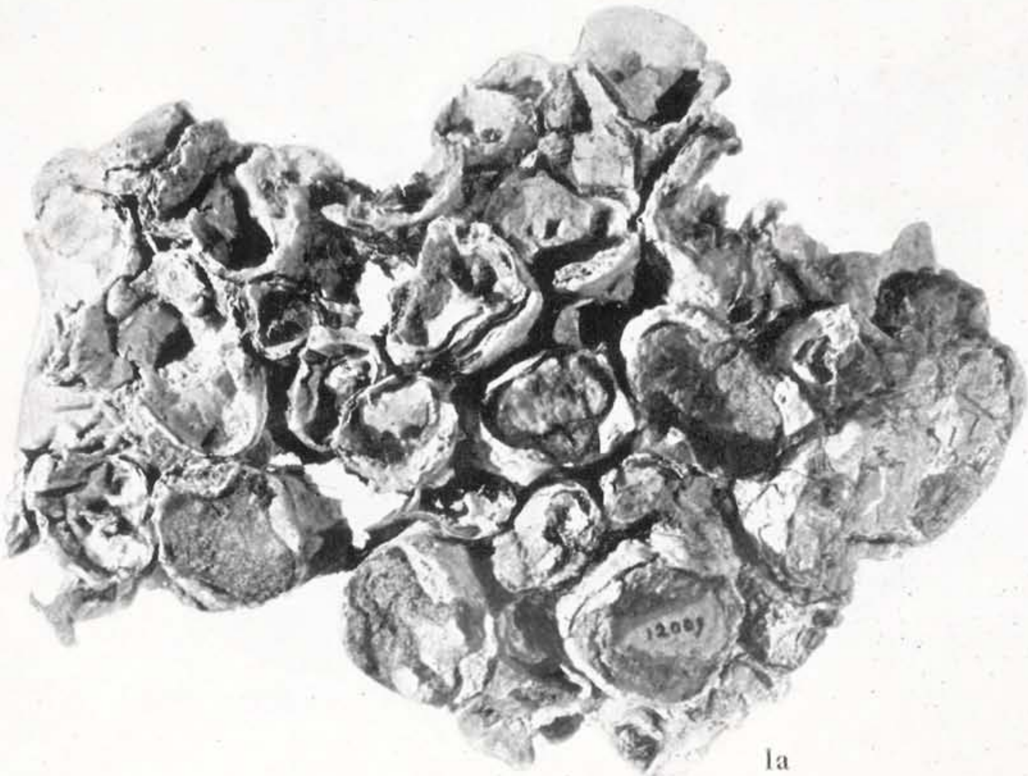
PLATE XXVIII

Figure— PAGE

1. *Prorichtofenia likharewi* King, n. sp. 98–99

1a. A large colony from the upper side. In some specimens the characteristic feature of the species, the sharp median ridge opposite the inside of the cardinal area, is visible. Y.P.M. 12009.

1b. The same from the lower side, showing their radial arrangement. Leonard formation, Glass Mountains, loc. 128.



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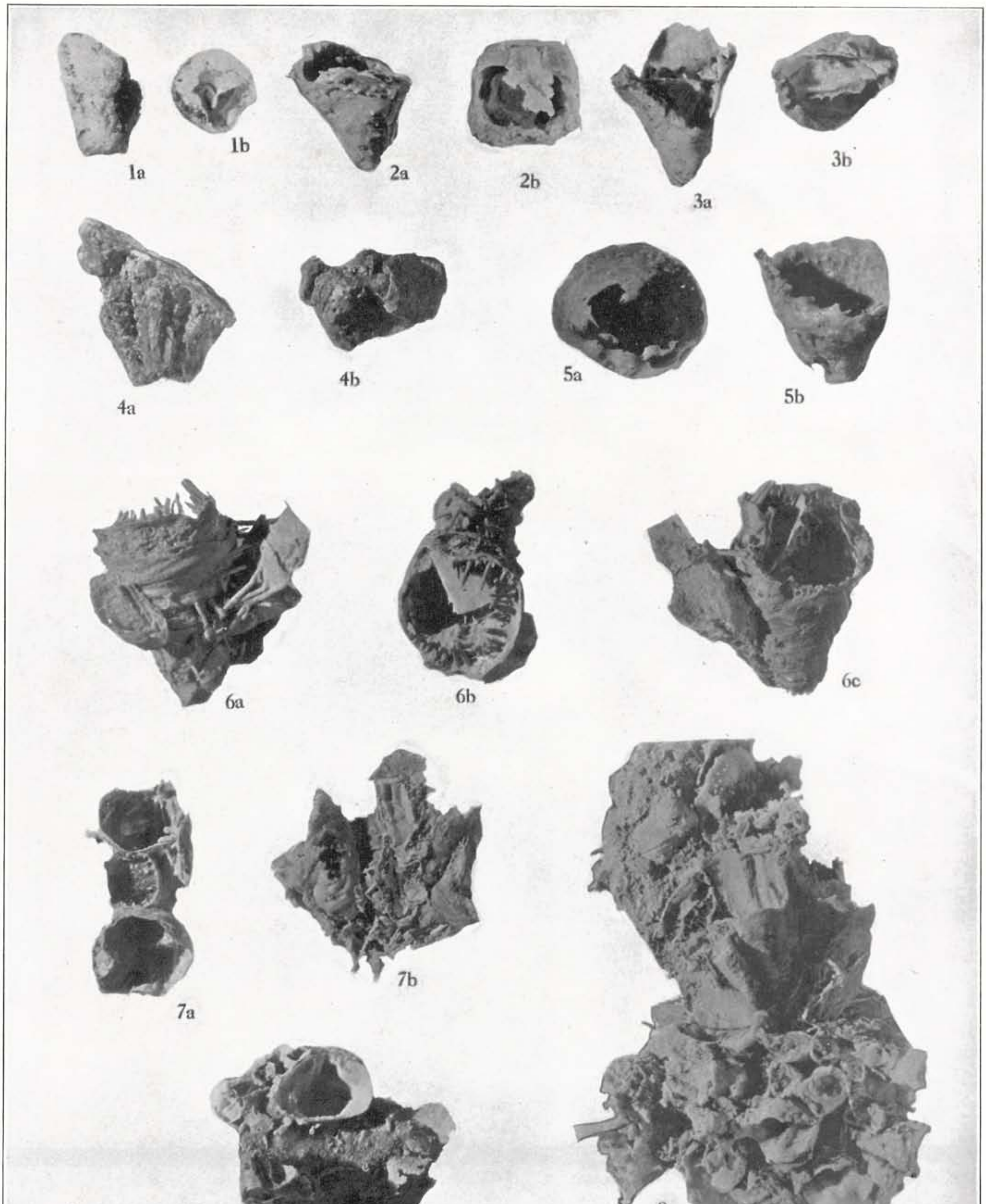
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PLATE XXX

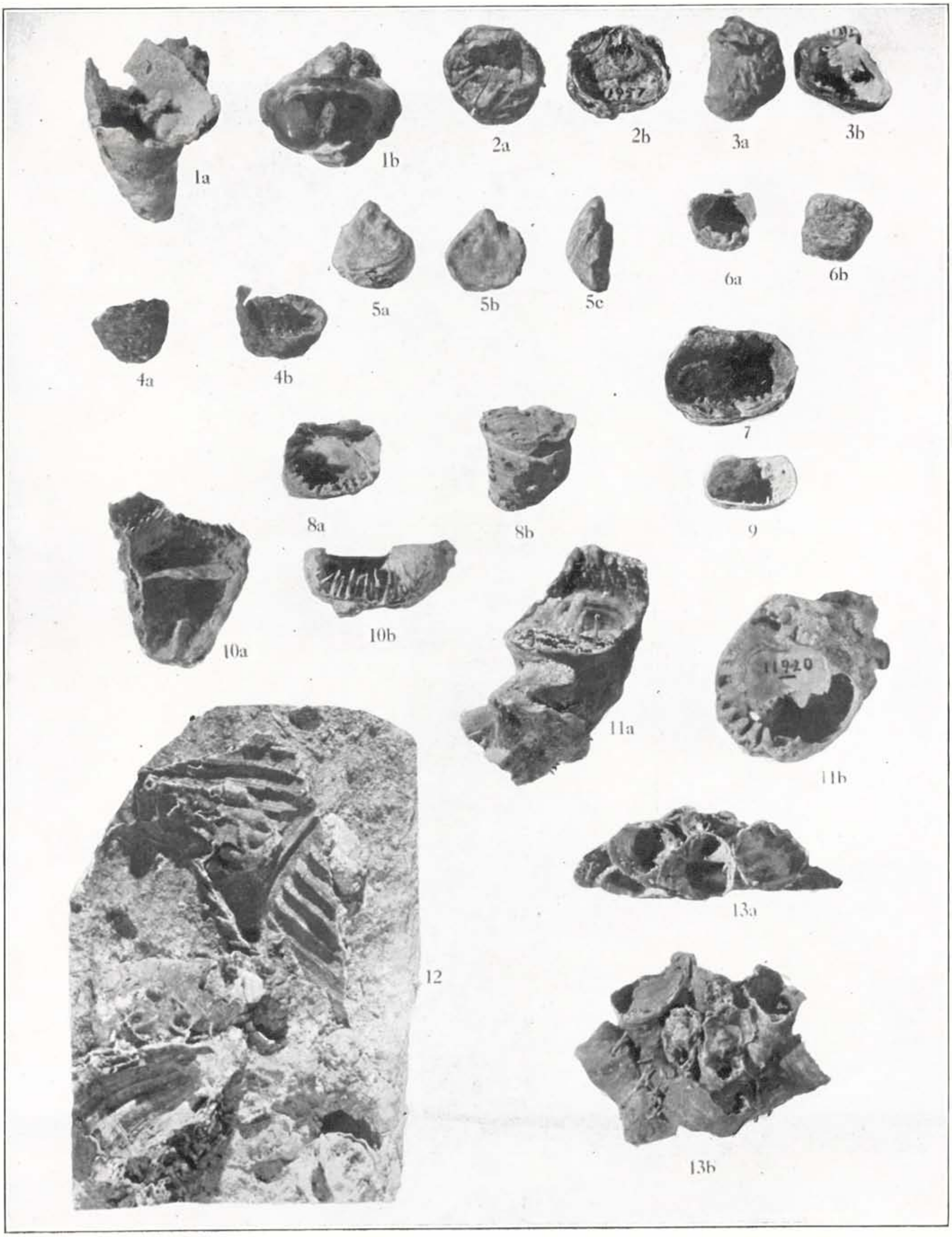
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PLATE XXXI

Figure— PAGE

1–6. *Prorichthofenia uddeni* (Böse) 100

1. Apertural view of a specimen from loc. 128, showing the median ridge on the cardinal side of the cone. T. 10114.

2. Apertural view of a specimen from loc. 128. Y.P.M. 11948.

3a–b. Lateral and apertural views of a specimen from loc. 128. Y.P.M. 11948.

4a–b. Lateral and apertural views of a specimen from loc. 128. T. 10114.

5. Apertural view of a specimen from loc. 120. Y.P.M. 11946.

6a–b. Lateral and apertural views of a specimen from loc. 120, showing the median ridge on the cardinal side of the cone. Y.P.M. 11946. Leonard formation, Glass Mountains.

7–9. *Parakeyserlingina fredericksi*, n. sp. 102

7a–b. Exterior and interior of the holotype, from loc. T. 93. The transition from forward-directed septal loops to loops perpendicular to the median line can be clearly seen. T. 10671.

8. Exterior of a specimen from loc. T. 93. The outer part of the shell has been removed in places, revealing the loops within. T. 10671.

9. Interior of a part of a specimen, from loc. 87 low, showing the divided character of the loops. Y.P.M. 12039. Wolfcamp formation, Glass Mountains.

10–13. *Lyttonia nobilis americanus* (Girty) 103–104

10a–b. Pedicle and lateral views of a specimen from loc. 128. In 10a the shell has been removed, showing the septa within. T. 10572. Leonard formation, Glass Mountains.

11. Mold of the interior of a pedicle valve from loc. 251. T. 10650.

12. Interior of part of a brachial valve from loc. 247. Y.P.M. 12041.

13. Interior of part of a pedicle valve from loc. 247. Y.P.M. 12041. Word formation, Glass Mountains.

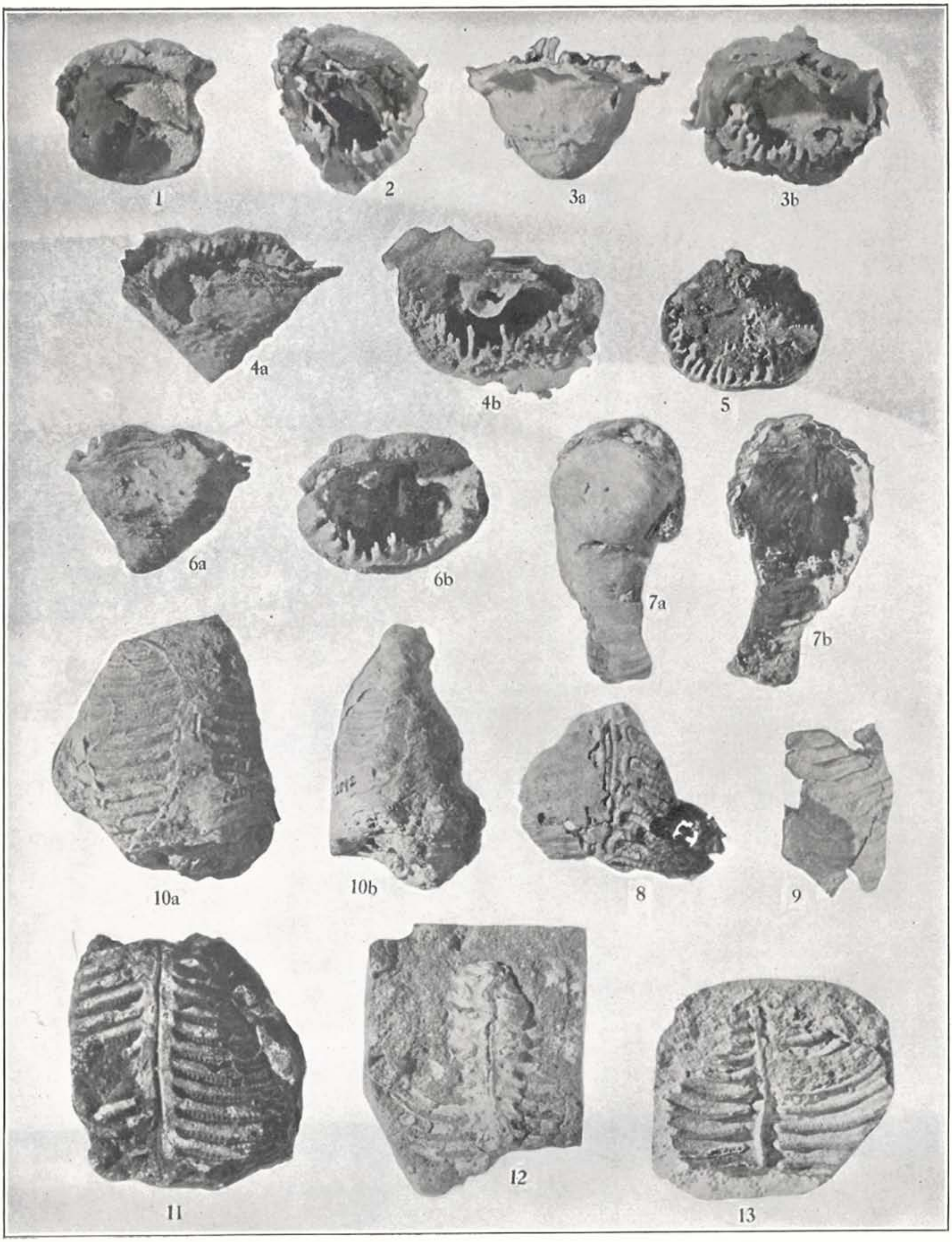
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PLATE XXXII

Figure— PAGE

1–9. *Lyttonia nobilis americanus* (Girty) ... 103–104; 54

1a–b. Exterior and interior of a pedicle valve from loc. 476. Within the shell may be seen a second, smaller pedicle valve (upper left of Fig. 1b). Y.P.M. 12820. Hess formation, Sierra Diablo.

2. Exterior of part of a brachial valve from loc. 250, showing granular nature of its surface. T. 10557.

3a–b. Interior and exterior of a pedicle valve from loc. T. 240a, showing the tangled posterior outgrowth of the shell and the double character of the first-formed septa, resembling *Parakeyserlingina*. T. 10074.

4. Interior of a pedicle valve from loc. 51, showing the posterior expansion of the shell. T. 11020. Word formation, Glass Mountains.

5. Axial part of the brachial valve of a *Lyttonia*, from loc. 128. Y.P.M. 12042.

6. Exterior of a pedicle valve from loc. 128, through a cavity in which may be seen the interior of the brachial valve. Y.P.M. 12042. Leonard formation, Glass Mountains.

7. Exterior of a pedicle valve, which is largely exfoliated so that the mold of the interior of the shell is visible; from loc. 152. Y.P.M. 12017. Word formation, Glass Mountains.

8. Piece of rock from loc. 151, showing the outside of a *Lyttonia*, traces of the septa showing through the shell. To the left are a *Linoproductus waagenianus* and a *Meekella globosa*. Y.P.M. 12660. Leonard formation, Glass Mountains.

9. Exterior of part of a brachial valve from loc. Tx. 148. T. 10528. Word formation, Glass Mountains.

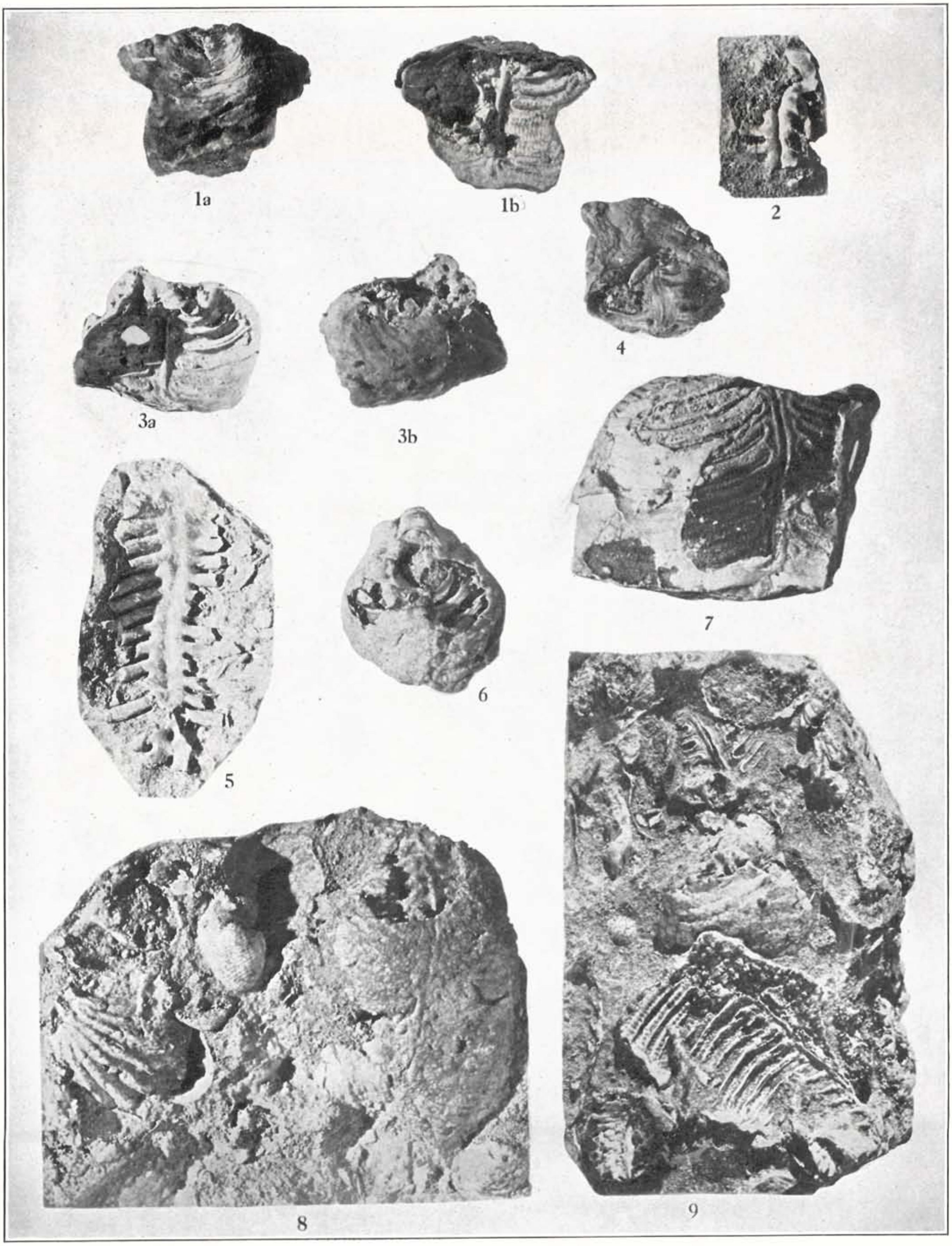

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PLATE XXXIII

Figure — PAGE

1–8. *Leiorhynchus bisulcatum* (Shumard) ... 105

- 1a–d. Pedicle, brachial, lateral, and anterior views of a specimen from section 1, bed 19. Y.P.M. 12558.
- 2a–c. Pedicle, brachial, and lateral views of a specimen from section 2, bed 6. Y.P.M. 12556.
- 3. Anterior view of a specimen from section 2, bed 6. Y.P.M. 12556.
- 4a–c. Brachial, lateral, and anterior views of a specimen from section 2, bed 6. Y.P.M. 12556.
- 5a–c. Pedicle, brachial, and anterior views of a specimen from section 2, bed 6. Y.P.M. 12556.
- 6. Anterior view of a specimen from section 2, bed 6. T. 11089.
- 7a–c. Pedicle, brachial, and anterior views of a specimen from section 2, bed 6. Y.P.M. 12556.
- 8. Pedicle view of a specimen from section 2, bed 6. *Waagenoceras* horizon near Las Delicias, Coahuila.

9–11. *Leiorhynchus weeksi nobilis* (Girty) ... 105–106

- 9a–d. Pedicle, brachial, lateral, and anterior views of a specimen from loc. 265. Y.P.M. 12553.
- 10a–c. Brachial, lateral, and anterior views of a specimen from loc. 144. Y.P.M. 12552.
- 11. Anterior view of a specimen from loc. 144. T. 10598. Word formation, Glass Mountains.

12–13. *Pugnoides elegans* (Girty) ... 106

- 12a–d. Pedicle, brachial, lateral, and anterior views of a specimen from loc. 106. Y.P.M. 12527.
- 13a–c. Brachial, pedicle, and anterior views of a specimen from loc. 108. Y.P.M. 12697. Hess formation, Glass Mountains.

14–17. *Pugnoides transversus*, n. sp. ... 108–109

- 14a–d. Brachial, pedicle, lateral, and posterior views of the holotype, from loc. 222. Y.P.M. 12518.
- 15a–c. Pedicle, posterior, and lateral views of a specimen from loc. T. 107. T. 10674.
- 16. Brachial view of a specimen from loc. 212. Y.P.M. 12519.
- 17a–c. Brachial, lateral, and posterior views of a specimen from loc. 107. Upper Hess formation, Glass Mountains. T. 10670.

18–19. *Lyttonia hortoni*, n. sp. ... 104

- 18. Interior of pedicle valve of the holotype, from loc. 7; only the right half is shown. Y.P.M. 12062. Leonard formation, Glass Mountains.
- 19. Interior of part of a pedicle valve from loc. T. 140, showing the interrupted nature of the septa. T. 10586. Word formation, Glass Mountains.

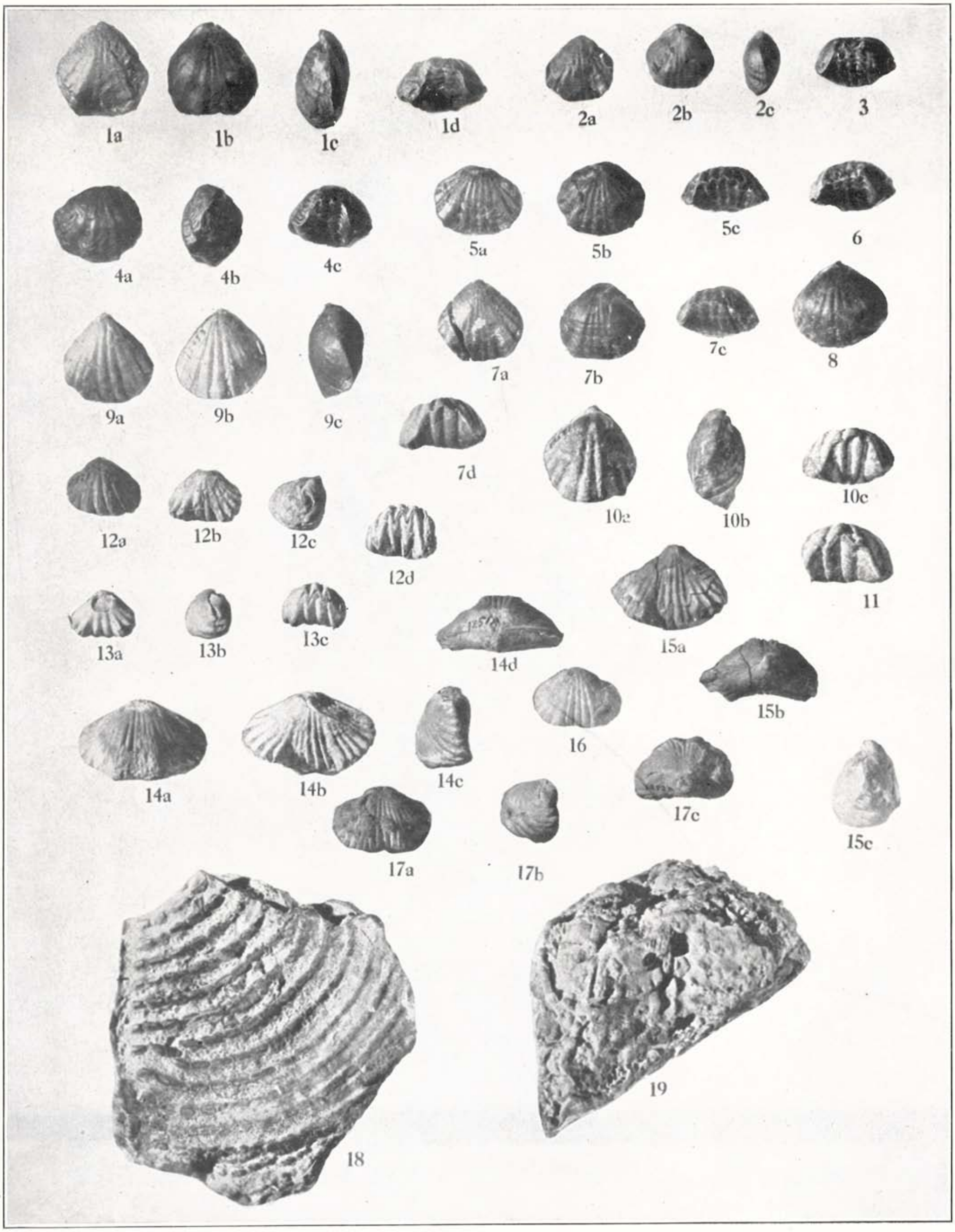
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PLATE XXXIV

Figure — PAGE

1. *Pugnoides bidentatus* (Girty) — 107–108

1a–c. Brachial, pedicle, and lateral views of a specimen from loc. 191. Y.P.M. 12562. Bone Canyon limestone, Delaware Mountains.

2–4. *Pugnoides elegans* (Girty) — 106

2a–d. Pedicle, brachial, lateral, and anterior views of a specimen from loc. 108. Y.P.M. 12549. Upper Hess formation, Glass Mountains.

3a–b. Pedicle and brachial views of a specimen from loc. 106. T. 10582. Hess formation, Glass Mountains.

4a–b. Brachial and lateral views of a specimen from loc. 104. T. 10645. Leonard formation, Glass Mountains.

5–9. *Pugnoides texanus* (Shumard) — 108

5a–d. Brachial, pedicle, lateral, and anterior views of a specimen from loc. 223. Y.P.M. 12530.

6a–d. Brachial, pedicle, lateral, and anterior views of a specimen from loc. 223. Y.P.M. 12530. Upper Hess formation, Glass Mountains.

7a–c. Brachial, pedicle, and anterior views of a specimen from loc. 440a. Y.P.M. 12527. Upper Gym formation, Hueco Mountains.

8a–b. Brachial, pedicle, and anterior views of a specimen from loc. 223. T. 10666.

9. Anterior view of a specimen from loc. 223. T. 10666. Upper Hess formation, Glass Mountains.

10–12. *Pugnoides swallovianus* (Shumard) — 107

10a–b. Exterior and interior of a brachial valve from loc. Tx. T. 11037.

11a–c. Brachial, pedicle, and anterior views of a specimen from loc. T. 240. T. 10470.

12a–c. Brachial, lateral, and anterior views of a specimen from loc. T. 240. T. 16470. Word formation, Glass Mountains.

13–14. *Pugnoides shumardianus* (Girty) — 107

13a–d. Brachial, pedicle, lateral, and anterior views of a specimen from loc. T. 15a.

14a–c. Brachial, lateral, and anterior views of a small specimen from loc. T. 15a. Leonard formation, Glass Mountains.

15–17. *Pugnoides pinguis* (Girty) — 106

15a–d. Pedicle, brachial, lateral, and anterior views of a specimen from loc. 124. Leonard formation, Glass Mountains. T. 10017.

16a–b. Pedicle and lateral views of a specimen from loc. 17. Y.P.M. 12521. Hess formation, Glass Mountains.

17. Anterior view of a specimen from loc. D. 3. Leonard formation, Glass Mountains.

18. *Rhynchopora illinoisensis* (Worthen) — 109

18a–d. Pedicle, brachial, lateral, and anterior views of a specimen from loc. T. 88. In 18d the pedicle valve is up, the brachial down. Wolfcamp formation, *Uddenites* zone, Glass Mountains.

19–23. *Rhynchopora taylori* Girty — 109–110

19. Anterior view of a specimen from loc. 144. Y.P.M. 12641.

20a–d. Brachial, pedicle, lateral, and anterior views of a specimen from loc. T. 240. Word formation, Glass Mountains. T. 10998a.

21a–b. Brachial and anterior views of a specimen from loc. 436. Y.P.M. 12636. Upper Gym formation, Hueco Mountains.

22a–c. Brachial, lateral, and anterior views of a brachial valve from loc. T. 240. Word formation, Glass Mountains. T. 10998.

23a–b. Brachial and anterior views of a specimen from loc. 436. This and the specimen illustrated in Fig. 21 are not typical because of their small size, but agree with the larger specimens in number of plications. Y.P.M. 12636. Upper Gym formation, Hueco Mountains.

24–27. *Camarophoria deloi*, n. sp. — 110

24a–c. Brachial, lateral, and posterior views of the holotype, from loc. 376. In 24c the shell surface is broken, so that the spondylium may be seen.

25a–c. Brachial, lateral, and anterior views of a specimen from loc. 241. Y.P.M. 12693. Word formation, Glass Mountains.

26. Brachial view of a specimen from Sawmill Canyon, Arizona. Y.P.M. 12694.

27a–b. Posterior and brachial views of a specimen from Sawmill Canyon, Arizona. Lower Permian, Santa Rita Mountains.

28. *Camarophoria thevenini* Kozlowski — 110

28a–c. Pedicle, brachial, and lateral views of a specimen from loc. 123. Y.P.M. 12695. Leonard formation, Glass Mountains.

29–31. *Camarophoria venusta* Girty — 110–111

29a–b. Posterior and brachial views of a specimen from loc. 107. Hess formation, Glass Mountains.

30a–b. Anterior and brachial views of a specimen from loc. T. 15a.

31a–b. Lateral and brachial views of a specimen from loc. D. 1. Leonard formation, Glass Mountains.

32. *Camarophoria? indentata* (Shumard) — 111–112

32a–c. Brachial, pedicle, and lateral views of an internal mold from section 1, bed 14. Y.P.M. 12691. Limestone of Cerro Caballo, near Las Delicias, Coahuila.

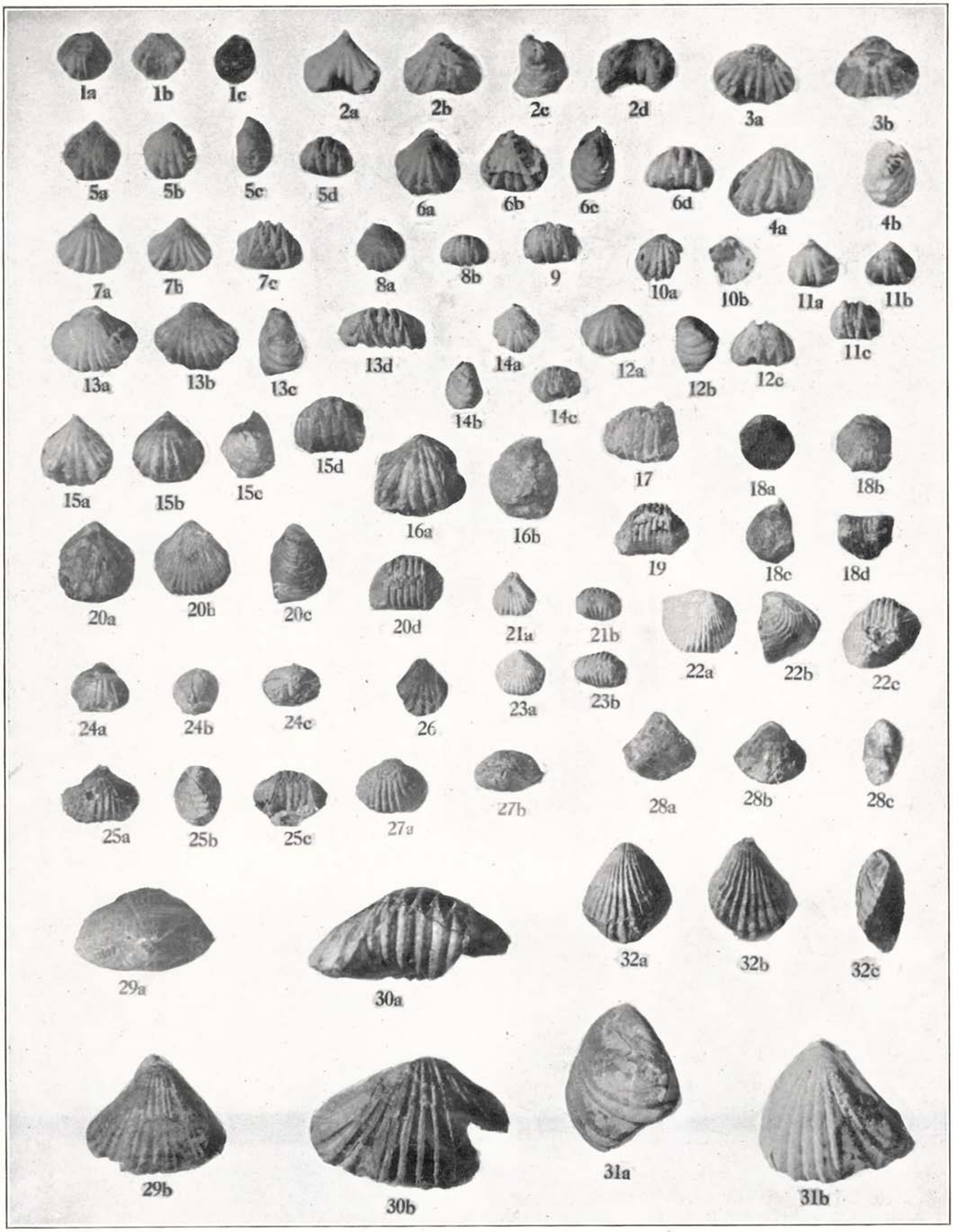
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PLATE XXXV

Figure— PAGE

1–5. *Camarophoria venusta* Girty 110–111

1a–c. Pedicle, lateral, and posterior views of a relatively broad specimen from loc. 484. Y.P.M. 12587. Bone Canyon limestone, Sierra Diablo.

2a–b. Pedicle and lateral views of a specimen from loc. 227. Y.P.M. 12614.

3a–d. Brachial, pedicle, lateral, and anterior views of a specimen from loc. 174. Y.P.M. 12620. Leonard formation, Glass Mountains.

4. Pedicle view of an exceptionally broad specimen from loc. 484. In breadth it resembles *Pugnoides transversus*, but it contains a spondylium. Y.P.M. 12587. Bone Canyon limestone, Sierra Diablo.

5. Interior, viewed from the front. Note cruralium above and spondylium below. The hair-like extension from the right-hand side of the cruralium is one of the crura. Loc. 107. Y.P.M. 12607. Upper Hess formation, Glass Mountains.

6–7. *Uncinuloides guadalupensis* (Shumard) 112–113

6a–c. Brachial, pedicle, and half lateral views of a specimen from loc. T. 128. In 6c may be seen the cruralium projecting spoon-like from the apex of the brachial valve, with one of the hair-like crura just below it on the far side. T. 10167.

7a–c. Pedicle, lateral, and anterior views of a pedicle valve from loc. 120, showing *Uncinulus*-like anterior part. Y.P.M. 12582. Leonard formation, Glass Mountains.

8–10. *Spirifer condor* (d'Orbigny) 113–114

8a–c. Posterior, brachial, and lateral views of a specimen from loc. Tmm. T. 10341.

9a–b. Pedicle and brachial views of a specimen from loc. Tmm, the posterior part of which has been so eroded that the median part of the pedicle valve shows the inner cavity of the shell, filled with limestone, surrounded by the apical callosity. T. 10341.

10. Interior of a pedicle valve from loc. 376. Y.P.M. 12493. Lower Gym formation, Hueco Mountains.

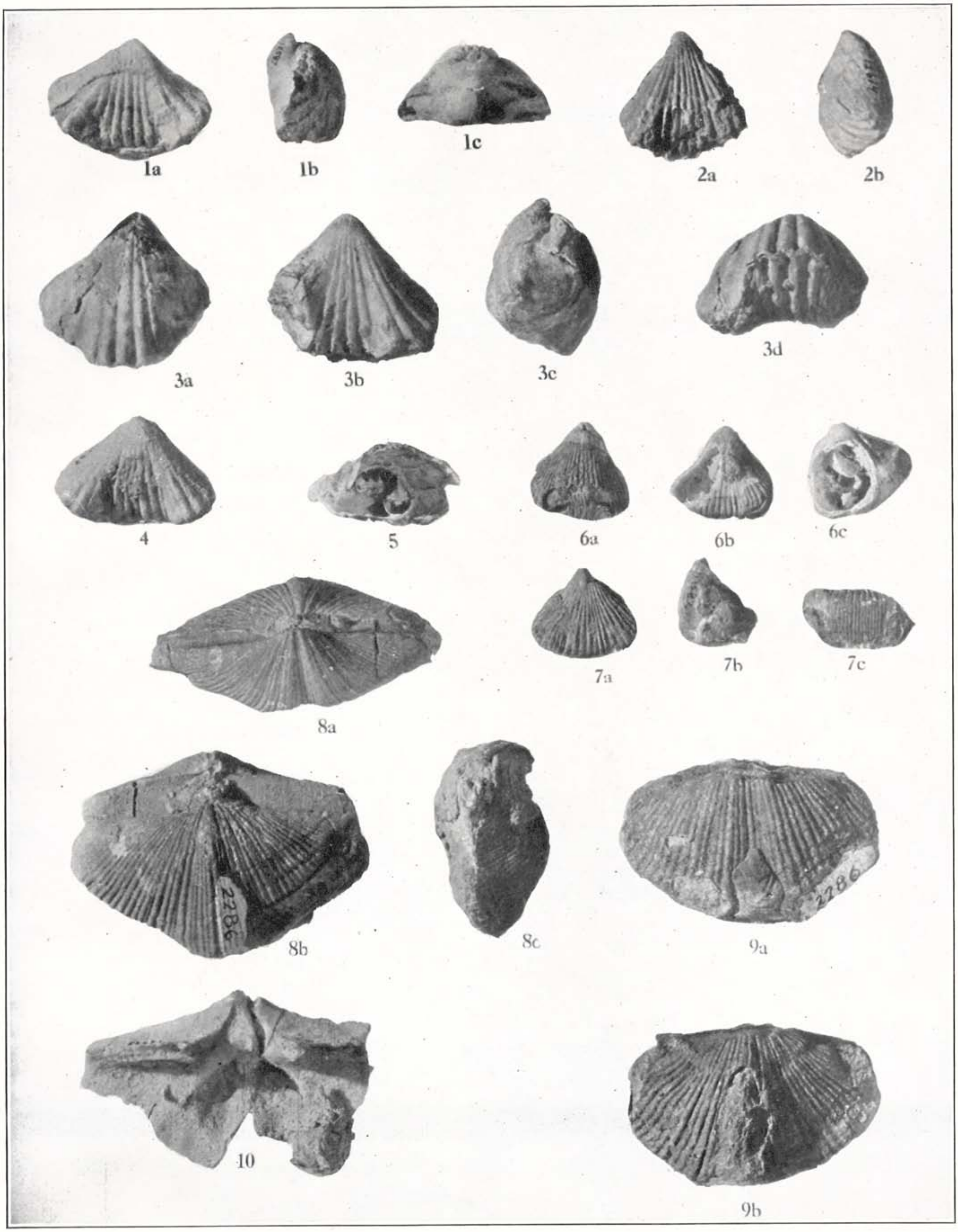
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PLATE XXXVI

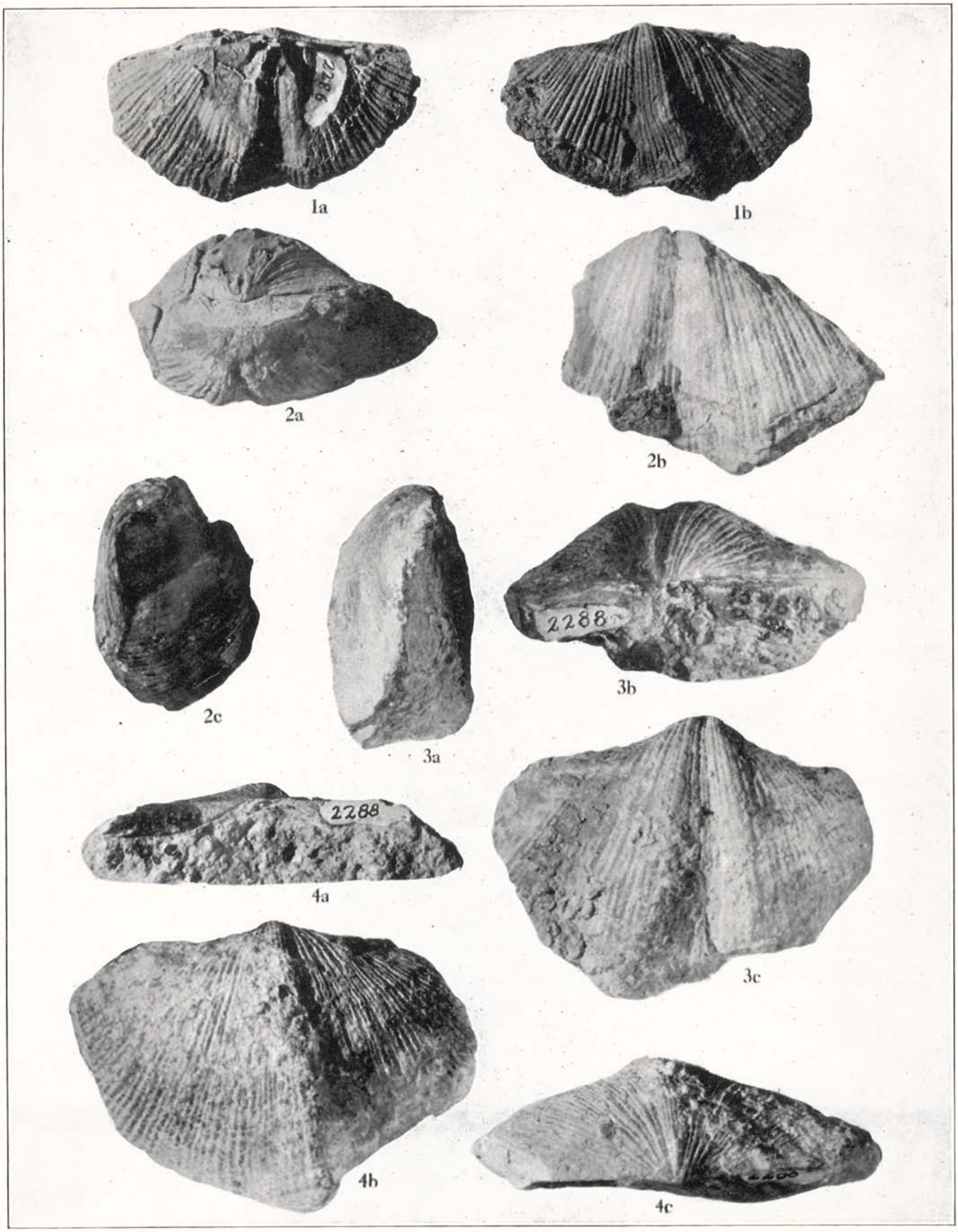
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PLATE XXXVII

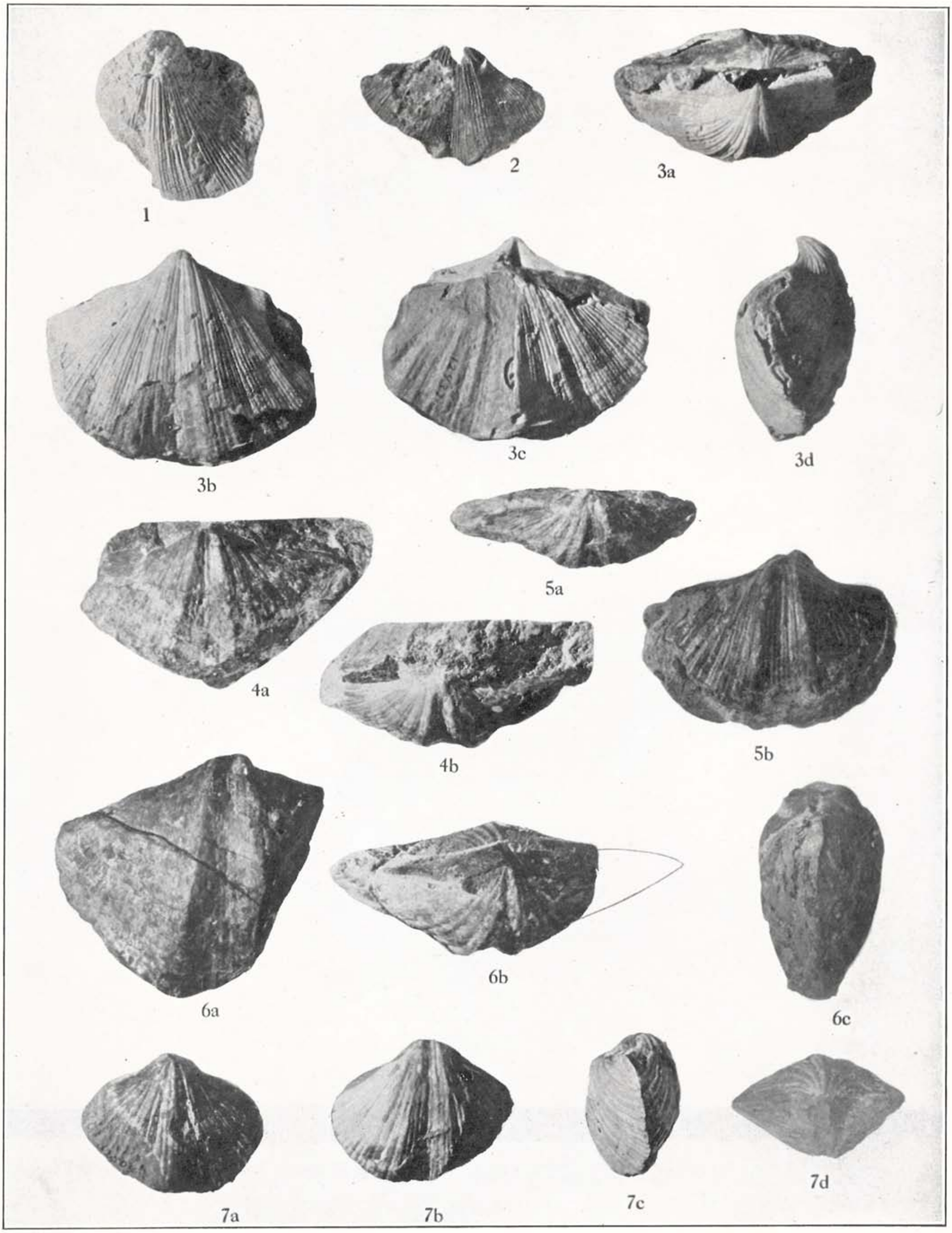
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PLATE XXXVIII

Figure— PAGE

1. *Spirifer (Neospirifer) mexicanus latus*, n. var. 116

1a–c. Pedicle, brachial, and posterior views of a specimen from loc. 126. Y.P.M. 12505. Leonard formation, Glass Mountains.

2–3. *Spirifer (Neospirifer) huecoensis*, n. sp. 116–117

2a–c. Pedicle, posterior, and lateral views of the holotype, from loc. 389. In 2b the pedicle valve is up, the brachial down. Y.P.M. 12441. Lower Gym formation, Hueco Mountains.

3a–b. Exterior and interior of a pedicle valve from loc. 107. Y.P.M. 12442. Hess formation, Glass Mountains.

4–6. *Spirifer (Neospirifer) pseudocameratus* Girty 116

4. Lateral view of a specimen from loc. 493. T. 10129. Victorio Peak limestone, Sierra Diablo.

5a–b. Brachial and posterior views of a specimen from loc. 44–46. Y.P.M. 12446. Word formation, Glass Mountains.

6. Brachial view of a specimen from loc. 493. Y.P.M. 12449. Victorio Peak limestone, Sierra Diablo.

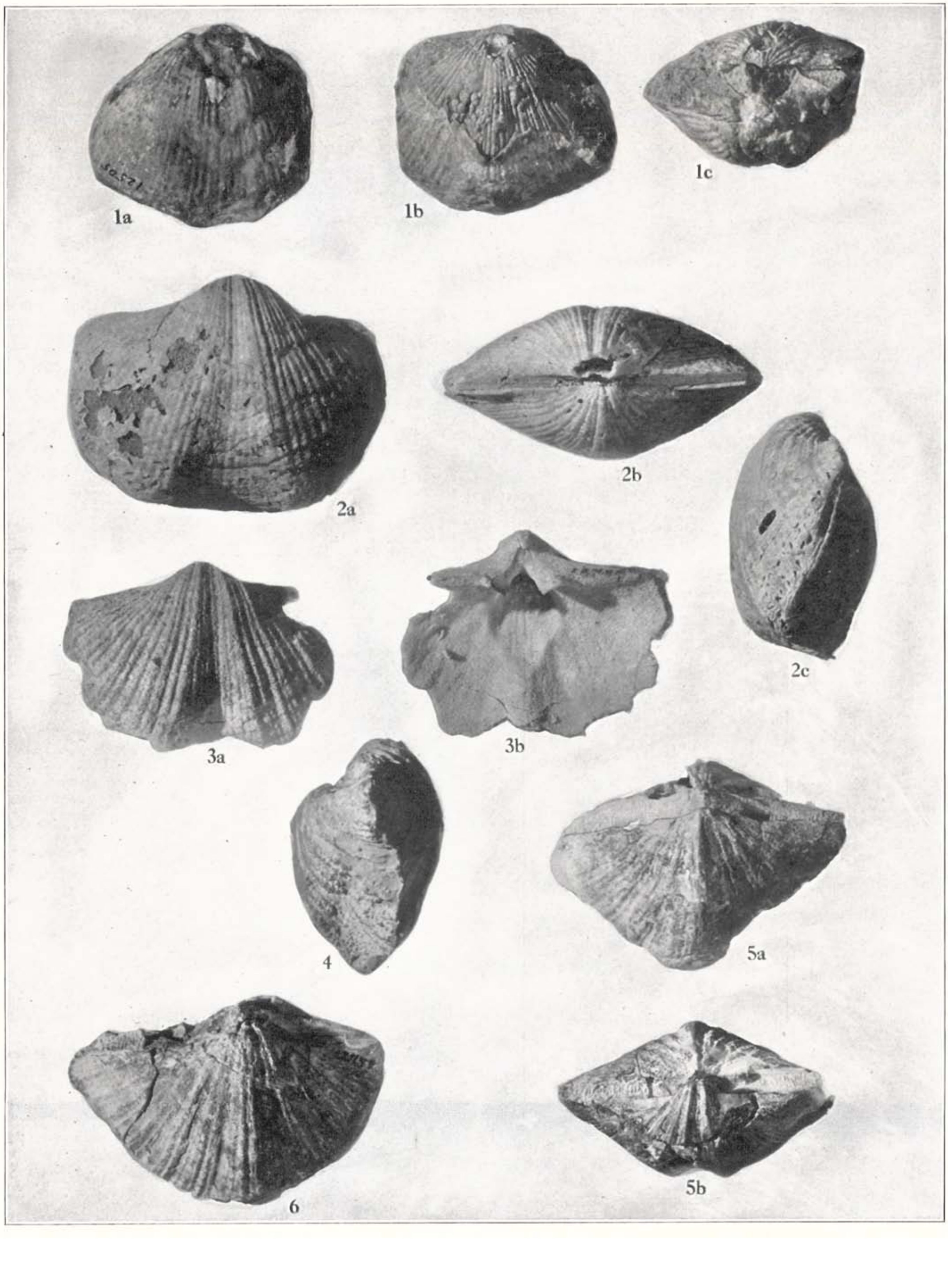
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PLATE XXXIX

Figure— PAGE

1–3. *Spirifer (Neospirifer) pseudocameratus* Girty 116

1. Pedicle view of an internal mold from loc. 6. Y.P.M. 12480. Word formation, Glass Mountains.

2. Lateral view of a specimen from loc. 174. T. 10228.

3a–c. Posterior, pedicle, and brachial views of a specimen from loc. 121. Y.P.M. 12458. Leonard formation, Glass Mountains.

4. *Spirifer (Neospirifer) triplicatus* Hall 117

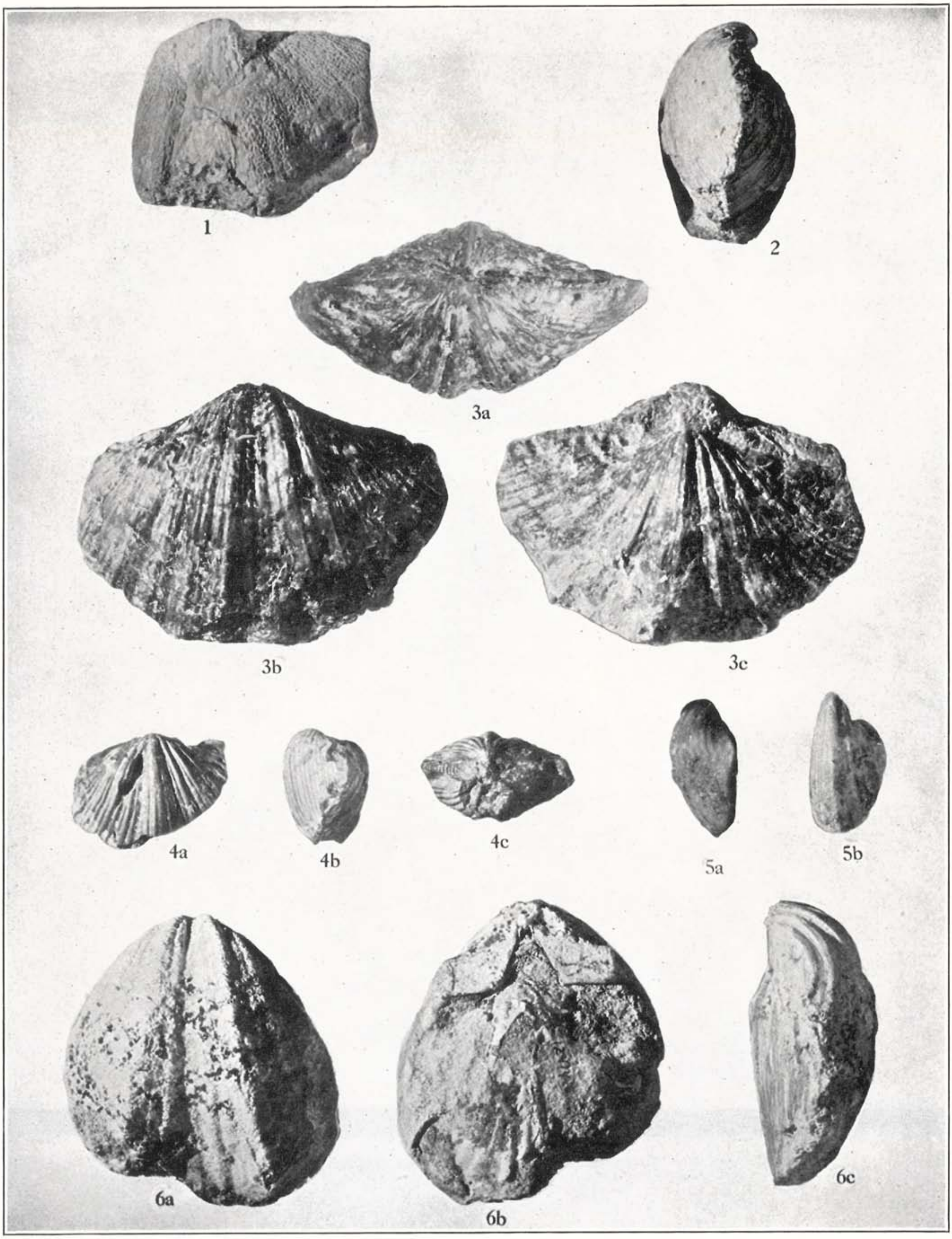
4a–c. Brachial, lateral, and posterior views of a specimen from loc. 201. Y.P.M. 12424. Wolfcamp formation, *Uddenites* zone, Glass Mountains.

5. *Spirifer (Neospirifer) texanus* Meek 117

5a–b. Lateral and pedicle views of a part of a pedicle valve from loc. 88. Y.P.M. 12399. Wolfcamp formation, *Uddenites* zone, Glass Mountains.

6. *Spirifer (Elivina) sulcifer* Shumard 118

6a–c. Pedicle, brachial, and lateral views of a large specimen from loc. 247. The brachial valve is somewhat crushed inward. Y.P.M. 12414. Upper Word formation, Glass Mountains.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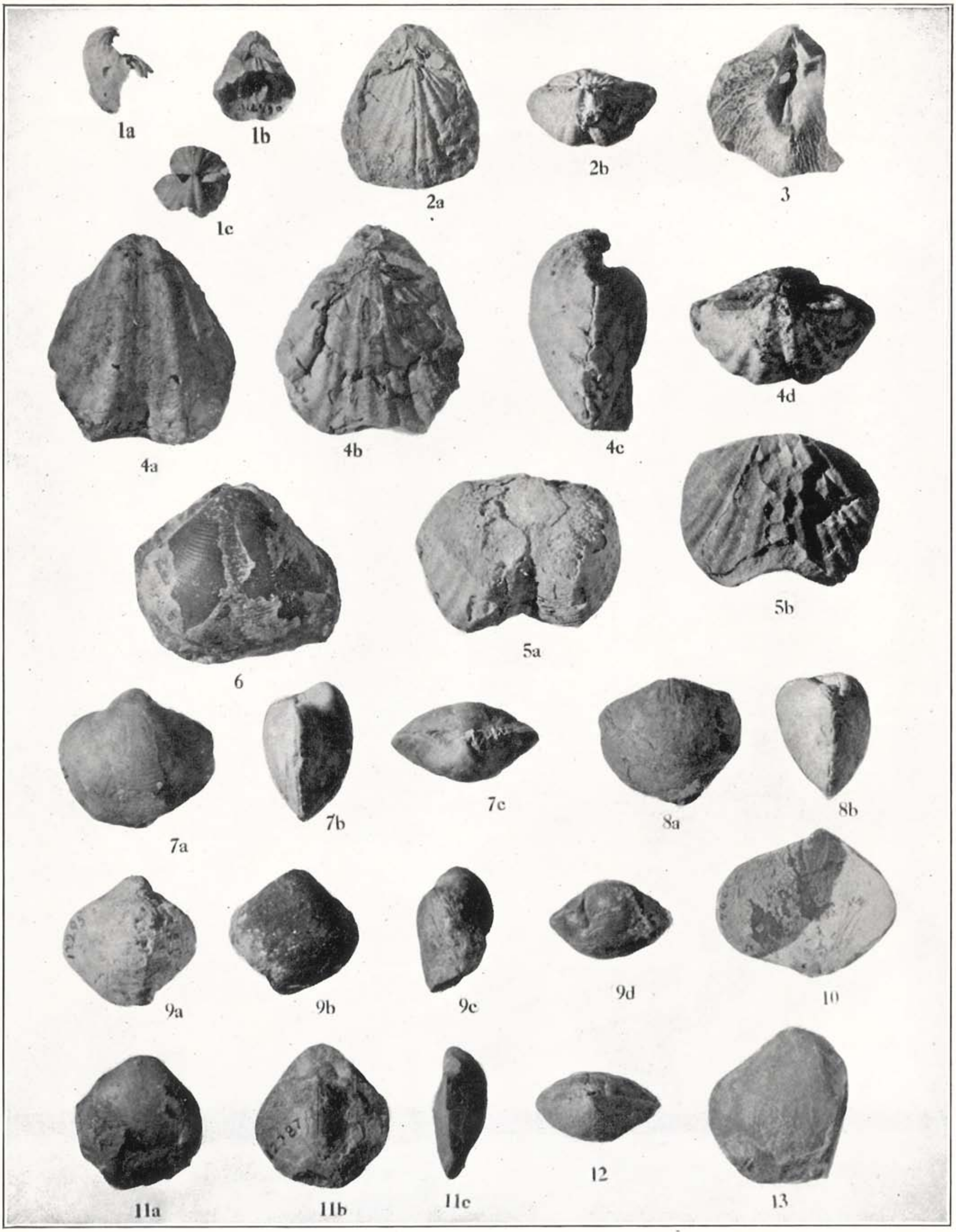
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PLATE XLI

Figure— PAGE

1–5. *Ambocoelia guadalupensis* Girty 119–120

1a–d. Pedicle, brachial, posterior, and lateral views of a specimen from loc. T. 120. T. 10061. Leonard formation, Glass Mountains.

2. Brachial view of an exceptionally small specimen rather doubtfully referred to this species. Loc. 414. Y.P.M. 12347. Middle Gym formation, Hueco Mountains.

3a–d. Pedicle, brachial, lateral, and posterior views of a specimen from loc. 491. Y.P.M. 12348. Bone Canyon limestone, Delaware Mountains.

4a–b. Pedicle and posterior views of a specimen from loc. 265. Y.P.M. 12340.

5a–b. Pedicle and lateral views of a specimen from loc. Tc. T. 10065. Word formation, Glass Mountains.

6–10. *Martinia rhomboidalis* Girty 120

6a–b. Brachial and posterior views of a specimen from loc. 77. The locality is supposed to be in the Wolfcamp, but probably this and other fossils were derived from float originating above. T. 10171.

7a–b. Posterior and brachial views of a specimen from loc. 120. T. 10153. Leonard formation, Glass Mountains.

8a–c. Pedicle, lateral, and posterior views of a pedicle valve from loc. 57. Y.P.M. 12319. Capitan formation, Altuda member, Glass Mountains.

9a–c. Posterior, pedicle, and lateral views of a specimen from loc. 123. Y.P.M. 12325. Leonard formation, Glass Mountains.

10. Large piece from loc. 57 containing several specimens. Y.P.M. 12319. Capitan formation, Altuda member, Glass Mountains.

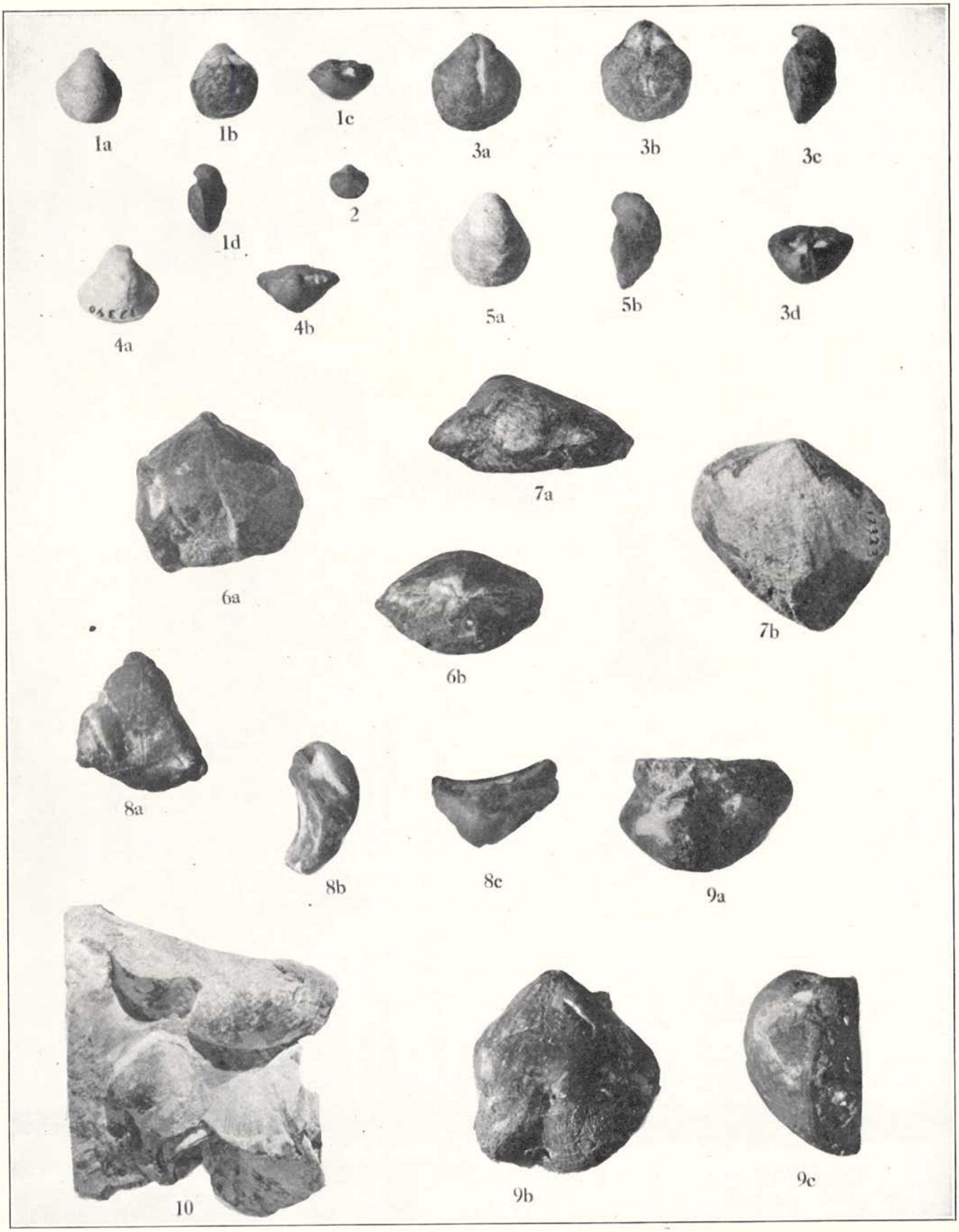
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PLATE XLII

Figure — PAGE

1–6. *Spiriferina hilli* Girty ... 122
1. Brachial view of a specimen from loc. D. 9. Leonard formation, Glass Mountains.
2. Pedicle view of a broad, non-typical specimen from loc. 208. Y.P.M. 12270. Hess formation, Glass Mountains.
3. Pedicle view of a specimen from loc. D. 20.
4. Posterior view of a specimen from loc. D. 20. Leonard formation, Glass Mountains.
5. Lateral view of a specimen from Cerro Pichagüia. Y.P.M. 12271.
6a–b. Posterior and pedicle views of a specimen from Cerro Pichagüia. Y.P.M. 12271. Limestone of Pichagüia, near Las Delicias, Coahuila.

7–11. *Spiriferina laxa* Girty ... 122–123
7. Interior of the apical part of a brachial valve from Cerro Pichagüia, showing the cardinal process, and hinge-sockets. Y.P.M. 12318.
8a–c. Exterior, interior, and lateral views of a pedicle valve from Cerro Pichagüia, showing median septum and hinge-teeth. Limestone of Pichagüia, near Las Delicias, Coahuila. Y.P.M. 12318.
9a–c. Pedicle, lateral, and posterior views of a pedicle valve from loc. T. 148. T. 9988.
10. Posterior view of a specimen from loc. 192. T. 9987.
11. Pedicle view of an exceptionally broad specimen from loc. 46. Y.P.M. 12311. Word formation, Glass Mountains.

12–13. *Spiriferina angulata*, n. sp. ... 122
12a–c. Pedicle, anterior, and lateral views of the holotype, from loc. 478. Y.P.M. 12301. Hess formation, Sierra Diablo.
13. Brachial view of a fragmentary specimen from loc. 106. T. 10675. Hess formation, Glass Mountains.

14. *Spiriferina pyramidalis* Girty ... 123–124
14a–c. Posterior, brachial, and lateral views of a specimen from loc. 264. Y.P.M. 12308. Word formation, Glass Mountains.

15–18. *Punctospirifer billingsii* (Shumard) ... 124–125
15a–c. Exterior, interior, and lateral views of a pedicle valve from loc. Tx. T. 10991.
16. Part of a brachial valve from loc. T. 148, showing nature of surface. T. 9958.
17a–b. Pedicle and lateral views of a pedicle valve from loc. 241. Y.P.M. 12285.
18a–c. Brachial, lateral, and posterior views of a specimen from loc. Tc. T. 9967. Word formation, Glass Mountains.

19. *Hustedia bipartita* Girty ... 125
19a–c. Pedicle, lateral, and posterior views of a specimen from loc. D. 2. Leonard formation, Glass Mountains.

20–26. *Hustedia pusilla* (Girty) ... 127–128
20a–c. Pedicle, brachial, and lateral views of a specimen from an unknown locality and horizon. T. 11032.
21a–b. Pedicle and anterior views of a specimen from an unknown locality and horizon. T. 11030.
22. Pedicle view of a specimen from an unknown locality and horizon. Y.P.M. 12686.
23. Anterior view of a specimen from an unknown locality and horizon.
24. Pedicle view of a specimen from loc. 195a, doubtfully conspecific with *H. pusilla*. Y.P.M. 12690. Wolfcamp formation, Glass Mountains.
25. Pedicle view of a specimen from an unknown locality and horizon.
26a–b. Front and posterior views of the jugum of an etched specimen from loc. 46. Y.P.M. 12688. Word formation, Glass Mountains.

27–32. *Hustedia mormoni papillata* (Shumard) ... 127
27. Lateral view of a specimen from an unknown locality and horizon.
28. Brachial view of a specimen from an unknown locality and horizon. T. 11024.
29. Exterior of an etched pedicle valve from an unknown locality. T. 11018. Word formation.
30a–c. Brachial, lateral, and posterior views of a specimen from an unknown locality and horizon. Y.P.M. 12683.
31a–d. Pedicle, brachial, lateral, and posterior views of a specimen from loc. 243. Y.P.M. 12187.
32a–b. Brachial and lateral views of a specimen from loc. 239. Word formation, Glass Mountains.

33. *Hustedia mormoni* (Marcou) ... 127
33a–c. Brachial, lateral, and posterior views of a specimen from loc. 93. Y.P.M. 12174. Wolfcamp formation, Glass Mountains.

34–39. *Hustedia meekana* (Shumard) ... 126–127
34a–d. Pedicle, brachial, lateral, and posterior views of a specimen from loc. 123. T. 10023. Leonard formation, Glass Mountains.
35. Brachial view of a specimen from loc. 491. Y.P.M. 12075. Bone Canyon limestone, Delaware Mountains.
36. Brachial view of a specimen from loc. T. 107. T. 9971. Hess formation, Glass Mountains.
37a–d. Pedicle, brachial, lateral, and posterior views of a specimen from loc. 123. T. 10023. Leonard formation, Glass Mountains.
38a–c. Brachial, pedicle, and lateral views of a specimen from loc. T. 243. T. 9973. Word formation, Glass Mountains.
39. Brachial view of a specimen from loc. 25. Y.P.M. 12094. Leonard formation, Glass Mountains.

40–42. *Hustedia huecoensis*, n. sp. ... 125–126
40a–c. Brachial, pedicle, and lateral views of a cotype from loc. 440a. Y.P.M. 12123.
41a–d. Brachial, pedicle, lateral, and posterior views of a cotype from loc. 440a. T. 11004.
42. Pedicle valve from loc. 440a. Y.P.M. 12123. Upper Gym formation, Hueco Mountains.

43–46. *Hustedia hessensis*, n. sp. ... 125
43a–c. Pedicle, lateral, and posterior views of a specimen from loc. 106. T. 10064. Hess formation, Glass Mountains.
44a–c. Brachial, lateral, and posterior views of a cotype from loc. 478. Y.P.M. 12127.
45. Brachial view of a cotype from loc. 478. Y.P.M. 12127.
46. Brachial view of a specimen from loc. 471. T. 10146. Hess formation, Sierra Diablo.

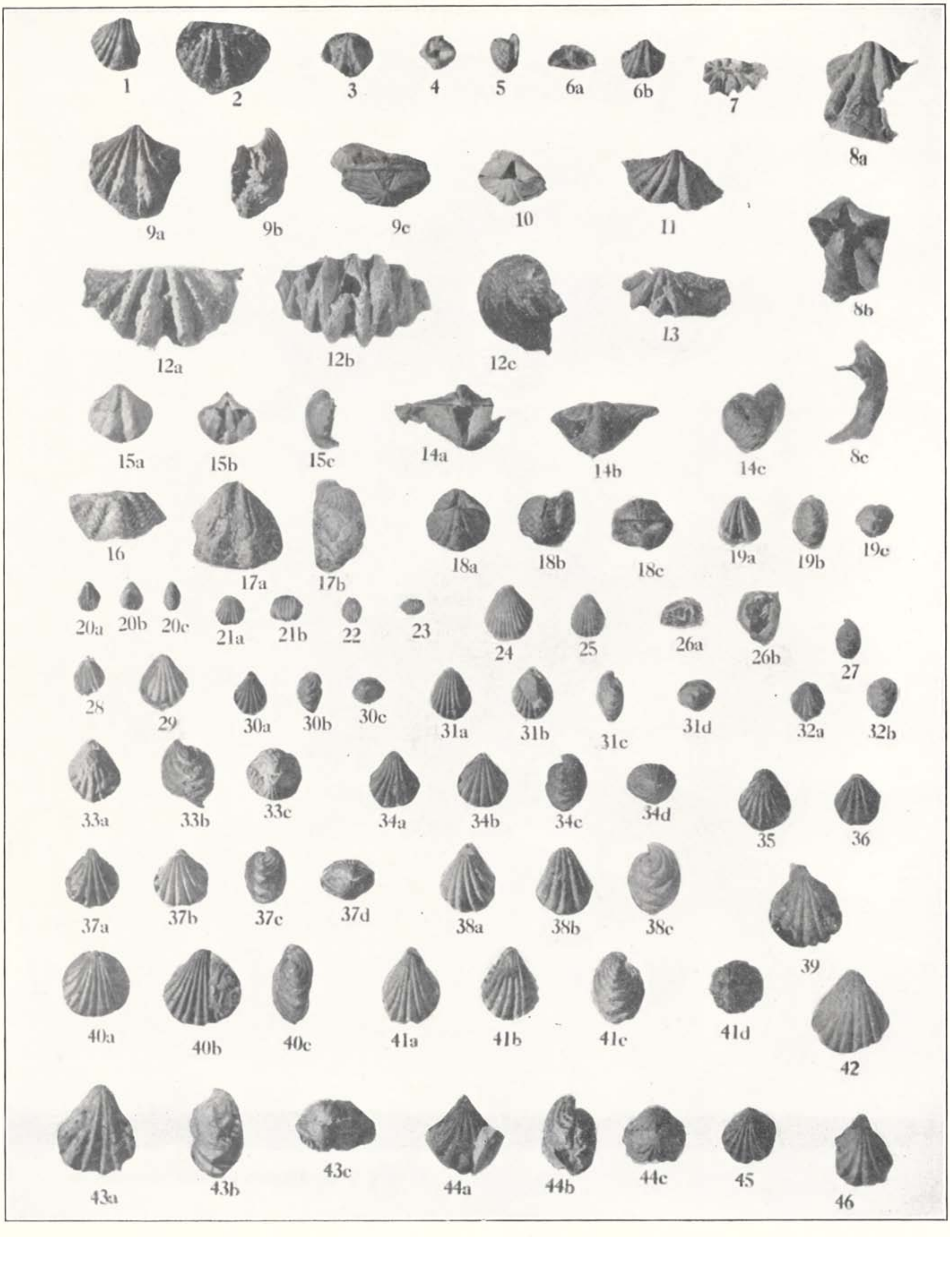
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PLATE XLIII

Figure — PAGE

1–11. *Composita mexicana* (Hall) 128–129

1a–e. Pedicle, brachial, lateral, anterior, and posterior views of a specimen from loc. 223. T. 9993.

2a–e. Pedicle, brachial, lateral, anterior, and posterior views of a specimen from loc. 223. T. 9993.

3a–e. Pedicle, brachial, lateral, anterior, and posterior views of a specimen from loc. 223. T. 9993. Hess formation, Glass Mountains.

4a–d. Brachial, posterior, pedicle, and lateral views of a specimen from loc. 397. Y.P.M. 12220. Lower Gym formation, Hueco Mountains.

5a–e. Pedicle, brachial, lateral, anterior, and posterior views of a specimen from loc. 223. T. 9993. Hess formation, Glass Mountains.

6. Pedicle view of a specimen from loc. 436b. Y.P.M. 12217. Upper Gym formation, Hueco Mountains.

7a–b. Brachial and lateral views of a specimen from an unknown locality and horizon. Y.P.M. 12681.

8a–c. Pedicle, brachial, and posterior views of a specimen from loc. 223. T. 9993.

9a–b. Brachial and lateral views of a specimen from loc. 223. T. 9993. Hess formation, Glass Mountains.

10a–d. Pedicle, brachial, lateral, and anterior views of a specimen from loc. 436b. Y.P.M. 12217. Upper Gym formation, Hueco Mountains.

11a–b. Pedicle and lateral views of a specimen from loc. 451. Gym formation, Diablo Plateau.

12–17. *Composita emarginata affinis* Girty 128

12a–d. Brachial, lateral, posterior, and anterior views of a specimen from loc. 247. T. 10118.

13. Brachial view of an internal mold from loc. 247. Y.P.M. 12249.

14a–b. Posterior and brachial views of an internal mold from loc. 247. T. 10118.

15a–d. Pedicle, brachial, lateral, and anterior views of a specimen from loc. 247. T. 10118. Middle and upper Word formation, Glass Mountains.

16a–b. Brachial and lateral views of a specimen from bed 12, section 12. Y.P.M. 12251. Cerro Caballo limestone, Las Delicias, Coahuila.

17. Pedicle view of a specimen from loc. 145. Y.P.M. 12258. Middle and upper Word formation, Glass Mountains.

18–19. *Composita persinuata* (Meek) 130

18a–c. Pedicle, posterior, and anterior views of a specimen from loc. 55. T. 10591.

19a–e. Pedicle, brachial, lateral, anterior, and posterior views of a specimen from loc. 241. Y.P.M. 12277. Word formation, Glass Mountains.

20. *Composita subtilita* (Hall) 130

20a–b. Lateral and brachial views of a specimen from loc. 93. Y.P.M. 12699. Wolfcamp formation, Glass Mountains.

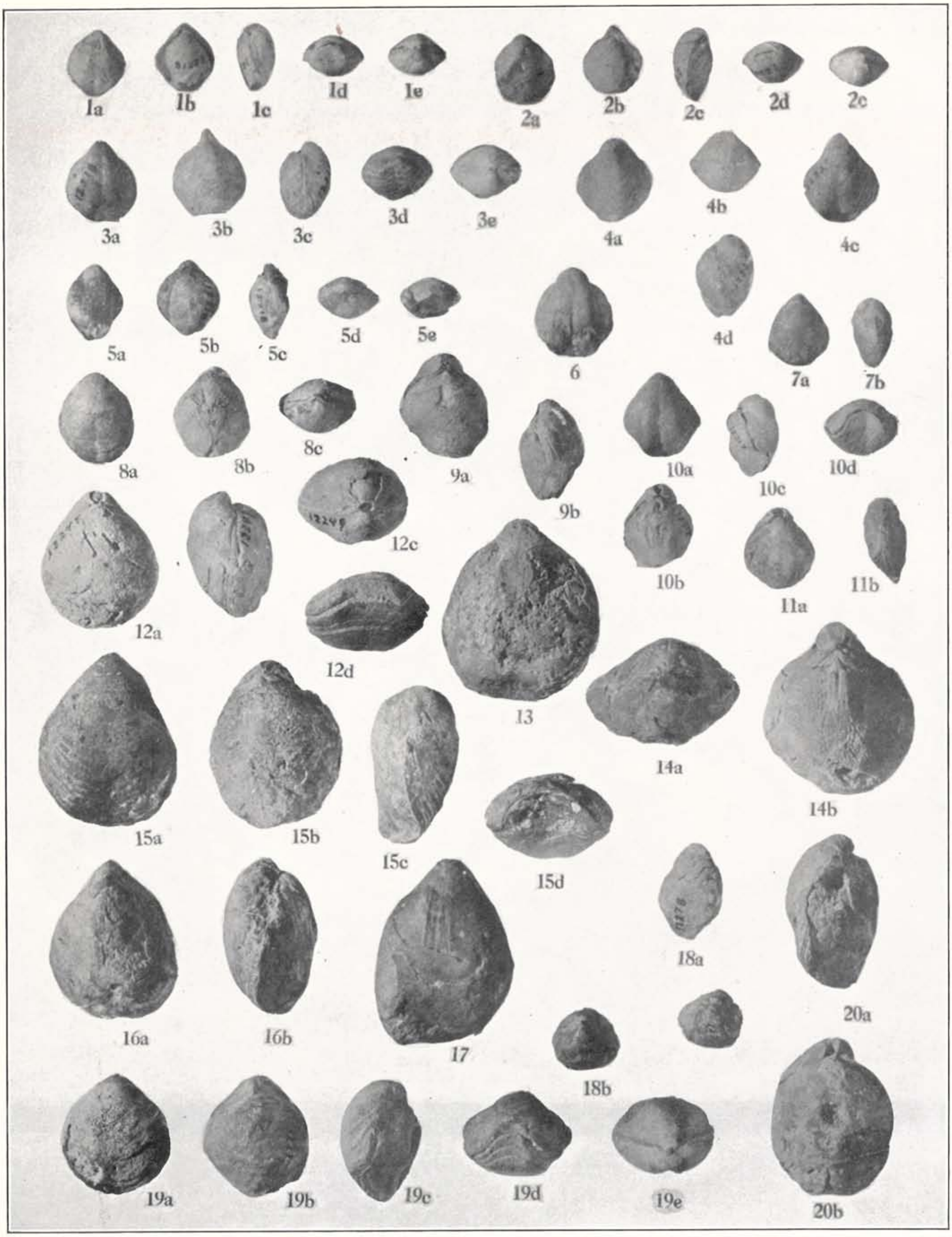
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PLATE XLIV

Figure— PAGE

1-2. *Composita subtilita* (Hall) 130

1a-b. Pedicle and anterior views of a specimen from loc. T.107. T. 10137. Hess formation, Glass Mountains.

2a-b. Lateral and pedicle views of a specimen from loc. D.3. Word formation?, Glass Mountains.

3-8. *Composita mira* (Girty) 129

3a-c. Brachial, lateral, and posterior views of a specimen from loc. Te. T. 10207. Gym formation, Three-mile Mountain, near Van Horn.

4a-d. Brachial, pedicle, lateral, and posterior views of a specimen from loc. 174. Y.P.M. 12203. Leonard formation, Glass Mountains.

5a-c. Brachial, lateral, and pedicle views of a specimen from loc. 484. Y.P.M. 12205. Bone Canyon member, Leonard formation, Sierra Diablo.

6a-c. Brachial, pedicle, and lateral views of a specimen from loc. 128. T. 10210.

7. Pedicle view of a specimen from loc. 174. Y.P.M. 12203. Leonard formation, Glass Mountains.

8a-b. Pedicle and lateral views of a specimen from loc. 46. Y.P.M. 12196. Word formation, Glass Mountains.

9-10. *Composita subtilita angusta*, n. var. 130-131

9a-d. Brachial, pedicle, lateral, and anterior views of a cotype from loc. 456. Y.P.M. 12191. Upper Wolfcamp formation, Sierra Diablo.

10a-d. Pedicle, brachial, lateral, and posterior views of a cotype from loc. 199. T. 10143. *Uddenites* member, Wolfcamp formation, Glass Mountains.

11. *Dielasma bovidens* (Morton) 132

11a-c. Brachial, lateral, and posterior views of a specimen from loc. 199. Y.P.M. 12140. *Uddenites* member, Wolfcamp formation, Glass Mountains.

12-14. *Dielasma schucherti minor*, n. var. 133

12a-d. Brachial, pedicle, lateral, and anterior views of a specimen from loc. 239. Y.P.M. 12156.

13a-b. Brachial and anterior views of a specimen from loc. 239. T. 9982.

14a-b. Brachial and anterior views of a specimen from loc. 239. Y.P.M. 12156. Word formation, Glass Mountains.

15. *Dielasmina guadalupensis* Girty 133

15a-d. Lateral, brachial, and anterior views of a specimen from loc. 223. Y.P.M. 12159. Hess formation, Glass Mountains.

16. *Dielasma problematicum wordense*, n. var. 131-132

16a-e. Brachial, pedicle, lateral, posterior, and anterior views of the holotype from loc. T.144. T. 10312. Word formation, Glass Mountains.

17-20. *Dielasma spatulatum* Girty 132

17. Etched interior of a brachial valve from loc. Tx. T. 11062.

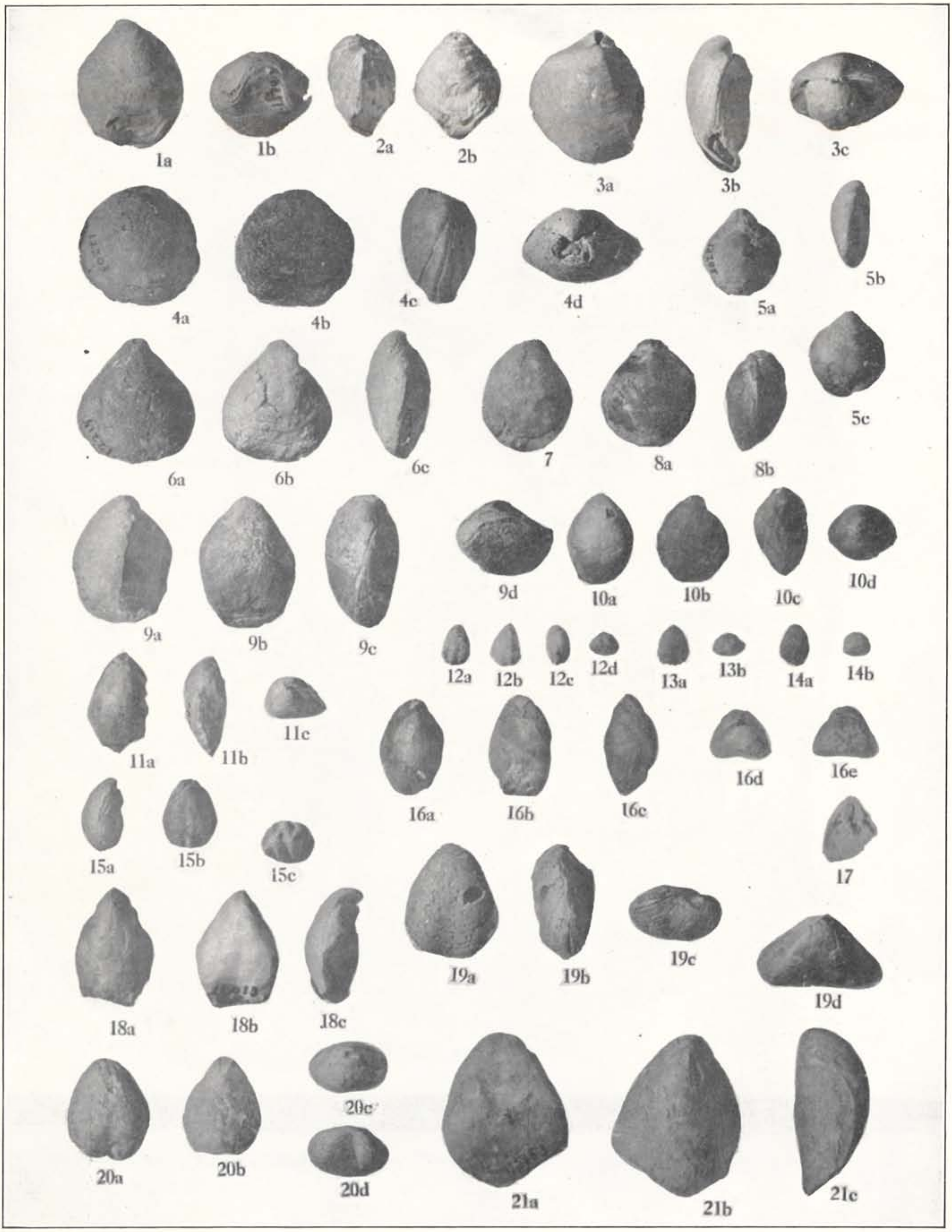
18a-c. Brachial, pedicle, and lateral views of a specimen from loc. T.240. T. 10151.

19a-c. Pedicle, lateral, and anterior views of a specimen from loc. 141. Y.P.M. 12144.

20a-d. Pedicle, brachial, posterior, and anterior views of a specimen from loc. T.240. T. 10151. Word formation, Glass Mountains.

21. *Dielasma shafterense*, n. sp. 132

21a-d. Pedicle, brachial, lateral, and posterior views of the holotype from loc. Tp. T. 10025. Cibolo limestone, Shafter district.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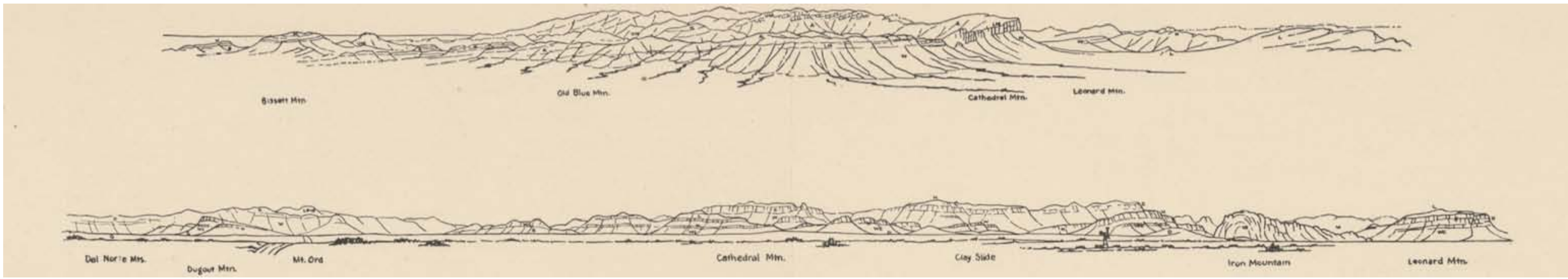
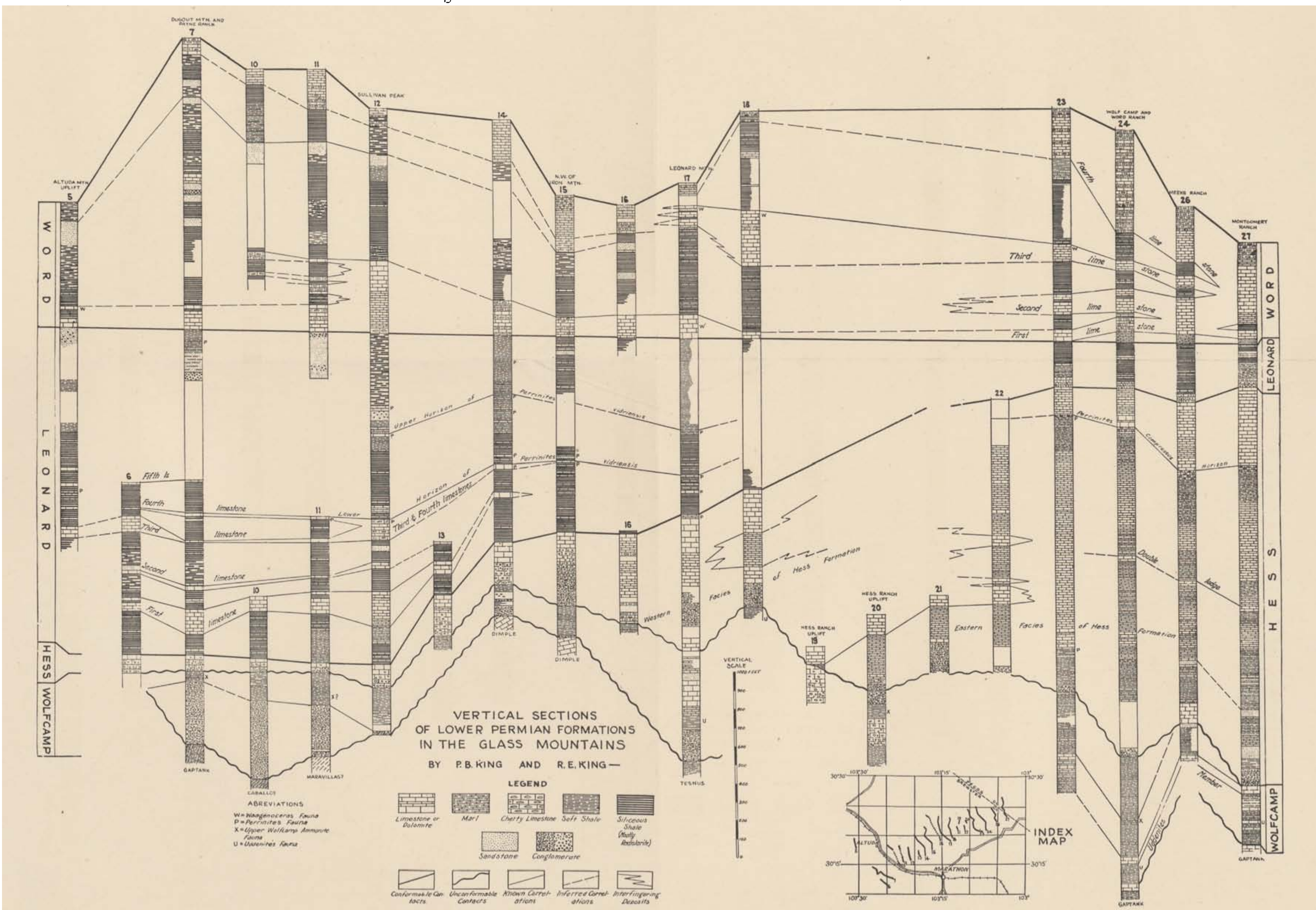
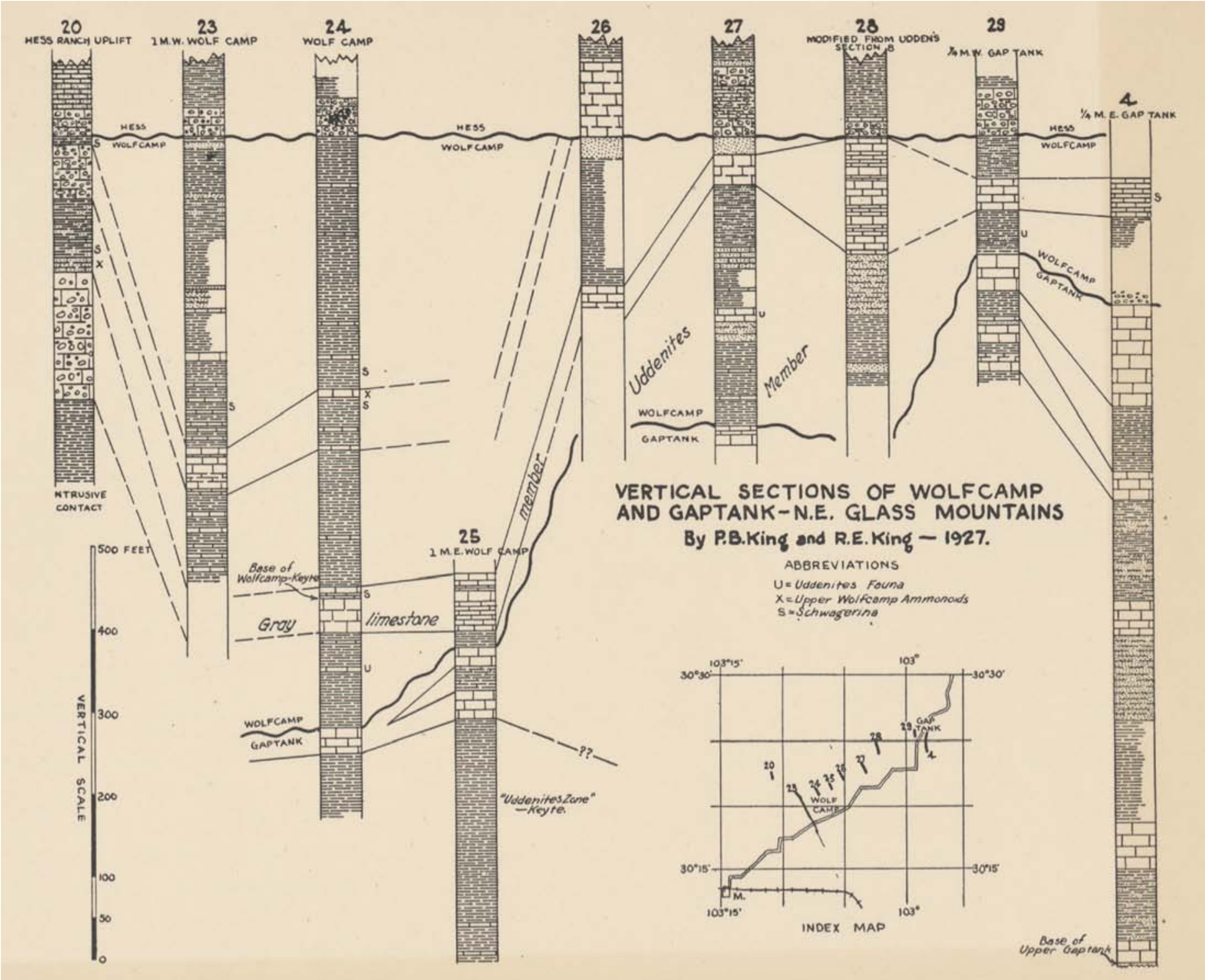


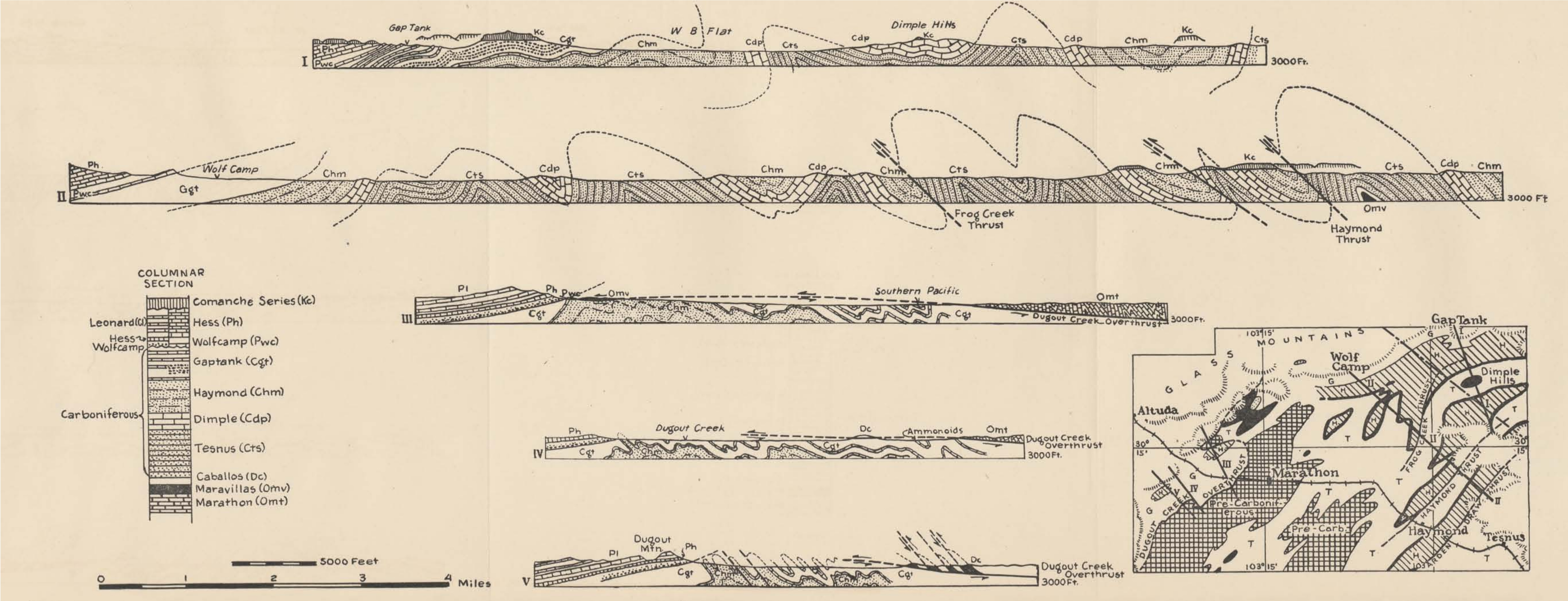
A. Two views of the Glass Mountains. Upper figure: from a high peak on the Del Norte Mountains looking northeast, showing the range in cross-section. Lower figure: view of the western half of the Glass Mountains from Marathon.



B. Vertical sections of Lower Permian formations of the Glass Mountains.



Vertical sections of Wolfcamp and Gaptank formations in northeast part of Glass Mountains.



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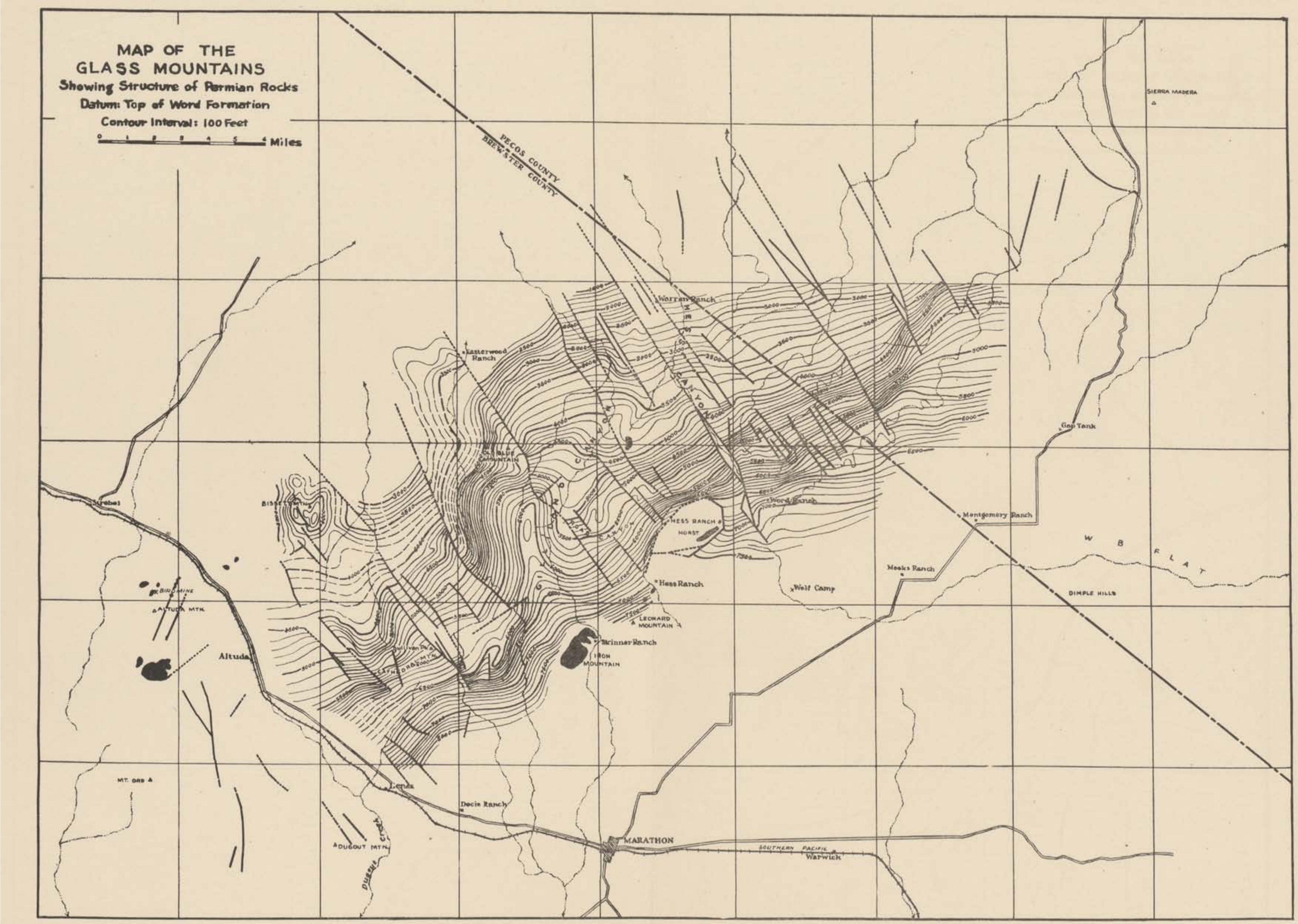
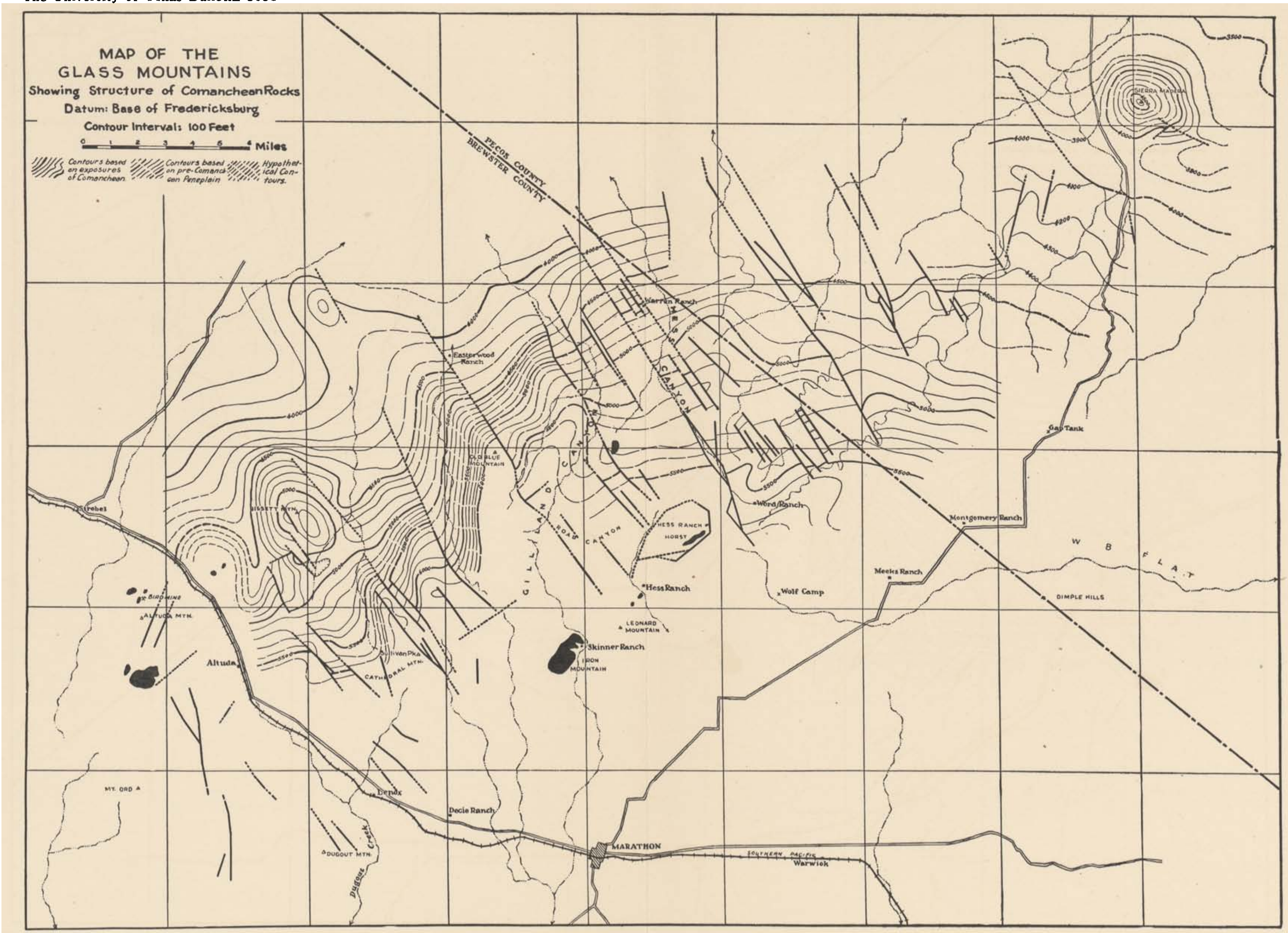
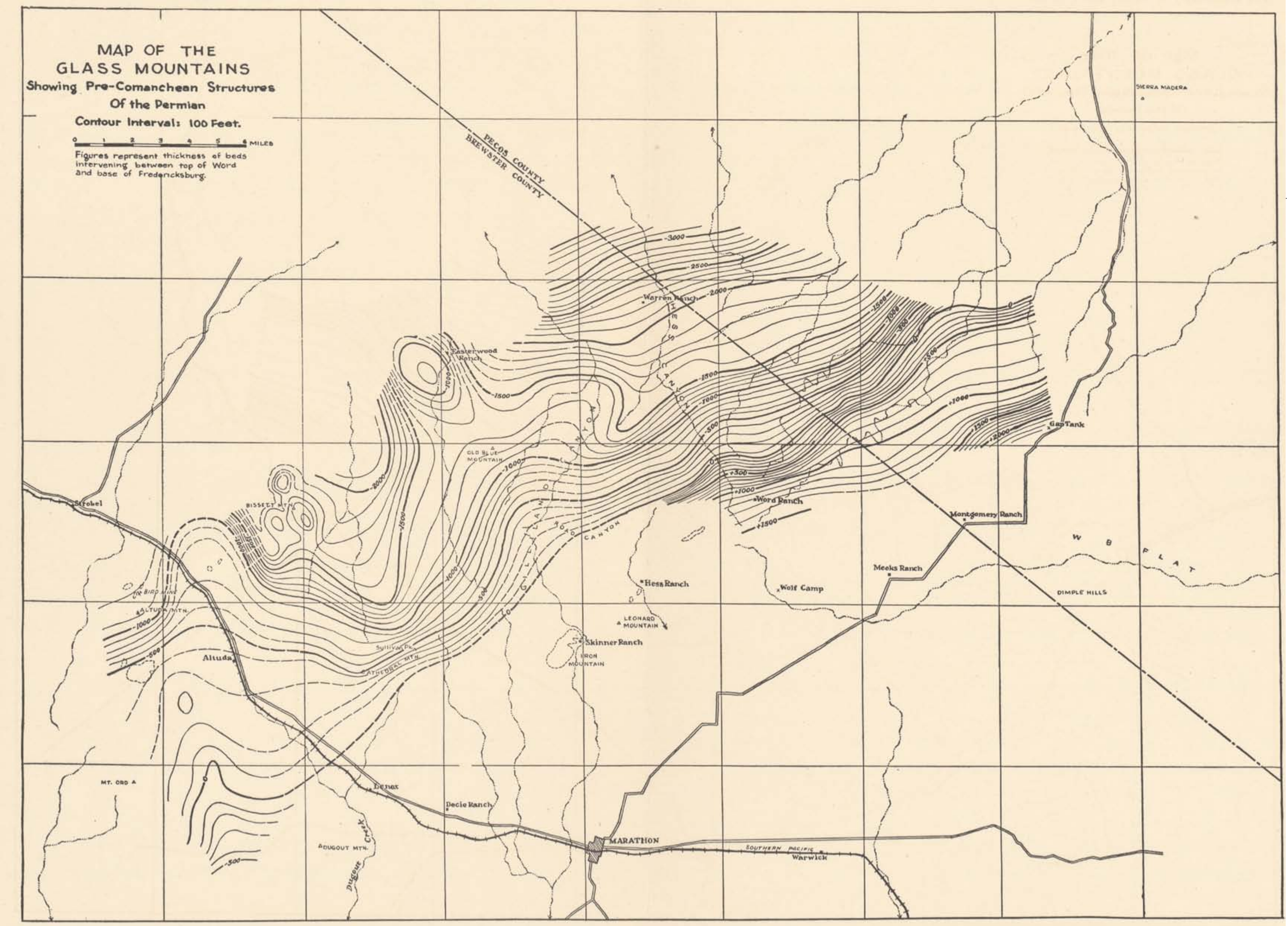


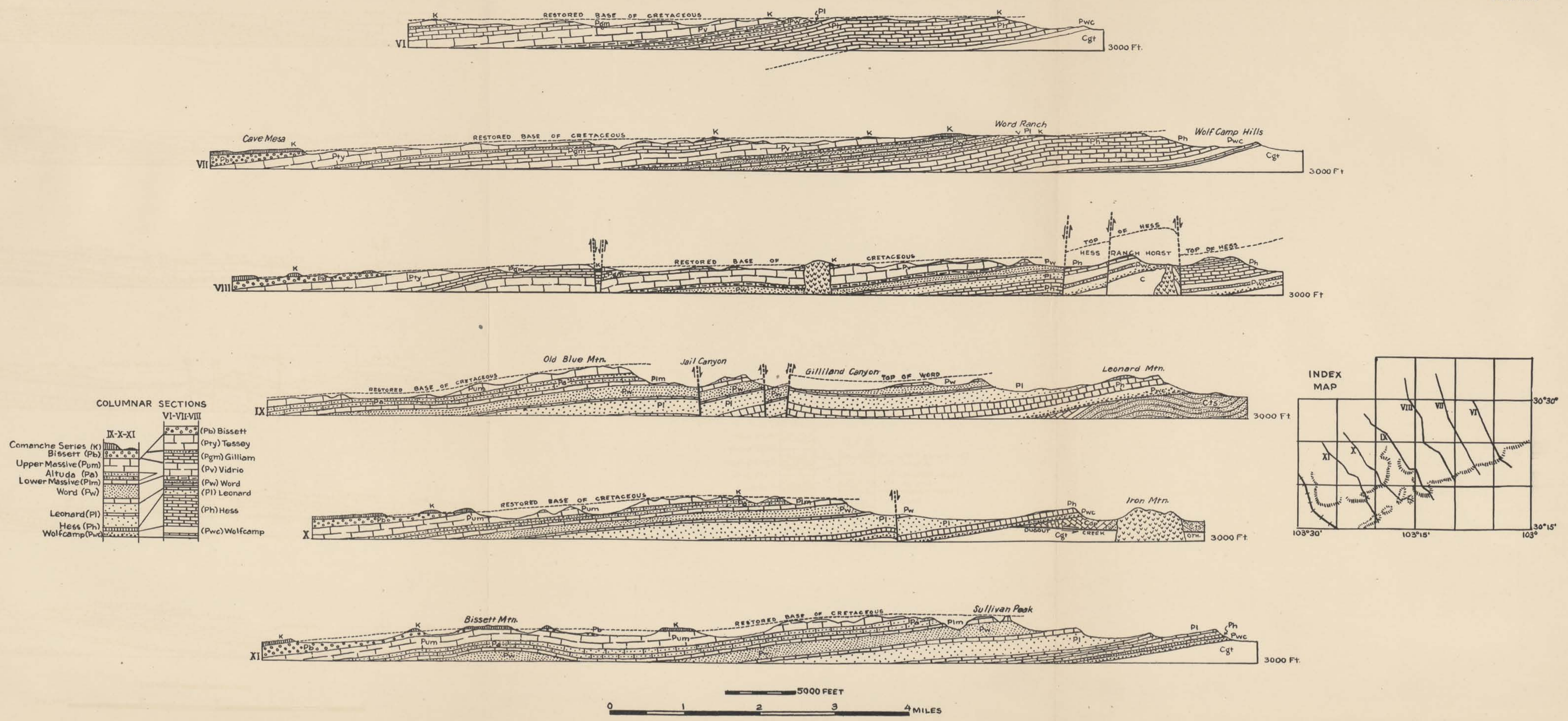
MAP OF THE GLASS MOUNTAINS SHOWING STRUCTURE OF THE PERMIAN ROCKS



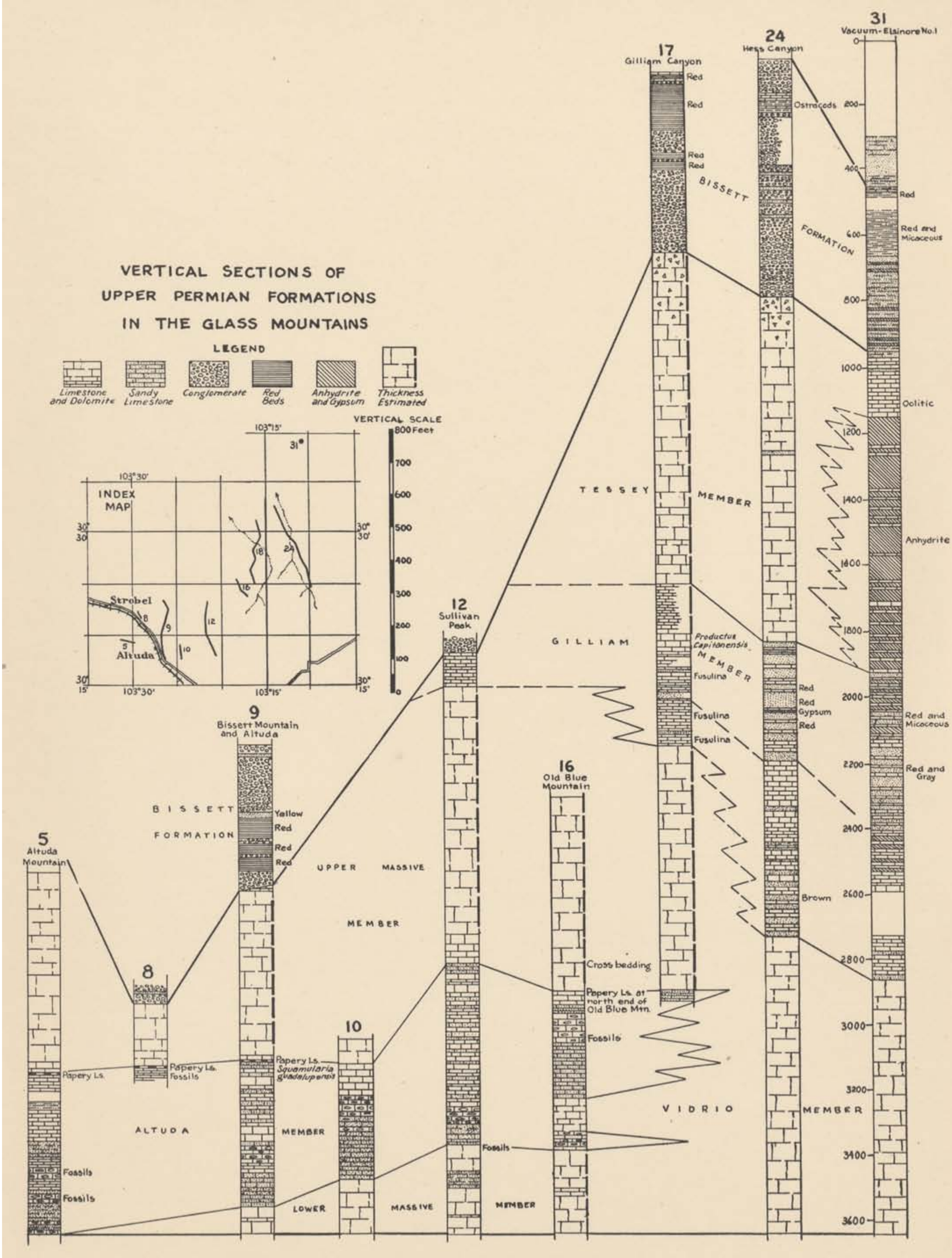
MAP OF THE GLASS MOUNTAINS SHOWING STRUCTURE OF THE COMANCHEAN ROCKS



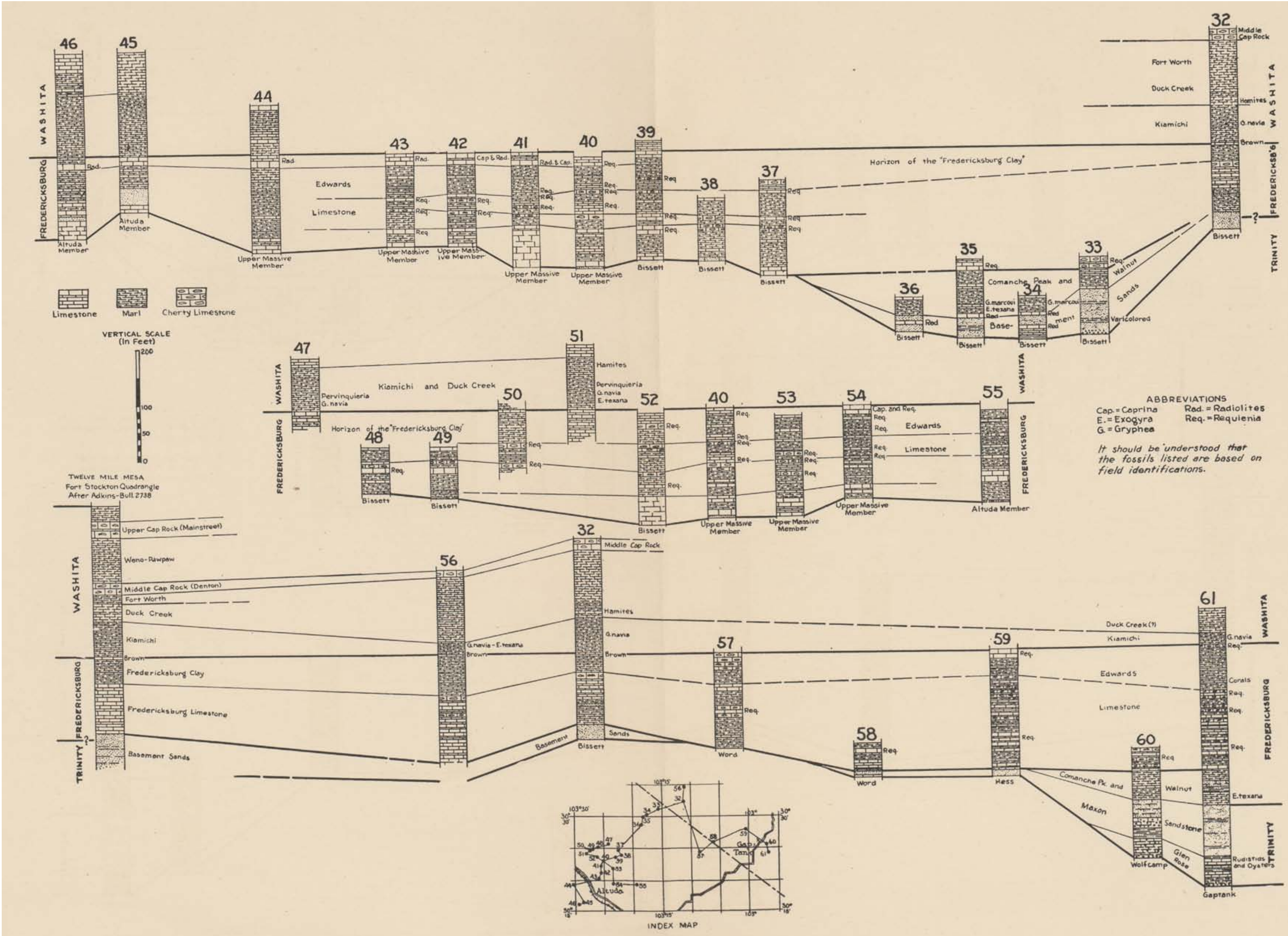
MAP OF GLASS MOUNTAINS SHOWING PRE-COMANCHEAN STRUCTURES OF THE PERMIAN



STRUCTURE SECTIONS IN THE GLASS MOUNTAINS



Vertical sections of Upper Permian formations of the Glass Mountains.



VERTICAL SECTIONS OF COMANCHE SERIES OF GLASS MOUNTAINS