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W. S. Adkins and W. M. Winton

Bureau of Economic Geology and Technology
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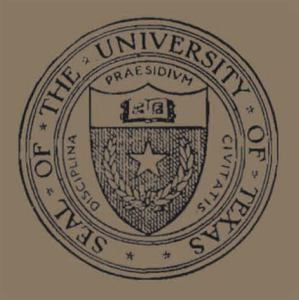


PUBLISHED BY
THE UNIVERSITY OF TEXAS
AUSTIN

565-2850-1019-2m

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PUBLISHED BY THE UNIVERSITY SIX TIMES A MONTH, AND ENTERED AS SECOND-CLASS MATTER AT THE POSTOFFICE AT AUSTIN, TEXAS, UNDER THE ACT OF AUGUST 24, 1912

**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. . . It is the only dictator that freemen acknowledge and the only security that freemen desire.**

**Mirabeau B. Lamar.**

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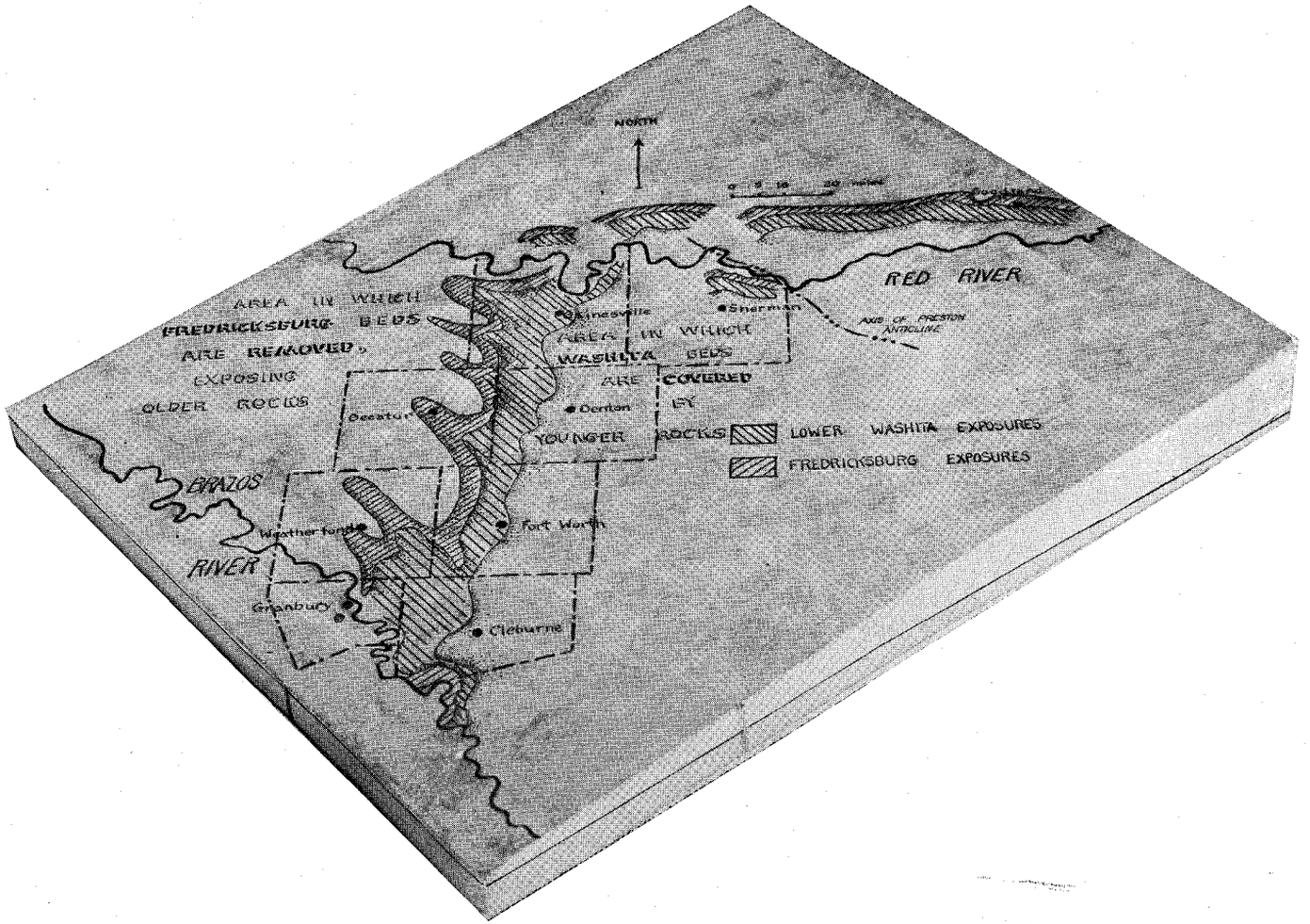


Diagrammatic representation of the attitude, relationships and thickness changes of the Fredericksburg and lower Washita beds in North Texas. From a model in the Museum of Texas Christian University.

# PALEONTOLOGICAL CORRELATION OF THE FREDERICKSBURG AND WASHITA FORMATIONS IN NORTH TEXAS

By W. S. ADKINS and W. M. WINTON[1]

## INTRODUCTION

This paper is intended to furnish details of the stratigraphy of the rocks of the Fredericksburg and Washita series of the Comanchean in the counties of COOKE, GRAYSON, WISE, DENTON, PARKER, TARRANT, HOOD, and JOHNSON. In this area, these rocks form a broad and irregular strip extending from the Red River to the Brazos River. The succession is a bewildering one of alternating limestones and marls; and the lithological characters show startling changes within short distances. The earlier writers commented on the rapid changes in a north-south direction, but further study has shown that the east-west changes both in lithology and thickness are quite as marked.

The writers of this paper, after six years of work in this area are convinced that the only practicable basis for field work here is paleontological. The data furnished herewith are intended as a guide for more exact vertical orientation. This work is simply an assembly of details, following the work of a number of others to whom the writers are greatly indebted. No special acknowledgment beyond the accompanying bibliography is possible, but exception is made in the case of Dr. R. T. Hill, whose work may be characterized as truly monumental. In view of the fact that Dr. Hill's work was done in the days of few railroads, poor roads and no automobiles, the enormous number of accurate observations which he assembled has repeatedly surprised the present writers.

In view of the extensive search now being made on this area for structures favorable for the concentration of petroleum products, this paper is made as practical as possible in tone.

With a dip sometimes as much as two degrees or more and with alternating beds of limestones and marls; and with limestones separated vertically one hundred feet or more having exactly the same lithology, the making of large scale structural maps in this region is an impossibility for even an alert and experienced geologist if the closest attention is not given to the fossils.

The paleontology of the Fredericksburg and Washita rocks in these eight counties is surprisingly rich and varied. We have collected over

---

[1]The order of names does not in any way indicate seniority. Ms. accepted September, 1919, published January, 1920.

one hundred undoubtedly new species. Of these a few are included in this paper, some because of their great stratigraphic value and others, notably the starfishes, because of the presence of unusually interesting species. Although several hundred species, old and new, occur in this region, a knowledge of only a limited number is indispensable for good work.

Other species will be described by the writers and others as rapidly as is practicable. The ammonites, especially those of the Schloenbachia group, are so abundant and so varied as to constitute a special problem. These ammonites are of world-wide distribution and have proven extremely valuable in working out the broader aspects of correlation.

It is hoped that this paper will furnish facts which will be suggestive and helpful in determining the exact correlation of the Comanchean rocks of north Texas and those of the south central portion.

Many problems of profound interest in connection with paleogeography project themselves into the study of the Comanchean rocks of the north Texas region. The writers have made a positive effort to refrain from remarks and conjectures concerning the various features of the paleogeography as such matter seems out of place in a paper of this nature.

An explanatory note concerning the use of terms in this paper seems worth while. Where the term *zone* is used unless otherwise indicated, it will refer to a vertical range of occurrence of ten feet or less; *horizon* will refer to a vertical range of twenty-five feet or less. Often a *horizon* includes one or more *zones*. Likewise certain fossils which cannot be limited to a horizon are sometimes concentrated into one or more *zones of abundance*, which for the area in question are of considerable practical importance. The problems of *recurrent* species and species of limited area are taken up in more detail later.

## GENERAL STATEMENTS

The stratigraphy of this region is best discussed in terms of the successive fossil horizons; and this method will be followed throughout; but a careful check will be made against the formation terms, introduced by Hill, and generally used. The formations,[1] from above downward are as follows:

[1]The introduction here of the terms "Upper Washita" and "Lower Washita" is for convenience and not to permanently introduce such terms. The writers further follow the general usage in placing the Kiamitia with the Washita, although on paleontological grounds this formation properly belongs with the Fredericksburg.

| | | Total Thickness at: | | | |
|---|---|---|---|---|---|
| | | Denison | Fort Worth | Southern Johnson County | Southern Parker County |
| UPPER WASHITA | Grayson<br>Mainstreet<br>Pawpaw<br>Weno (including Quarry) | 290 | 205 | 140 | ... |
| LOWER WASHITA | Denton<br>Fort Worth<br>Duck Creek<br>Kiamitia | 278 | 105 | 65 | 95 |
| FREDERICKSBURG | Goodland<br>(Edwards and Comanche Peak)<br>Walnut | 20 | 250 | 300 | 290 |

The beds referred to here as "Upper Washita" were grouped by Hill as the Denison beds, but this grouping included the Denton formation also. A marked paleontological break occurs between the Denton and the Weno. The findings of the writers with regard to the changes in thickness of the Fredericksburg and Lower Washita beds are illustrated diagramatically in the photograph of the model (p. 1). The Upper Washita beds, also, exhibit some striking changes in thickness and lithology, but, excepting the Mainstreet limestone, these beds are exposed in such an areally narrow strip that much more work must be done before a projection of their thickness changes can be made. As a broad statement made very cautiously and merely as a suggestion for future

work, we may say that these changes appear to be about as follows: The Weno and Pawpaw formations thin at about the same rate as the beds of the Lower Washita and the Grayson and Mainstreet thicken, and probably in the same direction. Careful study of well logs with a check on the fossil fragments may later determine the exact changes and their rate in the beds of the upper Washita and may furnish considerable refinement to the preliminary data here offered concerning the lower Washita and the Fredericksburg.

The changes in thickness of the rocks of the Fredericksburg and Lower Washita in this region are in a direction about northeast to southwest. The lithological changes of the Lower Washita are in a direction about perpendicular to the direction of thickness change. The optimum section in the entire area would, on theoretical grounds, be in the western part of Denton county. Unfortunately this particular district is on a divide, and exposures are few and poor. The experience of the writers has been that the Tarrant county section is the best, and furnishes a clue to the entire region. The Tarrant county exposures exhibit the changes in thickness, the Fredericksburg thickening a little less than 2 feet to the mile in a southwest direction, the Lower Washita thinning in the same direction and at a slightly greater rate. The lithological change of the Lower Washita, which is mainly a markedly increasing calcareousness in a direction perpendicular to the direction of thickness change, is well shown in Tarrant county.

An understanding of the Tarrant county sections is absolutely essential. The classic locality, is, of course, the Denison section; but a misunderstanding as to the succession of fossils, the lithology and other features of the Comanchean of north Texas will certainly arise in the mind of one who is familiar with the Denison section alone. This can be partly corrected by a comparative study of the nearby Gainesville section. But careful students are urged to study the Fort Worth region, if possible. The Trinity River drainage system furnishes many excellent exposures, which are rich in fossils, both littoral and deep sea species. A detailed description of the areal geology of the Fort Worth district is given in the writers' bulletin on the Geology of Tarrant County (University of Texas Bulletin No. 1931), to which the reader is referred; although, inevitably some of the matter must be repeated in this paper.

For practical purposes the entire region covered in this report will be divided into eight arbitrary districts or belts, which represent approximately similar conditions of thickness and fossil distribution. These belts will be referred to hereafter by letter. See map on page 11. These belts while projected far on each side of the outcrop area repre-

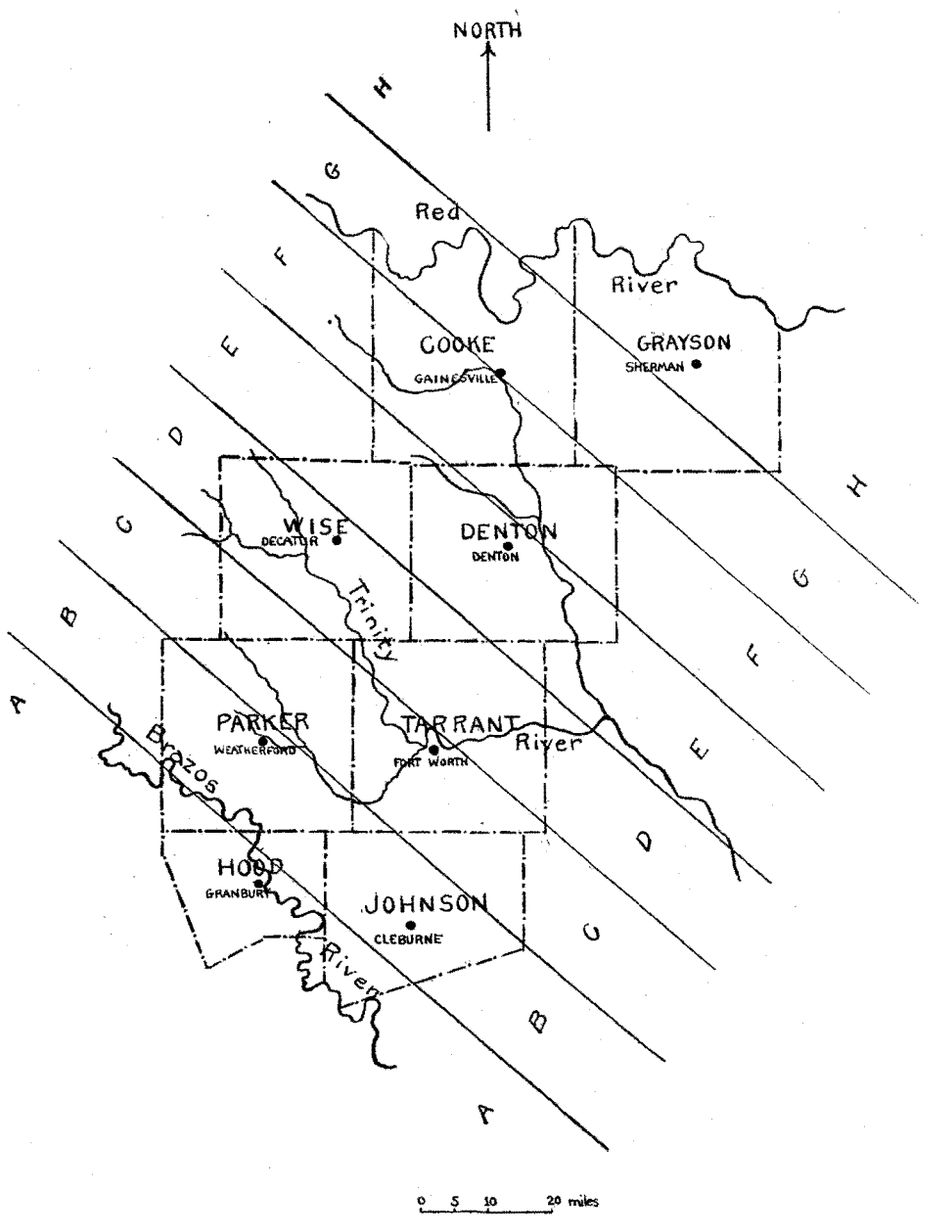


Fig. 1. Map showing districts referred to in description of fossil horizons.

sent only known conditions in that area, but are believed by the writers to extend for some distance—in fact about as far as shown. The range and direction of the extensions, can of course be finally determined only from paleontological checks on well logs; and as many wells are being drilled throughout the region it is hoped that geologists and oil operators will be inclined to place such material at the disposal of the writers.

As the belts actually grade into each other, thicknesses will usually not be given in greater refinement than the nearest ten feet, which is the minimum possible with the present state of knowledge; however, the thicknesses of many zones are accurately known, and in this case will usually be stated in the discussion of the zone. Where a blank is left for a horizon in a district, either information is lacking, the fossil does not occur, or is too rare to be reliable.

We have defined here forty-one horizons on paleontological grounds. These horizons are numbered from below upward, number one being the lowest stratigraphically. For more limited areas (and perhaps even for the entire region) the number of successive horizons can be increased considerably. In Tarrant county, the writers are able to recognize sixty definite horizons, or rather zones, in this case.

The horizons given here are not at all of equal thicknesses, such a feature is impossible to include in a general description of a large area. In certain districts, certain horizons are of greater value than in others. The following list is given of horizons upon which the greatest dependency must be placed in the districts in question:

A Horizons: 1-17.[1]
B Horizons: 1-41.
C Horizons: 1-41.
D Horizons: 1-41.
E Horizons: 1, 3, 4, 8, 9, 10, 11-30, 32-34, 35-41.
F Horizons: 1, 3, 4, 8, 9, 10, 11-30, 32-34, 35-41.
G Horizons: 1, 3, 4, 8, 9, 10, 11-30, 32-34, 35-41.
H Horizons: 1, 3, 4, 8, 10, 11-30, 32-34, 35-41.

The formations, as outlined by Hill, have the following correspondence with our horizons:

**GRAYSON,** Horizon 41.
**MAINSTREET,** Horizons 34-40.
**PAWPAW,** Horizons 31-33.
**WENO (and QUARRY),** Horizons 25-30.
**DENTON,** Horizons 23-24.
**FORT WORTH,** Horizons 18-22 and the upper part of 17.
**DUCK CREEK,** Horizons 11-16 and the lower part of 17.
**KIAMITIA,** Horizon 10.
**GOODLAND (EDWARDS and COMANCHE PEAK),** Horizons 2-9.
**WALNUT,** Horizon 1.

[1]These horizons, numbered as on this page, are described on pp. 15-31.

Some of these horizons will later be subjected to revision because greater refinement will be introduced by the discovery that certain fossils within the formations have a wider horizontal distribution and a more limited vertical range; and a general revision likely will be needed when the Comanchean formations south of the Brazos River are more closely correlated with those in our region.

The horizons have been arranged in three main groups as follows:

III. Horizons of *Gervilliopsis invaginata,* and upwards: Horizons 25–41.
II. Horizons below *Gervilliopsis invaginata* but above *Hamites comanchensis:* Horizons 12–24.
I. Horizons of *Hamites comanchensis* and down to and including the *Gryphea marcoui* cong'omerate: Horizons 1–11.

These three markers are easily recognized in any district in the region. In addition, certain other species are abundant enough even when limited to a horizon, or range vertically enough to be helpful in a preliminary separation.

The following species indicate a position stratigraphically higher than *Gervilliopsis invaginata:*

*Pecten texanus,* Roemer (Pl. 12, figs. 2-4).
*Pecten georgetownensis,* Knicker (Pl. 12, figs. 5-6).
*Hemiaster calvini,* Clark (Pl. 8, figs. 1-2).
*Enallaster bravoensis,* Boese (Pl. 9, fig. 11).
*Schloenbachia* sp. M. (Pl. 5, figs. 1-4).

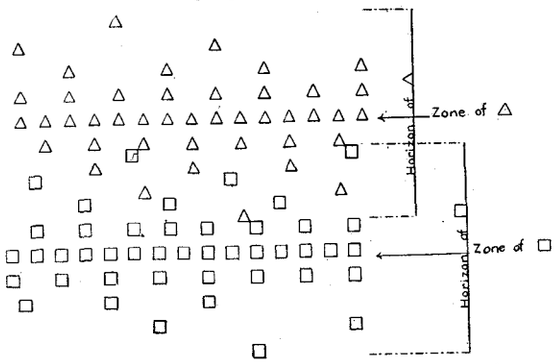


Fig. 2. Diagram illustrating overlapping horizons.

The following species indicate a position stratigraphically below *Gervilliopsis invaginata* but above *Hamites comanchensis:*

*Schloenbachia* sp. I. (Pl. 4, figs. 1-3).
*Holaster simplex,* Clark (Pl. 8, figs. 5, 6).

The following species indicate a position stratigraphically below *Hamites comanchensis* and above the *Gryphea marcoui* conglomerate:

*Gryphea navia*, Hall (Pl. 15, figs. 13-14).
*Hemiaster* species B. (Pl. 8, fig. 7).

Besides the above mentioned species, it is well also to be on the alert for characteristic species of even greater vertical range which have, however, a certain diagnostic value. For instance, the following species never occur as low as *Hamites comanchensis*, although appearing at several stratigraphic points above:

*Kingena* spp. (Pl. 19, figs. 3-12).
*Alectryonia* (*Ostrea*) *carinata*, Lamarck (Pl. 16, figs. 2-4).

Before taking up the description of the horizons, it seems advisable to remind the reader that the paleontological horizons of the Comanchean are not "layers" but in many cases overlap. This is referred to several times in the text of the descriptions and Fig. 2 illustrates graphically an idealized case of overlapping horizons.

## DESCRIPTION OF THE HORIZONS AND ZONES

I. Horizons of *Hamites comanchensis*, and down to and including the *Gryphea marcoui* conglomerate

1. Horizon of **EXOGYRA TEXANA** Roemer (Pl. 13, figs. 11-16) and conglomerate of **GRYPHEA MARCOUI** Hill and Vaughan (Pl. 15, figs. 15-18).

This is the lowest of the definable horizons in the Fredericksburg. It is marked by *Exogyra texana* in great abundance, together with its two more common varieties. (Pl. 13.)

Thickness of horizon in feet in—

Districts: A, 60; B, —[1]; C, 20; D, 10; E, —; F, —; G, 5; H. —.

This horizon is far inferior to many others, although a classic one and much used by field geologists. The horizon is underlain by white sands, lime seams and sandstones, which are usually referred to the Fredericksburg.

The two fossils which characterize this horizon range upward considerably, but the association of the two, and the position of the zone of greatest abundance of the Gryphea overlying that of the Exogyra, are fairly reliable.

In district D, there is an additional but much thinner zone of abundance of the Gryphea, about twenty feet higher.

2. Zone of **SCHLOENBACHIA ACUTOCARINATA** Shumard (Pl. 1, figs. 1-3).

This ammonite appears first in its zone of abundance which is at about the following height above the *Gryphea marcoui* conglomerate: District: A, —; B, 40; C, 30; D, 30; E, 20; F, 20; G, 20; H, 10.

The species ranges upward to near the middle of the Kiamitia formation, but becomes much less abundant.

3. Zone of **OSTREA SP. AFF. JOHANNAE** Choffat (Pl. 16, figs. 11-13).

The zone of abundance of this oyster reaches a vertical maximum thickness of about ten feet, but the species has in the thicker portions of the Fredericksburg a horizon of twenty feet.

Interval of Gryphea marcoui conglomerate:

Districts: A, —; B, 70, C, 60; D, 50; E. 30; F, 30; G, —; H, —.

Associated with *Protocardia texana* (Pl. 18, fig. 7); *Lima wacoensis* (Pl. 17, figs. 7-9); *Pecten irregularis* (Boese) (Pl. 11, figs. 11-15). All these fossils range upward: the *Lima* extends to the middle of the Fort Worth formation; the *Protocardia texana* and *Pecten irregularis* to the middle of the Kiamitia.

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[1]Fossil not known to occur; or too rare to be reliable.

In districts B and C, there is a wealth of species in this horizon. Among those occurring, but not described and figured in this paper are: *Pinna* sp.; *Dentalium sp.; Pecten* sp. (near *P. occidentalis*) ; *Homomya* sp.; *Turritella sp.; Tylostoma chihuahuense* Boese and many others.

4. Zone of **PHOLADOMYA SANCTI-SABAE** Roemer (Pl. 19, figs. 21-23).

This species ranges considerably but reaches a zone of abundance at this level. The zone is restricted to a thickness of less than two feet.

Interval from this zone to top of Gryphea marcoui conglomerate:

Districts: A, —; B, 75; C, 65; D, 55; E, 35; F, 35; G, —; H, —.

5. Horizon of **TRICHOTROPIS SHUMARDI** Cragin (Pl. 18, figs. 4-5).

This rare species is introduced tentatively as it appears to form a horizon at this stratigraphic level, although it is perhaps too difficult to find to be of much value except in the southwestern districts.

6. Zone of **SALENIA MEXICANA** Schlueter (Pl. 9, figs. 14-17).

This interesting and readily recognizable little echinoid has a zone of extremely limited range—less than three feet in district C. While rather difficult to find, even in its zone, it is worth searching for as it is a valuable check on other data. A clue to its level may be had from numbers of *Hemiaster species B,* and *Enallaster texanus* immediately above it.

Intervals from Salenia zone to the top of Gryphea marcoui conglomerate:

Districts: A, —; B, 95; C, 85.

7. Horizon of **HEMIASTER SPECIES B** (Pl. 8, fig. 8) and **ENALLASTER TEXANUS** Roemer (Pl. 9, figs. 12, 13).

This horizon is thick (twenty-five feet in district C) but is unmistakable. The Enallasters attain a palpable zone of abundance within the horizon, and just below is a less defined but similar zone of the Hemiasters. Both of these fossils range considerably, beginning near the bottom of the Goodland formation.

Intervals from middle of the horizon of *Hemiaster* and *Enallaster* to the top of the *Gryphea marcoui* conglomerate:

Districts: A, —; B, 100; C, 90; D, 80; E, 60; F, 40; G, 30.

This Hemiaster should not be confused with *Hemiaster whitei* Clark (Pl. 8, fig. 9) which is not a reliable stratigraphic species on account of its great range.

*Holectypus planatus* Roemer (Pl. 9, fig. 2) while rare always occurs in this horizon.

8. Zone of **PARASMILIA AUSTINENSIS** Roemer (Pl. 19, figs. 27-30) and **OTHER FREDERICKBURG CORALS.**

A well-defined zone of abundance. Readily recognized and immediately overlying the preceding horizon and overlapped by it.

Intervals to top of Gryphea marcoui conglomerate:

Districts: B, 105; C, 90; D, 85; E, 65; F, 35; G, 35.

9. **FIRST UNDEFINED HORIZON.**

This horizon contains various Goodland (Edwards) fossils, very scattered and rare. In many places it is non-fossiliferous. In district A, it contains a few peculiar fossils and is here called the Edwards limestone. This undefined horizon varies in thickness in our region from about thirty feet in district A to less than one foot in district H. The lithology is fairly constant throughout, a hard finely crystalline white limestone. This horizon should be readily recognized by a check on the fossils above and below it.

While the lithology is consistent, one should be extremely cautious, as the unfortunate mistake of confusing this with a similar poorly characterized horizon several hundred feet higher is entirely possible, until more detailed areal geological maps are available.

10. Horizon of **SCHLOENBACHIA BELKNAPI** Marcou (Pl. 2, figs. 4, 5) and **GRYPHEA NAVIA** Hall (Pl. 15, figs. 13, 14).

The horizon of this ammonite grades into that of the Gryphea, the latter being marked throughout by increasing abundance of individuals. (In districts G and H, the individuals are so abundant as to form a shell conglomerate.) Another ammonite closely similar to *Schloenbachia belknapi* occurs much lower down, but should not cause confusion in this region.

These two intergrading horizons together constitute the Kiamitia formation and vary in combined thickness from sixty feet in district H to fifteen feet in district B.

A broad grouping into upper, middle, and lower thirds is possible as follows: Lower third, *Cyprimeria texana* (Roemer) (Pl. 18, fig. 6), abundant. Middle third, *Exogyra plexa* Cragin (Pl. 13, figs. 6-10), forming a zone. Upper third, characterized by great abundance of *Gryphea navia.*

In all parts of our region, the rocks of this horizon are mainly marls, with occasional thin, flaggy, layers of sandy limestone.

Intervals in feet from middle of horizon to top of Gryphea marcoui conglomerate:

Districts: A, —; B, 160; C, 140; D, 120; F, 80; G, 60; H, 40.

11. Zone of **HAMITES COMANCHENSIS** n. sp. (Pl. 6, figs. -10).

This ammonite occurs in a zone which is so definable and so limited vertically, that it is placed by us as one of the three grand markers of the Fredericksburg and Washita in this region—the others being the Gryphea marcoui conglomerate below and the Gervilliopsis zone above In district G, this ammonite occurs with a veritable riot of associated gerontic ammonites; of these, only two, *Hamites fremonti* Marcou (Pl. 6, fig. 3), and *Hamites nokonis* n. sp. (Pl. 6, figs. 5, 6) are described in this paper, as they are the only ones whose horizontal range is at all comparable to that of *Hamites comanchensis.*

The thickness of this zone varies from fifteen feet in district H to two feet in B. It is further characterized by a remarkable uniformity in lithology, being made up of one or two hard ledges of limonite-stained limestone, containing spheroid nodules of pyrite, hematite and limonite. These ledges resist weathering and frequently stand out sharply on slopes. This zone forms the lowest part of Hill's Duck Creek formation. The Hamites zone slightly overlaps the horizon of *Desmoceras brazoense.*

II. Horizons below *Gervilliopsis invaginata* but above *Hamites comanchensis*

12. Horizon of **DESMOCERAS BRAZOENSE** Shumard (Pl. 2, figs. 1, 2).

The horizon of this large ammonite is remarkably constant in vertical extent, being slightly less than fifteen feet thick in all parts of our region. The horizon exhibits a zone of abundance in the lower part. This conspicuous and readily recognized species is at all times present in sufficient numbers to make its horizon easily defined. The horizon overlaps below that of *Hamites comanchensis,* and has associated with it a succession of small ammonites having limited vertical zones. While this succession is of extreme interest, the various species are not described in this paper since for practical purposes their values as horizon markers are overwhelmed by that of Desmoceras. It is of interest to note, however, that this succession of ammonite zones has been observed by the writers as far south as Georgetown (in lower part of the Georgetown limestone).

Two of these associated forms are introduced here, one is *Desmoceras species A* (Pl. 2, fig. 3), which immediately underlies the zone of abundance of Desmoceras brazoense; the other is *Schloenbachia species I* (Pl. 4, figs. 1-3), which is a species absolutely diagnostic of the combined Duck Creek and Fort Worth formations. This species appears with Desmoceras and ranges upward, maintaining a fair average of numbers of individuals, to near the top of the Fort Worth limestone.

The *Desmoceras brazoense* horizon is in a hard compact limestone in nearly all parts of our region. A slight tendency toward marliness is observable in the northwestern half of the area, as near Gainesville where

the upper part of the horizon is entirely marl, and the large ammonites weather out conspicuously.

13. Horizon of **INOCERAMUS COMANCHEANUS** Cragin (Pl. 17, figs. 1-3).

This horizon varies only slightly in thickness in the entire region. It has associated with it, various gastropods, a few echinoids, and a few scattering individuals of *Schloenbachia trinodosa* whose horizon is the next higher. If an imaginary line be drawn through Denton and Granbury it will indicate roughly the lithological differences in the horizon of Inoceramus, that is, southeast of this line massive limestones make up the horizon, and northwest of this line marl prevails.

14. Horizon of **SCHLOENBACHIA TRINODOSA** Boese (Pl. 3, figs. 1-3).

The horizon of this large ammonite extends downward, including, by a few scattered individuals the one below, and in districts G and H, the two below. The horizon like many others contains individuals concentrated into a recognizable zone of abundance, in this case at the top of the horizon. Careful distinction should be made between this ammonite and the closely similar *Schloenbachia leonensis* (Pl. 4, fig. 4). The two are alike superficially and of the same size. Battered specimens are very difficult to distinguish, but in such individuals the inner tubercles of *Schloenbachia leonensis* are the larger and usually the outer tubercles of *Schloenbachia trinodosa* are the larger, giving it a distinctive "square shouldered" effect.

Although these two ammonites occur separated by a vertical distance of from 100 to 30 feet, they have been frequently confused. Many remarks in the literature on north Texas Comanchean indicate this clearly, both species being referred to loosely as "leonensis."

As to the lithology of the horizon, the remarks concerning the preceding horizon apply; that is, the northwestern portion of each district is marl; the southeastern, limestone, the two grading into each other.

Intervals from top of horizon of Schloenbachia to top of *Hamites comanchensis* ledge:

Districts: A, —; B, 25; C, 30; D, 30; E, —; F, 40; G, 45; H, 45.

15. **SECOND UNDEFINED HORIZON.**

This is another of the poorly characterized horizons, but differs from the other three of this region in that it contains a fair number of fossils. unfortunately these of themselves are not reliable; most important of all is *Pecten subalpina* Boese (Pl. 12, figs. 5-16), which is found throughout the Fredericksburg and the lower Washita.

A few scattering echinoids and gastropods also occur, but so far the writers have been unable to find a diagnostic species limited to this horizon.

The horizon is marly throughout with a few thin ledges of limestone in the southeastern part of the various districts.

The thickness varies from little more than 100 feet in district H to 20 feet in district A.

16. Horizon of **SCAPHITES WORTHENSIS** n. sp. (Pl. 7, figs. 1, 2).

This horizon is marked in all parts of the region by an inconspicuous but important limonite fauna. Many of the species are not limited in range and are not included here. Associated with *Scaphites worthensis is Hamites tanima* n. sp. (Pl. 6, figs. 1-12) and *Crania sp.*, a small circular brachiopod and *Salenia* sp., not described in this paper.

All of the fossils of this horizon are small and inconspicuous, except the widely ranging *Schloenbachia species I* (Pl. 4, figs. 1-3), of which mention has been made in the description of Horizon 12. Occasionally downward ranging individuals of *Holaster simplex* (low phase) occur in this horizon. *Pecten subalpina*, a species reliable only for broad separations is also likely to be present in considerable numbers.

17. Horizon of **HOLASTER SIMPLEX** (low phase) Clark (Pl. 9, fig. 19 and pl. 8, figs. 5, 6).

This is the thickest horizon in the region, but is readily subdivided in most districts. The species is easily recognized and occurs in sufficient numbers to be readily found in any exposure. The zone of abundance is also thick—two to thirty feet—and contains such a wealth of individuals as to lend a value to this horizon which is seldom seen in a horizon of a form ranging so much vertically.

The species should be distinguished from the tall phase (possibly a different species, Pl. 9, fig. 18, but not so considered by Clark). The tall phase is much less abundant but occurs only in a restricted zone and is extremely definite when found.

As individuals of the species are sometimes found far below and above the zone of abundance, the horizon of *Holaster simplex* (low phase) is none too well defined, but the associated fossils are helpful in further subdivision, and the lithology in most districts is also an excellent guide.

This horizon includes the lower portion of the Fort Worth formation and the upper portion of the Duck Creek formation. In most districts, the upper part of the horizon contains limestone ledges and the lower part is wholly marl. The zone of abundance is about the middle of the horizon, being usually partly in the limestone above and partly in the marl below.

The lower part of the horizon is marked by the zone of occurrence of

*Pleurotomaria austinensis* Shumard (Pl. 18, figs. 2-3), in all districts. This species, however, is rare and difficult to find. In districts C and D the lower and middle parts of the horizon are marked by *Kingena* sp. (Pl. 19, figs. 3-12) occurring in great numbers and in two slightly separated zones of abundance.

The upper part, especially just above the zone of abundance of the Holaster is marked in districts C and D by *Pecten wrightii* Shumard (Pl. 11, figs. 8 and 10). The upper part also exhibits in all districts occasional downward ranging individuals of *Pecten bellula* Cragin (Pl. 11, figs. 3-7). The small *Schloenbachia species I* (Pl. 4, figs. 1-3) occurs throughout the horizon.

Intervals from middle of horizon of *Holaster simplex* (low phase) to top of *Hamites comanchensis* ledge:

Districts: A, —; B, 45; C, 55; D, 65; E, —; F, —; G, 85; H, —.

18. Horizon of **PECTEN BELLULA** Cragin (Pl. 11, figs. 3-7).

This small fine-ribbed Pecten is recognizable even from small fragments. The species is sharply limited in vertical extent, and illustrates the neglected possibilities in the use of Pectens as horizon markers. The writers are convinced that in this region, at least, careful collecting and study of these fossils will furnish a considerable number of definable zones and horizons. At present the taxonomy is rather loose and most of the so-called species include more than one species. The defining of so-called varieties merely adds to the confusion now existing. If the varieties have definite characters, no matter how inconspicuous, and occur in limited horizons, the field worker would be greatly helped by having the varieties raised to the grade of species.

The horizon of *Pecten bellula,* like most of the others exhibits a zone of abundance within the horizon. In this case the abundance is relative only. The individuals are nowhere abundant in the same sense as some of the Grypheas or even certain other fossils occurring in the Comanchean. However, the ordinary exposure should show after careful search enough individuals of *Pecten bellula* to make the determination of the horizon and its relative zone of abundance certain.

The depth or thickness of this horizon is fairly constant, closely approaching in this respect the uniformity shown in the horizon of *Desmoceras brazoense* (No. 12). The thickness of *Pecten bellula* horizon is twenty feet in district H and fourteen feet in B. The zone of abundance is about eight feet throughout.

In a broad sense this horizon corresponds with the lower part of the Fort Worth formation.

This horizon is rich in associated fossils in districts C and D. The most

conspicuous of these is a small ammonite, averaging one inch in diameter, belonging to the large group of species showing affinities with *Schloenbachia inflata.* This species is not figured in this paper. Pectens and echinoids are also abundant.

The lithology throughout is the characteristic combination of strata of the Fort Worth limestone, so well described by Hill, that is, an alternating series of marl and limestone seams, with the members of either kind seldom more than a foot in thickness. The additional observation of the writers should be noted that the limestone members increase in thickness ana numbers, and the marl members decrease correspondingly toward the southeast (See discussion concerning Horizons 12 and 13).

Intervals from middle of horizon of *Pecten bellula* to top of *Hamites comanchensis* ledge:

Districts: A, —; B, 75; C, 85; D, 95; E, —; F, —; G, 130; H, —.

19. Horizon of **HEMIASTER ELEGANS** Shumard (Pl. 8, figs. 3, 4) and **SCHLOENBACHIA LEONENSIS** Conrad (Pl. 4, fig. 4).

This horizon contains definable zones of abundance of the two fossils, that of the ammonite underlying that of the echinoid.

The lithology is the characteristic Fort Worth limestone combination, having the features briefly discussed in connection with the preceding horizon. As mentioned in the description of the horizon of *Schloenbachia trinodosa* (No. 14), these two large Schloenbachias have been frequently confused.

The Hemiaster might sometimes be confused with a similar large Hemisater which occurs in the Weno formation, but the association of *Hemiaster elegans* and *Schloenbachia leonensis* is unmistakable.

The Hemiaster extends both upward and downward rather further than the Schloenbachia, rare individuals occurring in the horizon below and extremely rarely extending into the second horizon below.

The maximum thickness of the combined horizons of *Hemiaster elegans* and *Schloenbachia leonensis* is about twenty-five feet.

The two superimposed zones of abundance mark the middle portion of the Fort Worth formation.

There is an association of many fossils, conspicuous among these are fine, large, individuals of *Pecten subalpina* (Pl. 11, figs. 1, 2, and Pl. 12, figs. 5-16) together with other widely ranging fossils of the lower Washita.

Besides these there are several new species, the stratigraphic value of which if there is any, has not been determined by us.

The lowest occurrence of *Alectryonia (Ostrea) carinata* Lamarck (Pl. 16, figs. 2-5) is in this horizon. This fossil like the *Kingena* sp. is one which has the peculiarity of recurrent zones between which the most painstaking

search has, so far, not resulted in the discovery of a single individual. This peculiar recurrence, if it be recurrence, has been described and discussed by us in the Geology of Tarrant County (University of Texas Bulletin No. 1931).

20. Zone of **HOLASTER SIMPLEX** Shumard (tall phase) (Pl. 9, fig. 18).

This is a restricted zone of considerable value, in spite of the difficulty in finding the fossil which is rather rare. In districts G and H, this zone is included in the upper part of horizon No. 19, but in other parts of the region, it is sharply distinct, being associated only with the usual widely ranging species of the lower Washita formations. The vertical extent of this zone is less than two feet.

Interval from zone of Holaster simplex (tall phase) to top of *Hamites comanchensis* ledge:

Districts: A, —; B, 95; C, 105; D, 130; E, —; F, —; G, 160; H, —.

21. Horizon of **EXOGYRA AMERICANA** Marcou (Pl. 14, figs. 1, 2).

This horizon is near the top of the limestone in the Fort Worth formation and is succeeded by a layer of marl in all parts of the region.

The association is that of the common ranging fossils of the Fort Worth and Duck Creek formations, with rare upward ranging individuals of Hemiaster elegans.

22. Zone of **ENALLASTER LONGISULCUS** n. sp. (Pl. 9, figs. 4, 8, 9).

This is a zone of five feet or less marking the top of the Fort Worth formation in all districts of the regions. The species occurs in marl except in the extreme southeastern end of each district, where a few seams of limestone may appear.

Undoubtedly this Enallaster has been frequently mistaken for *Enallaster texanus* Roemer. Careful examination of the literature on this region will reveal the further fact that *Enallaster bravoensis* Boese occurs only in the upper Washita formations, in which we have never found an individual of *Enallaster texanus*. In general it may be said that *Enallaster texanus* (Pl. 9, figs. 12-13) occurs in the Fredericksburg and possibly in the extreme lowest Washita, while *Enallaster bravoensis* (Pl. 9, fig. 11) occurs only in the upper Washita. *Enallaster longisulcus* as has been noted is so narrowly limited as to serve as a horizon marker.

23. Horizon of **GRYPHEA WASHITAENSIS** Hill (Pl. 15, figs. 5-12), and **ALECTRYONIA (OSTREA) CARINATA** Lamark (Pl. 16, figs. 2-4).

Although long used by geologists in north Texas, this is a rather indefinite horizon and one which can sometimes be misleading. The "zone of

Ostrea carinata" of the earlier writers is likely this horizon. Unfortunately this oyster is one of the peculiar recurring species, previously mentioned.

The *Gryphea* ranges (and in considerable abundance) throughout most of the Washita formations. This horizon, however, contains the *Gryphea washitaensis* greatly concentrated—often forming shell conglomerate. In the association there is also a great number of juvenile forms, which were studied and described by Hill.[1]

The combination of extremely abundant *Gryphea washitaensis* and one or two zones of *Ostrea carinata* is fairly easy to recognize and is entirely usable and reliable in practice, especially within limited areas. In general it is well to confirm the diagnosis of this horizon by a check against more readily defined horizons above or below.

This horizon forms the lower two-thirds of the Denton formation classed with the Denison beds or upper Washita group of Hill, but showing closer paleontological affinities with the Fort Worth formation which is below, than with the Weno formation above.

24. Horizon of **LEIOCIDARIS HEMIGRANOSUS** Shumard (Pl. 9, fig. 6).

The horizon of this large echinoid grades imperceptibly into that of *Gryphea washitaensis* and *Alectryonia* (*Ostrea*) *carinata*. In lithology the horizon is wholly marl in all districts. In districts C and D this marl has the consistency and appearance of a pipe-clay.

The spines only of most individuals of the species are preserved and are associated with the spines of the other (and unknown) sea-urchins of the same general type. The horizon is five to fifteen feet in thickness.

III. Horizons of *Gervilliopsis invaginata*, and upwards

25. Horizon of **GERVILLIOPSIS INVAGINATA** White (Pl. 18, fig. 1).

This fossil which has superficially the appearance of the modern razor clam occurs in a horizon which is about thirty feet thick in district H and about one foot thick in district B; but is marked by a definite zone of abundance at the base of the horizon.

This zone of abundance varies from a few inches to about one foot in thickness, and in all districts is conspicuous and readily recognized as the individuals are piled upon each other in dense layers.

In districts G and H the fossils are well preserved, often being nacreous and white. They are known to the natives by the astonishing name of "petrified sardines."

From district H to district B, the horizon becomes progressively more calcareous, being a soft, bluish marl in H and a very hard, compact lime-

[1]Bull. 151, U. S. G. S., 1898.

stone in B. In districts B to F the individuals are preserved as iron-stained casts and impressions, but their relative abundance is not perceptibly decreased.

This horizon marks the beginning of a large number of new species which increase in number with the sedimentary progression upward, and reach their climax with the remarkable and varied fauna of the upper Weno and Lower Pawpaw. For this reason as well as for the reason that the base of the Gervilliopsis horizon (its zone of abundance) is a convenient measuring point, the writers refer to the Washita beds including and above Gervilliopsis as "upper Washita" and those below as the "lower Washita."

Just as measurements in horizons 1-10 were given to the top of the *Gryphea marcoui* conglomerate and those of horizons 11-24 were in depths to the top of the *Hamites comanchensis* ledge, measurements in horizons above number 25 will be given to the base of the *Gervilliopsis invaginata* horizon, which is more readily recognized than is the top of the same horizon.

26, 27, and 28. **THIRD UNDEFINED HORIZON.**[1]

This horizon is one of vast paleontological possibilities. The fauna is extremely rich and varied and shows a puzzling lack of continuity in the various districts. Although we have spent much time in the study of this group of rocks, we are as yet not prepared to present even tentative horizons or subdivisions.

A large number of new species have been found, but as already noted, none has apparently any great horizontal extent.

In most districts the areal extent of this horizon is rather insignificant, since the rocks are mainly soft marls and clays and break down readily; and the great thickness is often unsuspected; even so keen an observer as Hill estimated the thickness at Gainesville, at thirty-five feet. Since that time, a brick yard pit southeast of Gainesville has been sunk in through the Quarry limestone in this group of rocks to a depth of over sixty feet.

Even in districts C and D these rocks attain a considerable thickness. In many interpretations of well logs which have been published the rocks of this horizon have been completely ignored.

In a broad sense this undefined horizon is equivalent to the lower three-fourths of the Weno formation. The thickness of the horizon grades from 105 feet in district H to 30 feet in district B.

A brief description of this undefined horizon in several districts it is believed will be of some value.

[1]A special paper on this and adjacent horizons is being prepared.

*District H.* An excellent description is given by Stephenson[1] and was written after careful field work in which the great thickness was fully appreciated. Here clays predominate although lenticular sand layers are numerous. The paleontology and lithology in this district are much the same as in district G. The upper part in each district is strikingly similar, although there is a considerable thinning of the strata in district G as compared with corresponding strata in district H.

Attention is called to the small concretions in the upper strata in district H. This phenomenon is well demonstrated in district G (see "ginger shale" in brick yard section).

There is more of a similarity between the two groups of fossils in districts G and H than between any other two districts; for example, in passing from district C to district B, one witnesses within a few miles the rapid passing out of a varied and rich fauna and the coming in of another, equally rich but with different species.

*District G.* This is excellently exposed in the pit of the brick yard one and three-fourths miles southeast of Gainesville. The fauna is extremely rich and the preservation is perfect, most of the material being nacreous and in many fossils the iridescent luster of the mother-of-pearl is present.

Some of the species seem to have considerable horizontal range, although not sufficiently limited vertically to serve as horizon markers. An example is figured in this paper: *Trigonia clavigera* Cragin (Pl. 17, figs. 4-6). A generalized lithological section in district G between the easily recognized Quarry group above and the Gervilliopsis invaginata horizon below is as follows:

| | | Feet |
|---|---|---|
| | *Quarry group,* forming the caps of the hills, southeast of Gainesville. | |
| 4. | Shale containing pure sand layers, many small concretions, a few thin layers of red ironstone. Very fossiliferous. Because of the concretions, known locally as "ginger shale" | 15 |
| 3. | Blue-gray, finely laminated shale, with many thin layers of red ironstone, in which are imbedded perfectly preserved nacreous fossils | 30 |
| 2. | A loose, unconsolidated, argillaceous marl, known locally as "buff marl," because of the color to which it burns | 15 |
| 1. | Compressed, laminated clay, blue in color. Marked by *Hemiaster* sp. This clay when excavated, tends to form kidney-shaped lumps, and is known locally as "kidney shale" | 20 |
| | *Gervilliopsis invaginata* horizon. | |

[1]Prof. Paper 120-H, U. S. G. S., page 141. 1918.

*District C.* In this district this part of the Weno formation is reduced to a total thickness of about fifty feet and is roughly divisible into an upper or massive limestone member and a lower or yellow marl member. Toward the southwest limestone seams in the marl member become thicker and more numerous.

As compared with the districts near the Red River, this horizon in district C exhibits a great increase in calcareousness; is far more consolidated; sand beds and seams are absent; and the red ironstone layers of the northern districts are represented here by a few thin seams of red jasper fragments. As to fossils, both members contain *Schloenbachia* sp. M (Pl. 5, figs. 1-4) and *Hemiaster calvini* Clark (Pl. 8, figs. 1, 2) of which the former is the more valuable, so far not having been found anywhere lower than in the Weno formation.

The lower member is marked also by numbers of *Turritella* sp., a variety of echinoids of the genera Hemiaster and Holaster (none of which are figured here) together with *Pecten georgetownensis* Kniker (Pl. 12, fig. 5-6).

The upper or limestone member contains fewer fossils, the most conspicuous being *Nautilus texanus* Shumard (Pl. 20, fig. 1-2).

*District B.* This horizon is thinned in this district to about thirty feet. The upper massive limestone member is roughly separable from the lower marly member, but the latter has become very calcareous.

The jasper fragments noted in district C no longer persist. *Nautilus texanus* and *Schloenbachia* sp. M are present, but a new and varied echinoid fauna has made its appearance, including a species near *Enallaster longisulcus* n. sp., and another near *Hemiaster bexari* Clark.

29. Horizon of **NODOSARIA TEXANA** Conrad (Pl. 19, figs 1, 2; Pl. 21).

This rather thick horizon is marked by the unusual feature of two concentrations or zones of abundance, one at the base and the other at the top of the horizon. A close search is required, to find these minute fossils even where, as is often the case, many occur in a square yard of exposure. This species seems to have a very wide horizontal distribution being reported at the same relative level from many parts of the Comanchean in Texas and Mexico.

In lithology, the upper half of the horizon is fairly constant, being a red clay in all districts; but the lower half is marl with a few ledges of limestone in districts E to H and is a hard compact limestone in districts B to D.

This horizon includes the Quarry limestone which appears at the top of the Weno formation, thinning gradually from district H to district E. From district E on to district B the Quarry limestone is enveloped and

lost in the increasing calcareousness of the upper part of the Weno formation.

In general this horizon is marked more clearly by its upper zone of abundance in districts F to H and more sharply by the lower zone in the southwestern districts, although in district C, both zones are easily demonstrable.

The entire horizon is twenty feet thick in district C where both limits are clearly defined.

This horizon includes the two following which are more properly zones and which have so far proved to be of rather local value only, as will be noted in the discussions concerning them.

Interval in feet from the *base* of horizon of *Nodosaria texana* to the base of horizon of *Gervilliopsis invaginata*:

Districts: A, —; B, 30; C, 45; D, 55; E, —; F, —; G, —; H, —.

Intervals in feet in feet from the *top* of horizon of *Nodosaria texana* to the base of horizon of *Gervilliopsis invaginata*:

Districts: A, —; B, —; C, 65; D, 75; E, —; F, —; G, 115; H, 160.

30. Zone of **OSTREA QUADRIPLICATA** Shumard (Pl. 16, figs. 6-10).

This is a zone of abundance of a species which can not be limited to a horizon of practical value because of its considerable vertical range. The zone of abundance of this pecular oyster may be considered as being included in the horizon of *Nodosaria texana.*

This zone is of interest and has value as a stratigraphic marker because it is, so far as known, the highest occurrence of this species in this region. The location of this zone with reference to the formations is low in the Pawpaw formation in all districts; and is much in evidence in districts E to H, but is progressively less and less conspicuous in the southwestern districts, being hardly detectable in district B.

31. Zone of **TURRILITES WORTHENSIS** n. sp. (Pl. 7, figs. 9-13) and **SCAPHITES HILLI** n. sp (Pl. 7, figs. 3-6).

This restricted zone, itself included within the horizon of *Nodosaria texana* (Horizon 30) contains within a few vertical feet a rich and varied fauna. The preservation of this is best in districts C and D. Here there are found in this zone various echinoids including *Salenia* sp.; *Metopaster hortensae* n. sp. (Pl. 10, figs. 2-4) ; an undescribed starfish (Pl. 10, fig. 1) ; *Remondia acuminata* (Cragin) (Pl. 19, figs. 13-15) ; *Placosmilia* sp. (Pl. 19, figs. 24-26) ; *Hamites tenawa* n. sp. (Pl. 6, fig. 4) ; teeth and vertebrae of sharks; *Ostrea quadriplicata* Shumard (Pl. 16, figs. 6-10) ; and many others

*Turrilites species B* (Pl. 7, figs. 7-8) which ranges upward, first appears here.

The fauna shows a reduction and presently an extinction as one passes in either direction from districts C and D, where the zone is of greatest value. In district B a few scattering individuals can be found after careful search and in district E the same situation exists. Further than this we have been unable to find the members of this remarkable pyrite fauna.

In all districts where the zone is demonstrable, the lithology is constant, the strata being loosely laminated, reddish clays.

32. Zone of **ARCA** sp. (Pl. 19, figs. 16-20).

This zone immediately overlies and grades into the zone of the Turrilites but is far more extensive, being demonstrable from district B to district G. This zone, like the one preceding is included in the horizon of *Nodosaria texana.*

The lithology is constant, the rocks being red sandy clays throughout. This zone is about eighteen feet deep in district G and about three feet in district C. In district G, particularly just southeast of Gainesville, these small clams occur in enormous numbers in association with equally large numbers of *Nodosaria texana* imbedded in soft red sandstone slabs. In ordinary weathering the fossils, being nacreous dissolve away so rapidly that their presence would be unsuspected.

In the southwestern districts the nacreous character of the fossils is not preserved, but hard pyritized casts remain, which resist weathering fairly well.[1]

33. **FOURTH UNDEFINED HORIZON.**

This is readily recognized from its lithology. This horizon which makes up all of the Pawpaw formation except the basal portion consists of red sands and soft sandstones in districts G and H and increase in argillaceous content until in district C the entire series is a fine grained reddish clay.

In thickness this horizon varies from four feet in district B to about 40 feet in district H. In districts G and H there are a number of fossils but these totally disappear in the southwestern districts, occasional individuals of *Ostrea quadriplicata* only being found and these in the extreme lower part of the horizon.

34. Zone of **PACHYMYA** sp. (Pl. 17, fig. 10).

This is more of a zone than a horizon and marks the basal part of the Mainstreet formation. The individuals of this species are much more

[1]For brevity we call this a pyrite fauna; some fossils are pyrite, some hematite and some limonite.

abundant in districts B to E but become so rare that this zone is of doubtful stratigraphic value in districts F to H.

In all districts the lithology is the same, a hard, slightly yellowish limestone. This zone grades into the one above it.

35. Horizon of **PECTEN CLEBURNENSIS** n. sp. (Pl. 12, fig. 1).

This horizon is another one based on rather rare individuals, but the vertical range is so limited and this species marks the basal Mainstreet so certainly that its diagnostic value should be kept in mind.

36. Horizon of **HOLECTYPUS LIMITIS** Boese (Pl. 9, figs. 1, 3).

This horizon overlaps the two below it by scattered individuals, and like the two preceding, is of value in determining the basal part of the Mainstreet limestone.

This species is far more abundant in the southwestern districts than in the northeastern ones, but occurs throughout at this relative level in sufficient numbers to be readily found.

37. Zone of **EXOGYRA ARIETINA** Roemer (Pl. 13, figs. 1-5).

This is a zone of relative abundance of a species which ranges upward from this point through many feet.

38. Horizon of **TURRILITES BRAZOENSIS** Shumard (Pl. 7, figs. 14, 15).

This species marks a horizon which is rather deep (nearly thirty feet in district C) but is a horizon marker whose great value is already well known to geologists in this region.

39. Zone of **ALECTRYONIA (OSTREA)** sp. (Pl. 16, fig. 1).

This species marks a zone immediately overlying the preceding horizon and indicates stratigraphic position near the top of the Mainstreet formation.

40. Zone of **KINGENA** sp. (Pl. 19, figs. 3-12).

This species which occurs in the upper two-thirds of the Mainstreet formation reaches, in the southwestern districts a recognizable zone of abundance near the top of the formation. As this increase in numbers occurs where the Mainstreet formation has thickened considerably, it has enough stratigraphic value to deserve including in this list. This is the Kingena zone most frequently mentioned in the literature.

41. Horizon of **GRYPHEA MUCRONATA** Gabb (Pl. 15, figs. 1-4).

This species appearing always in a marl, marks the Grayson formation. It is associated with a large number of species whose stratigraphic value has not yet been determined. Among these is an Exogyra of a species undetermined, but which superficially resembles *Exogyra arietina* except that the beak is distinctly less spired and the entire animal is smaller.

An *Engonoceras,* species undetermined, also is fairly persistent. Besides these, there are various echinoids, exogyras, inocerami, pectens, etc. and a few ammonites. Much work needs to be done on this varied fauna before the Grayson formation can be subdivided into horizons. As in many other unsatisfactory horizons in the Washita, the clue to the situation is undoubtedly in the ammonites.

## DESCRIPTION OF SPECIES[1]

### NAUTILUS TEXANUS Shumard

Pl. 20, figs. 1-2

BRIEF DIAGNOSIS: This species may be readily confused with the much rarer, but coextensive, *N. hilli* Shattuck. According to Shattuck, the latter species may be distinguished from *N. texanus* by the lack of decorations, the smaller size, and the more widely separated septa. While worn individuals are indistinguishable, for practical field purposes in this region separation of the two species is non-essential.

Shell laterally compressed, sides convex, umbilicus shallow and nearly circular. Septa sinuous, with first a deep long concavity forward then a short low convexity forward balanced by an equal and succeeding concavity forward, then crossing the dorsum.

The exterior of the shell is marked by small flattened, slightly sinuous costae.

Preservation is usually poor, frequently no trace of the animal being shown except the impression, in a small depression of the rock matrix, of the sinuous ribs. Even these impressions are characteristic and not confusable with any other fossils in this region.

HORIZON: From the top of the Fort Worth limestone, where it is very rare, increasing to a zone of relative abundance in the Weno (best exhibited in the southwestern districts of the region) with a second and less conspicuous zone of relative abundance in the Mainstreet formation.

### SCHLOENBACHIA ACUTOCARINATA Shumard

Pl. 1, figs. 1-3

BRIEF DIAGNOSIS: Shell greatly compressed and only slightly convex. Keel sharp, flat, and in well preserved individuals extending outward nearly half an inch. Ribs numerous (25-40), slightly sinuous, flat, elevated, widening outward, sides of ribs sharply vertical marking off the shallow depressions between them.

Size from three inches to one foot in diameter.

This species can not possibly be confused with any other in this region.

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[1]Types are deposited in the Walker Museum, Chicago; and figured material in the Bureau of Economic Geology and Technology, Austin, except when otherwise stated.

HORIZON: Goodland limestone, ranging by a few scattered individuals to the lower Kiamitia clays.

### SCHLOENBACHIA BELKNAPI Marcou

Pl. 2, figs. 4-5

BRIEF DIAGNOSIS: Shell moderately compressed, sides convex. Keel inconspicuous. Ribs numerous and rounded, widening slightly outward, separated by depressions about three times the width of a rib, which depressions are shallower anteriorly than posteriorly.

Individuals reach a diameter of about eighteen inches, but because of their occurrence in soft marls and clays are usually found in fragments, which, in this region, are characteristically iron stained.

This species must be distinguished in this region from a related species occurring low in the Goodland limestone. The latter is less compressed and more convex than *S. belknapi*, its ribs are more angular and the interspaces not so broad.

HORIZON: Kiamitia formation.

### SCHLOENBACHIA SPECIES I (aff. INFLATA)

Pl. 4, figs. 1-3

1919: Schloenbachia sp. I. Winton and Adkins: Univ. of Texas Bull. 1931.

BRIEF DIAGNOSIS: This small species may be distinguished roughly by its size, its small arcuate ribs with ventral tubercles and a few scattered umbilical tubercles; and by the suture pattern. No attempt is made in this paper to diagnose this ammonite critically; the features given will serve to distinguish it from other ammonites found in this region.

There is a series of smaller inflata-like Schloenbachias ranging from the basal Duck Creek limestone to high in the Fort Worth limestone. At the top of the marl member of the Duck Creek formation there is a zone of abundance of small ammonites of several species.

HORIZON: Duck Creek and Fort Worth formations.

### SCHLOENBACHIA TRINODOSA Boese

Pl. 3, figs. 1-3

1910: Schloenbachia trinodosa Boese: Inst. Geol. Mexico, Bol. 25.
1919: Schloenbachia sp. H. Winton and Adkins: Univ. of Texas Bull. 1931.

BRIEF DIAGNOSIS: Shell convex. Keel conspicuous and relatively thick and rounded. Ribs heavy, rounded, well elevated, with interspaces

about two and one-half times the width of a rib. Ribs simple and unbranched and each ornamented with three heavy conical tubercles, the outermost being the largest and giving to even battered specimens a characteristic appearance.

Individuals range in size from six to fourteen inches in diameter, but the most common is ten to twelve inches.

This species should not be confused with *S. leonensis* (?) whose horizon is higher. The latter has only two rib tubercles, the ribs are more complicated, and other differences are evident on even a superficial comparison.

HORIZON: Upper part of limestone member of Duck Creek formation.

### SCHLOENBACHIA LEONENSIS (?) Conrad

Pl. 4, figs. 4-5

1902: Schloenbachia leonensis Hill: 21st Ann. Rept. U. S. G. S., pt. 7, pl. 36, fig. 1.
1919: Schloenbachia sp. J. Winton and Adkins: Univ. of Texas Bull. 1931.

BRIEF DIAGNOSIS: This common ammonite of the Fort Worth formation seldom exhibits enough preservation to show the suture pattern. As it is quite widely known to geologists of this region as "leonensis" and critical identifications are being passed over in this paper, this name will serve. This is referred to as "species J" in our "Geology of Tarrant County." (Bull 1931, Univ. of Texas.)

Shell convex, Keel elevated and rounded. Ribs heavy, separated by interspaces about twice the width of a rib. The ribs are not simple and their arrangement is not absolutely constant, but usually every third rib is shorter and slightly nclined anteriorly at the umbilical end, giving the effect of a branch from the next preceding rib. These shorter ribs have a conical tubercle near the outer end. The longer ribs have an additional tubercle at the umbilical end.

The range in size is from about four inches to eighteen inches, but the most common is about one foot in diameter.

HORIZON: Fort Worth formation.

### SCHLOENBACHIA SPECIES M

Pl. 5, figs. 1-4

1919: Schloenbachia sp. M. Winton and Adkins: Univ. of Texas Bull. 1931.

BRIEF DIAGNOSIS: This species, which is limited to the Weno formation, may be distinguished from any others in this region (particularly from a closely similar species in the Mainstreet formation) by the fact that the outer (ventral) tubercle on each rib is distinctly double or notched.

Shell convex. Ribs heavy, with an occasional one shorter and inclined anteriorly giving the branched effect seen in many local species of this genus. The longer ribs are ornamented with two heavy conical tubercles each, an inner or umbilical one which is simple and an outer or ventral one which is double. Interspaces between ribs slightly less than twice the thickness of a rib. Keel low and rounded.

Range in size from two inches to eight inches in diameter, six inches being the most common.

### DESMOCERAS SPECIES A

Pl. 2, fig. 3

1919: Desmoceras sp. A. Winton and Adkins: Univ. of Texas Bull. 1931.

BRIEF DIAGNOSIS: Shell very convex. Umbilicus shallow and wide. Ribs twelve to sixteen, thick, rounded, elevated, and of about equal diameter through the entire length of each. Interspaces between ribs almost flat. Size three to six inches in diameter.

This species can be readily distinguished from *D. brazoense* whose horizon it overlaps by its small size and its relatively conspicuous ribs.

HORIZON: Basal Duck Creek limestone.

### DESMOCERAS BRAZOENSE Shumard

Pl. 2, figs. 1-2

1860: Ammonites brazoensis Shumard. Trans. Acad. Sci., St. L. Vol. 1, p. 594.
1889: Ammonites brazoensis Hill. Bull. 4, Geol. Surv. Texas, p. 21.
1893: Pachydiscus brazoensis Cragin. 4th Ann. Rept., Geol. Surv. Texas, p. 236. Pl. 44, fig. 3.
1919: Desmoceras sp. B. Winton and Adkins: Univ. of Texas Bull. 1931.

BRIEF DIAGNOSIS: This large and conspicuous ammonite marks the basal part of the Duck Creek formation in this region. Its shell is very convex. Umbilicus shallow, wide, and usually filled with rock matrix. The ribs are heavy, rounded, low, and in worn specimens are barely perceptible. The suture pattern is elaborate and characteristic. Individuals range in size up to twenty-five inches in diameter, the most common being about fifteen inches.

This species can not be confused with any other in this region, occurs in large numbers in all districts, and is a valuable horizon marker. Dr. Boese has pointed out that the Texas species is a Desmoceras.

HORIZON: Basal part of Duck Creek formation.

**SCAPHITES WORTHENSIS** n. sp.

Pl. 7, figs. 1-2

1919: Scaphites sp. B. Winton and Adkins: Univ. of Texas Bull. 1931

BRIEF DIAGNOSIS: This small, iron-stained scaphite is fairly abundant in its horizon. Only the coil is usually found, but the complete individual is considerably unrolled, having a long "hook." Its ribs are more or less in the order: one long prominent rib—branched simple—followed by two shorter simple ribs, while *Scaphites hilli* of the Pawpaw has a different arrangement. *Scaphites hilli* is also more globose, has in this region better preservation, including the suture, and shows usually a faint mid-ventral line or depression.

HORIZON: *Scaphites worthensis* characterizes the upper marly part of the Duck Creek formation. It seems to range upwards to the lower Kingena zone and down to *Schloenbachia trinodosa.*

DESCRIPTION: Form: The shell consists of a discoid, ventricose coiled portion, and an almost straight extended portion terminating in the aperture, which is defective in the type individual. The coiled portion is small, involute and closely coiled, with rather embracing volutions and a medium-sized umbilicus; the diameter of the whorl increases moderately to the turn. The inflated extended portion is slightly concave on its ventral margin, so that it is thickest near the middle. Its apertural end is constricted and narrowed ventrally so that the shell bends dorsally; details of the aperture can not be described here. The extended portion is broadly excavated dorsally, the excavation extending from the coil, which fits into it, to the apertural end, at which the excavation ceases; the cross-section of the extended portion is therefore subquadrate near the aperture and very thickly crescentic elsewhere.

Ribs: The shell bears fine continuous ribs, branched or unbranched. The ribs are of two lengths, the longer ones reaching the umbilical margin. The shorter ones arise just lateral to the umbilical margin. On the sides of the shell, the ribs describe a gentle sigmoid curve which is sharper ventrally, where the ribs turn backwards and pass straight across the center. On the dorsum the ribs sweep gently forwards and cross the mid-line. At places one prominent longer rib alternates with two shorter ones.

*Suture:* Not observed.

Locality: Frisco Creek, three miles southwest of Fort Worth, Texas.

**SCAPHITES HILLI** n. sp.

Pl. 7, figs. 3-6

1919: Scaphites sp. A. Winton and Adkins: Univ. of Texas Bull. 1931.

BRIEF DIAGNOSIS: This inflated, globose, slightly unrolled pyrite scaphite is the most frequent one in the basal Pawpaw formation and will be easily recognized.

HORIZON: Base of Pawpaw formation, associated with an abundant pyrite fauna in Cooke, Grayson, Denton, and Tarrant counties. Rare on the Red River.

Locality: 714, Sycamore Creek, Fort Worth, Texas.

DESCRIPTION: Form: Shell, small, subglobose, ventricose, inner volutions regularly coiled and closely embracing; diameter of whorl increases rapidly in the outer volution; extended body portion very little unrolled, giving to the scaphite only a slight elongation; umbilicus narrow. The living chamber is missing in most of our material but the apertural end of the coil is slightly raised above the inner volutions and has a thick crescentic or semilunar shape. There is a conspicuous, low, rounded apertural tubercle on each dorso-lateral margin near the aperture.

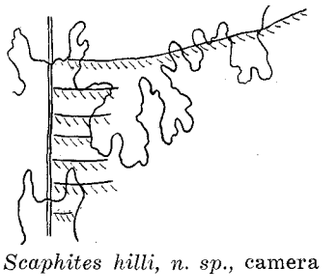

Fig. 3. Suture, *Scaphites hilli, n. sp.*, camera lucida drawing.

Ribs: The type individual has on the last whorl 22 fine ribs per cm. or 15 ribs in a length equal to the average width of the whorl over the length measured. These ribs are mostly long branched, long unbranched and short unbranched. The unbranched ones do not extend to the umbilical margin. There is a variable alternation between long and short ribs; on the terminal limb of the last whorl most of the ribs are long and unbranched, except that the end of the short rib at the junction point is sometimes obliterated, producing an alternation of short and long unbranched ribs; while on the other limb of the last whorl branched ribs prevail. The point of branching, which lies one-third the breadth of the whorl from the umbilical margin, lacks nodes or tubercles. These ribs are all equal, and on passing from the sides to the venter, bend gently forwards, but at the ventral mid-line curve backwards, thus making a

to the dorsal margin is concealed. Between two adjacent suture lines is marked throughout by a shallow, straight narrow linear groove.

The species has a great resemblance to *Scaphites aequalis* and *S. obliquus* Sowerby, especially the latter. The suture is partly concealed in adult individuals and will require critical study for its complete determination. The first lateral saddle is tall, broad and bifid, being deeply dissected by a long narrow lobule. The second lateral saddle is smaller, less elevated and bifid. The siphonal lobe is bifid and broad; the first lateral is of about the same length, but is more dissected. The remainder of the suture to the dorsal margin is concealed. Between two adjacent suture line is the space of about six ribs.

### HAMITES Parkinson

This genus, in the broad sense (including *Anisoceras*), contains diverse gerontic ammonites with more or less open spire, consisting of two nearly straight limbs connected by a curved portion. The two limbs may be parallel or may diverge at various angles. The casts are ribbed and often tuberculate; shell and suture are usually not preserved in our material.

Hamites have been found at four stratigraphic levels:

| | |
|---|---|
| (a) **Pawpaw, base.** | Small pyrite species associated with Scaphites hilli. |
| (b) **Weno, lower third.** | A few species in association with Remondia acuminata (Cragin). |
| (c) **Duck Creek Marl.** | Several small pyrite species and a variety of casts, associated with Scaphites worthensis. |
| (d) **Duck Creek limestone, base.** | Hamites fremonti, comanchensis and several other species. This is the Hamites horizon of the literature. |

In addition, one other inconspicuous species ranges from the Goodland limestone to at least the Fort Worth limestone.

### HAMITES COMANCHENSIS n. sp.

Pl. 6, fig. 10

1919: Hamites sp. A. Winton and Adkins: Univ. of Texas Bull. 1931.

BRIEF DIAGNOSIS: This is a slender, hooked, open-spired hamite with almost circular cross-section. The ribs are prominent, equal, evenly

spaced and devoid of distinct tubercles. It is perhaps the commonest species of Hamites in its horizon and is preserved usually as a fragmentary mud cast of the straight portion.

HORIZON: This is one of a number of species of Hamites which occur in a horizon at the base of the Duck Creek limestone. At Denison the bed is about twelve feet thick. At Fort Worth it is about six feet, but only the lower eighteen inches contains Hamites in any abundance.

DESCRIPTION: Form: The oval limb is the longer and thicker and its diameter is practically uniform to the middle of the curve; thereafter the cast tapers to the end opposite the mouth; the end of this limb was not seen. The diameters near the mouth, at the middle of the curve, and near the end opposite the mouth are in the ratio of 10:9.5:7. The cross-section is subcircular. The two limbs have a slightly spiral course. The thicker limb is practically straight, the thinner one slightly curved; the two make an angle of about 28.° The shell and suture are missing.

Ribs: The ribs are prominent, simple and oblique in reverse direction on the two limbs, sloping backwards towards the curve from dorsum to venter. On the thicker limb, they make a small angle (17°) with the long axis; on the curve, almost the same angle; on the smaller limb, they are almost perpendicular to the axis. On the venter the ribs are thickened, the breadths of ribs and valleys being almost equal; they decrease in height and breadth on the sides and one is practically obliterated upon crossing the dorsum. There is a pair of ventral tubercles per rib which in the type individual are more prominent on the curve than on the long limb; the rib between them has a slightly rounded top. On the curve also, every second rib with its ventral tubercles is more prominent. There is a slight bulging of the ribs in the lateral region, but lateral and dorsal tubercles apparently are lacking. In a length along the axis taken equal to the breadth of the whorl at the point, there are three ribs. The shell and suture have not yet been observed by us.

### HAMITES NOKONIS n. sp.

Pl. 6, figs. 5-6

1919: Hamites sp. B. Winton and Adkins: Univ. of Texas Bull. 1931.

BRIEF DIAGNOSIS: This small hamite, seen almost always as short, straight fragments, may be instantly recognized by its broad, flat form, its long elliptical cross-section and its narrow, close-set, numerous ribs.

HORIZON: It occurs in the Hamites horizon at the base of the Duck Creek limestone from Southern Oklahoma to Central Texas.

DESCRIPTION: Form: We have seen only straight fragments de-

void of suture pattern, but have decided to describe the species on account of its stratigraphic importance. The fragments, probably of the longer limb, are very slightly curved. The individuals are quite broad and have a long, elliptical cross-section. The ribs are simple, slender, flexuous, close set and slightly oblique, bending perceptibly (5°) towards the tapered end of the coil on the ventral half of the whorl and noticeably thickening toward the venter. They have low rounded tops and average two times the width of the intervening depressions. Dorsally they are attenuated, and on crossing the dorsum they appear as thin rounded elevations. Tubercles are lacking. In a space along the long axis equal to width of whorl at a given point, there are seven ribs. There are slight inequalities in the prominence of the ribs, every third rib being most prominent at places near the middle of the limb. Suture not seen. Type: Length 21 mm.; width 11 mm.; height 6.5 mm.

**HAMITES FREMONTI** Marcou

Pl. 6, fig. 3

1842: *Hamites fremonti* Marcou, Geology of North America. Plate 1, figure 3 (figure labeled Baculites fremonti, n. sp.)
1902: *Hamites fremonti* Hill, 21st Ann. Rept., U. S. G. S. Plate XXXV, figure 3.
1919: Hamites sp. C. Winton and Adkins: Univ. of Texas Bull. 1931.

BRIEF DIAGNOSIS: This hook-shaped ammonite is of medium size, diameter about three-fourths inch, length of fragments usually found 1-5 inches. The thicker limb is shorter. The ribs are prominent on the back, become faint upon crossing the venter, and near the back have each a pair of low tubercles. The tubercles of every second or third rib are stronger. Shell and suture usually absent.

HORIZON: This and several other species of gerontic ammonites mark the base of the Duck Creek limestone from Oklahoma to the Brazos and thereafter a zone near the base of the Georgetown limestone. Other associated fossils are, in the Red River section, *Kingena* sp., *Exogyra plexa* Cragin, *Schloenbachia belknapi* (Marcou), *Schloenbachia acutocarinata* (Shumard); while south of Cooke County these associated species are rarely found.

DESCRIPTION: Form: This ammonite, preserved as a mud cast, usually fragmentary, consists of an ascending narrower and longer limb terminating in the mouth, a descending (wider and shorter) limb and a curve connecting the two. The shell and suture are almost always lacking. The coil increases gradually in thickness to the end of the shorter limb, the dorso-ventral thickness near the mouth being about 1.4 and on the

curve 1.25, the thickness near the end of the longer limb. The sides are thus sub-parallel. The coil is open, the two limbs making an angle of about 43° with each other. The two limbs do not lie in the same plane but form a slightly elevated spiral. The dorsal side of the longer limb is nearly straight; at the curve, it has nearly the form of one end of a short ellipse. The ventral side of both limbs is irregular, due to the ribs and tubercles. The cross-section is a short oval.

Ribs: The inclination of the ribs to the long axis varies from point to point. Near the lower end of the longer limb, the ribs are nearly perpendicular to the long axis at that point, while approaching the curve they make angles of about 15° to the axis at that point. In Marcou's figure, the ribs, on the long limb, make angles of about 40° with the axis. On the shorter limb the ribs are nearly perpendicular to the long axis of the limb. The ribs are elevated and prominent, having rounded tops and concave valleys between. The valley has about twice the breadth of the ribs. There are 3½–4½ ribs in a length along the shell taken equal to the breadth of the shell at the point, the ribs slightly more crowded at the lower end of the longer limb. The ribs are strong, simple, prominent at the venter, attenuated to fine lines at the dorsum, tuberculate and unequal. Each rib bears a pair of ventral tubercles at which the rib courses forward slightly to cross the venter, making an arcuate curve, convexed forwards. In one individual there is a slight splitting of each rib between the ventral tubercles. Proceeding dorsally, the ribs remain elevated until they reach the dorsal tubercles, one on each side, and then quickly attenuate and cross the dorsum.

Marcou states that every third rib is tuberculate but his figure, in agreement with our material, shows that every rib is tuberculated and that the prominence of the tubercle varies. We refer our material provisionally to Marcou's species.

### HAMITES TANIMA n. sp.[1]

Pl. 6, figs. 1-2

BRIEF DIAGNOSIS: This species can be easily recognized by its angular contour, prominent angular ribs with three rows of tubercles, and by its suture pattern. It is larger than the usual pyrite species and has roughly a hexagonal or circular cross-section.

HORIZON: Duck Creek limy marl about 8 feet below the bottom of the mineralized ledge. It is rare, having been found most frequently in the cut of the military road, one-half mile north of Texas Christian University, near Fort Worth, Texas.

[1]Comanche clan and place names have been assigned to several species.

DESCRIPTION: Form: We have found only a few fragments which consist of one limb and part of the curve. These fragments have nearly a hexagonal section, four sides of the hexagon lying on the venter and sides, while the dorsum is a continuous curve. This hamite consequently has three rows of prominent tubercles, one on the mid-ventral line and two ventro-lateral.

Ribs: The shell tapers slightly near the curve. It bears a few coarse, wide-spread, compound, tuberculated, slightly oblique ribs. The ribs run forwards (5°) towards the venter. The ribs consist of coarse, partly split, tuberculated primaries and thin auxiliary, simple, non-tuberculated secondaries; one of which lies on the hind slope of each prmary and makes an elevation on it. The primary rib on the venter is prominently elevated, having a roughly triangular cross-section, and between the tubercles a straight or slightly depressed rounded top which shows, variably developed on different ribs, a slight transverse split just in front of a plane passing through the tubercles of the same rib, giving the effect of doubling. These primary ribs bear mid-ventral and ventro-lateral tubercles as already mentioned. On the sides the primaries are conspicuously elevated, unbranched, round-topped and decrease in elevation to the dorsum, which they cross as fine continuous elevations. The auxiliary ribs lie on the hind slope of the primaries and are separated from them by a shallow, evenly rounded valley which, however, is bridged by an elevation running backwards from each tubercle of the primary rib to the crest of the auxiliary rib. The auxiliary ribs cross the dorsum as continuous elevations which are finer

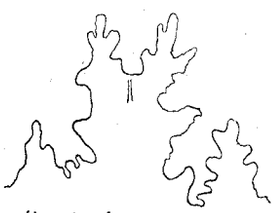

Fig. 4. Suture, *Hamites tanima n. sp*, camera lucida drawing.

than those of the primaries. The primaries on one side (left) have faint traces of dorso-lateral tubercles. In a length along the long axis equal to the diameter of the shell, there are three compound ribs.

*Suture:* More elaborate than in *H. tenawa*; siphonal lobe tall, bifid, each half being trifid at the tip and dissected on the sides; the remaining lobes and saddles are bifid with the lobules dissected.

**HAMITES TENAWA** n. sp.

Pl. 6, fig. 4

BRIEF DIAGNOSIS: This small, slender, curved pyrite Hamites may be distinguished from most Texas species by its size and form, smooth surface, lack of tubercles, suture pattern, and its almost circular cross-section. Most of the small pyrite hamites from both the Duck Creek and Pawpaw horizons have elliptical cross-sections and the suture pattern is faint or lacking. This hamite is the most frequent one of its horizon.

HORIZON: Base of Pawpaw, associated with Scaphites hilli, Metopaster hortensae and numerous echinoids and other distinctive fossils. A few individuals have been found in the basal third of the Weno marl near the level of *Remondia acuminata* (Cragin).

DESCRIPTION: Form: The type is a fragment apparently most of the thicker limb of the species. It is evenly curved, being approximately an arc of a circle of 25 mm. diameter. The limb tapers, its diameters at the large end and on the curve having the ratio of 4:3. The cross-section subcircular at all points.

Ribs: The ribs are prominent, oblique, simple, similar, evenly graded in size towards the smaller end of the cast and devoid of tubercles. They are elevated with evenly rounded tops and evenly concave valleys. The breadths of the ribs and valleys are in about the ratio of 2:3. The ribs make a slight angle (7° or less) with the long axis. A length along the axis equal to the width of the shell, contains 2 ribs and 2 valleys. Except for slight irregularities, the ribs appear to be equal and similar. They thicken somewhat on the venter and reduce on approaching the dorsum, on which they appear as slight crenulations. No auxiliary lines or ribs appear on the dorsum. One rib near the center of the fragment is doubled on the venter.

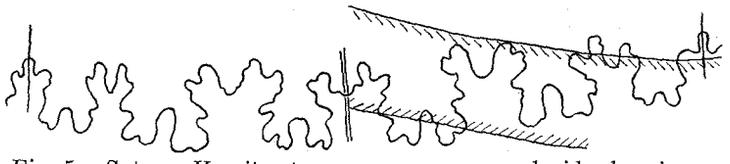

Fig. 5. Suture, *Hamites tenawa n. sp.*, camera lucida drawing.

The suture has three bifid saddles and bifid first and second lateral lobes. The saddles progressively decrease in size and slightly in complexity towards the antisiphonal region. The suture has a great similarity to those of *Hamites simplex* D'Orbigny (Cenomanian) and *H. virgulatus* (Albien).[1]

[1]Pervinquiere, Et. pal. tun., pp. 83-4, fig. 19.

**TURRILITES WORTHENSIS** n. sp.

Pl. 7, figs. 10, 11, 13

1919: Turrilites sp. A. Winton and Adkins: Univ. of Texas Bull. 1931.

BRIEF DIAGNOSIS: In the Pawpaw pyrite fauna there are several closely related species of Turrilites, some right handed and some left handed. This species may be roughly distinguished by its being small, about 1 inch long, spiral angle 48°, left handed (sinistral), three rows of prominent tubercles. All these pyrite turrilites practically identify this stratigraphic level. Base at Pawpaw formation, Tarrant, Johnson, and Denton counties; rare on the Red River.

DESCRIPTION: Form: Shell conical, turreted, sharp spired, volutions at least four, decreasing rapidly in size apically, spiral angle 48.° The siphuncle lies nearly on the superior angle of the volution; superiorly no tubercles are concealed by overlap of the next volution; inferiorly one

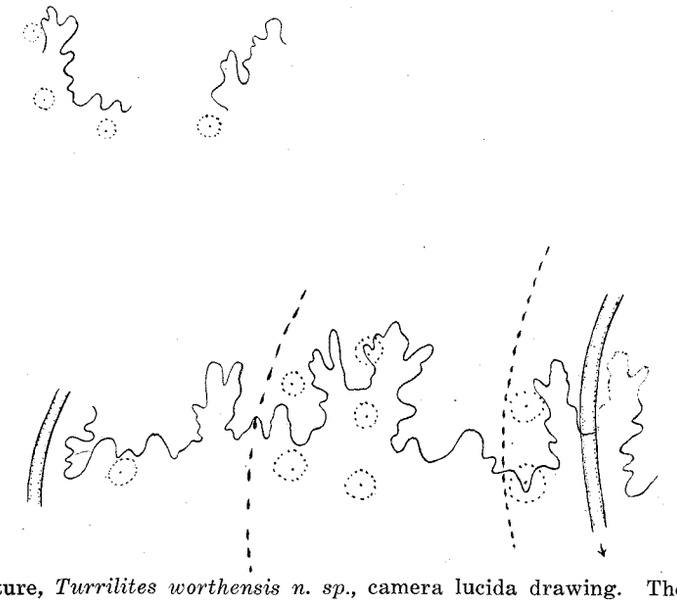

Fig. 6. Suture, *Turrilites worthensis n. sp.*, camera lucida drawing. The upper left hand figure is from the type.

row of very poorly developed elongate depressed tubercles is covered. The terminal volution is short elliptical in cross-section: the supeior one-fourth of the exposed surface is a nearly smooth surface lying between the superior angle of the volution and the upper row of tubercles, and is crossed only by obsolete elevations proceeding from the upper row of tubercles around the dorsum. The exposed portion bears three closely spaced spiral rows of tubercles which are arranged also in vertically oblique rows.

These tubercles are prominent, elongated vertically, and connected by depressed ridges which practically encircle the volution but become obsolete on the dorsum.

Siphonal lobe tall, narrow and bifid, with each lobule split. The first saddle is tall, broad and bifid, each half being dissected laterally and terminally; the first lobe is as tall and nearly as broad as the first saddle. There is a further series of simpler, internal mostly trilobed saddles and bifid lobes. The three exposed rows of tubercles are confined to the first saddle and lateral lobe as figured, from a fragment showing the suture (Fig. 6).

HORIZON: Pawpaw clay, base. This turrilite is to be distinguished from various right and left handed species in the Pawpaw, by its large angle, its conical shape, few volutions and by its suture.

Locality: Five miles southeast of Fort Worth, Texas, and one-half mile southeast of the International and Great Northern railway bridge across Sycamore Creek (Locality 714).

### TURRILITES sp. B

Pl. 7, figs. 7-8

BRIEF DIAGNOSIS: A sinistral turrilite of about 5-6 volutions is common in the Pawpaw, Mainstreet and Grayson formations. It has four rows of tubercles arranged as follows: The two upper rows have their tubercles corresponding and oblique and lie upon an elevation which follows the middle of the spire and which is connected to the top of the spire by a smoth inclined space. The third row of tubercles lies upon the margin of the whorl; while the fourth row of inconspicuous tubercles lies within the margin and is, therefore, covered by the next whorl. Spiral angle 20.° Our material, as yet, lacks the suture pattern, but the species is mentioned here for its stratigraphic value. Rarely in the Pawpaw it is pyritic.

### TURRILITES BRAZOENSIS Roemer

Pl. 7, figs. 14-15

1849: *Turrilites brazoensis* Roemer: Texas, etc., p. 45.

1852: *Turrilites brazoensis* Roemer: Die Kreidebildungen von Texas, etc., p. 37, pl. 3, fig. 2.

1865: Not *Turrilites brazoensis* Stoliczka, in: Blanford and Stoliczka: The fossil cephalopoda of the Cretaceous rocks of Southern India. Pal. Ind., pl. 88, figs. 3-a-b.

1901: *Turrilites brazoensis* Hill: 21st Ann. Rept. U. S. G. S., pl. 37, fig. 3a (not fig. 3).

1913. *Turrilites brazoensis* Whitney: Trans. Texas Acad. Sci., Vol. 12, pl. 12, fig. 1.

BRIEF DIAGNOSIS: This is the largest, most abundant and most striking turrilite in the Mainstreet formation throughout southern Oklahoma and north and central Texas. It is seen usually as large fragments of mud casts. The cast is large, steep (spiral angle about 30°), tightly coiled, sinistral and somewhat variable in the prominence and arrangement of the tubercles. Perhaps the most frequent form is that figured by Roemer and Hill in which there five rows of prominent tubercles. The upper two rows are close together and lie upon a slanting surface; the tubercles of these two rows are practically paired, being joined by slight elevations which with the tubercles lie on radii from the long axis of the shell. Between the second and third rows of tubercles is a wide smooth space which is distinctly concave and which may or may not be crossed by longitudinal ridges connecting the tubercles of the second and third rows, the third and fourth rows are close together and the tubercles alternate; these two rows lie upon an elevated spiral band or shelf. Between the fourth and fifth rows is a wide, slanting, smooth, slightly convex space on which lower margin are the tubercles of the fifth row. The fifth row is almost covered by the succeeding whorl.

These Turrilites have not yet been found by us outside the Mainstreet limestone, though they and related forms elsewhere are in need of critical study.

## ECHINODERMS

### METOPASTER HORTENSAE n. sp.

Pl. 10, figs. 2-4

1919: Metopaster sp. 1. Winton and Adkins: Univ. of Texas Bull. 1931.

BRIEF DIAGNOSIS: This starfish is pentagonal with concave sides. It is of small size (¾inch), is thick set, and has short rays, shallow arcs and eight marginal plates.

HORIZON: A two-inch sandstone stratum, 4 feet above the base of the Pawpaw clay. Bench in side of hill five miles southeast of Fort Worth, Texas, and one-half mile south of the International and Great Northern railway bridge across Sycamore Creek (locality 714 type). One-half mile northeast of this locality in the same stratum, one-fifth of another individual was found.

DESCRIPTION: The type individual is slightly twisted so that the aboral side appears concave; and some of the interior plates of each side are missing; the fossils are pyritic and completely weathered out.

The starfish is pentagonal with concave sides and short, blunt rays, and

the disc is proportionately large. The plates within the marginal plates are so eroded that the amount of elevation of the radii and the disc is not seen; the disc was apparently rather thin. As preserved, the margin is the thickest part of the animal.

ORAL SIDE: This side is shown in the type and in the fragment. There are four prominent infero-marginal plates: the middle two are subrectangular, with parallel outer margins and convexed inner margin. The two end plates are each almost a right angled isosceles triangle with the long side facing the ambulacral groove, and its outer angle truncated. Finally, there is a narrow, elongate triangular terminal plate which fits against the ambulacral plates. On each side of the ambulacrum, which extends to the tip of the ray, there is a single almost straight row of ambulacral plates decreasing in size towards the tip of the ray. These two rows end against the supero-marginal terminal plate which therefore closes the ambulacral groove at the tip of the ray. The ambulacral plates, near the tip, are short rectangular with rounded angles; nearer the disc their shape is not determinable.

ABORAL SIDE: There are six supero-marginal plates which are paired with the six largest infero-marginals, and in addition at the end of each interarc, a terminal, unpaired plate which lies at the tip of each ray and is common to the two adjacent arcs. They are of a truncate wedge shape, the sides being not quite parallel while the outer margin is shorter than the inner due to the curve of the inter ray. The plates decrease in size from the inter-radius outwards. The terminal supero-marginal plate is small, semi-cylindrical, excavated below and notched at the end; the terminal plates of two ambulacral rows fit into it. The marginal plates are closely set with smooth low, rounded tubercles; the inner edges of the supero-marginals are slightly fluted.

MAJOR RADIUS, type, 10.5; fragment 13.0.
MINOR RADIUS, type, 7.5, fragment 11.0.
RATIO, type, 1.4; fragment, 1.18.

### PENTAGONASTER TEXENSIS n. sp.

Pl. 10, figs. 5-6

1919: Pentagonaster sp. 1. Winton and Adkins: Univ. of Texas Bull. 1931.

BRIEF DIAGNOSIS: This starfish may be distinguished from *Pentagonaster browni* Weller by its having twelve marginal plates. Its form and size distinguish it from other Texas starfishes.

HORIZON: Top of Weno limestone.

DESCRIPTION: The type individual is viewed from the oral side. The oral plates, except the marginal plates and a few internal small plates are eroded off.

*Measurements of the Type Individual:*
MAJOR RADIUS (Average of 5) 23.5 mm.
MINOR RADIUS (Average of 5) 14.8 mm.
RATIO: 1.58:1.
WIDTH OF RAY AT EDGE OF DISC 18 mm.
ANGLE AT TIP OF RAY 41.°
INTERRADIAL ANGLE 127.°

This starfish is stellate-pentagonal in outline; the disk is large and was apparently somewhat elevated and thin. Inter-radial arcs shallow; rays short, sharply rounded at tips. Infero-marginal plates twelve in each interradial arc, large, wide and rectangular-cuneiform in the center of the arc and narrowing towards the tip of the ray. There are two rows of paramarginal plates lying against the marginal plates and extending from the disc to the tip of the ray; these plates are small, square and numerous. Between them are radial rows of variable lengths consisting of small irregular plates. Finally, there are two rows of square adambulacral plates. There are no structural markings on any of the plates in our material. Locality: 702, east slope of valley of Sycamore Creek, 6 miles southeast of Fort Worth, Texas, at a point 29 feet below the bottom of the Mainstreet limestone. The individuals are in an indurated limonite stained limestone slab.

Another individual (Pl. 10, fig. 6), which was found at the same time and place as the type individual, shows the following details: Portions of two radii are present. On one interradial arc there are eleven marginal plates, a terminal one being lacking. In this fragment the terminal plate is common to two adjacent interradial arcs, so that this individual shows the reverse side from the type. In the type, as exposed, the paramarginal and adambulacral plates are minute, subquadrate, and number about twelve in half a major radius. The intermediate plates are in scattered rows and are larger, and of irregular, in part, hexagonal, shape. The paramarginal plates are not shown in this individual, but in the type they are crowded, lie in straight lines, and are quadrate near the tip of the ray. Apparently the small plates of the oral side are removed in the individual shown in Pl. 10, fig. 6. The three starfishes pictured here have Pacific affinities.

**COMPTONIA (?)** sp.

Pl. 10, fig. 1

BRIEF DIAGNOSIS: This phanerozonian has a flat disc and numerous marginal plates. It occurs in the starfish zone of the basal Pawpaw clays in association with Metopaster hortensae and other species.

**SALENIA MEXICANA** Schlueter

Pl. 9, figs. 14-17

1887: Salenia mexicana Schlueter: Sitzber. Naturh. Ver. Preuss. Rheinl., Vol. 44, p. 41.
1910: Salenia mexicana Boese: Inst. Geol. Mex., Bol. 25, p. 152, pl. 32, figs. 4-19.

BRIEF DIAGNOSIS: The Salenias have small nearly globose tests with convex upper surface bearing a conspicuous cap, and concave under surface. The sides are inflated and consist of large plates each with a relatively large tubercle. The ambulacra are flexuous and narrow, with two rows of small rounded granules. Interambulacra consist of two alternating rows, each with six large angular plates which bear prominent tubercles. Roughly the "cap" will distinguish this genus from others of the Texas Comanchean. Minute differences separate this species from *S. texana* Credner (Vraconien) and *S. volana* Whitney (Upper Cenomanian). The average size of *Salenia mexicana* is less than of *Salenia texana,* and the former species is stated to come from a higher level.

HORIZON: The Upper Salenia horizon of the Goodland limestone lies at Fort Worth 26-32 feet below the top of the formation with a zone of abundance at the 27-foot level. A single Salenia was found in the basal Duck Creek limestone, and another in the basal Pawpaw clay.

**LEIOCIDARIS HEMIGRANOSUS** Shumard

Pl. 9, fig. 6; Pl. 20, fig. 3

1860: Cidaris hemigranosa Shumard: Trans. St. Louis Acad. Sci., Vol. 1, p. 609.
1883: Cidaris hemigranosus White: U. G. G. and G. S. Terr., 12th Ann. Rept., p. 38, pl. 18, figs. 2a-b.
1893: Leiocidaris hemigranosa Cragin: 4th Ann. Rept. Geol. Surv. Texas, p. 160, pl. 46, fig. 4.
1915: Leiocidaris hemigranosus Clark and Twitchell: U. S. G. S., Mon. LIV, p. 48, pl. 10, figs. 1a-g; pl. 11, figs. 1a-b.

BRIEF DIAGNOSIS: This large cidarid is very rare and so far as now known to us, is limited to the Denton marl. Our material agrees

poorly with White's figure of Shumard's material. The test is globose and inflated; an interambulacral area consists of two rows of five plates each, the plates decreasing in size towards the bottom of the test. The plates are large, roughly hexagonal and have clearly marked boundaries. Each plate bears a central large tubercle consisting of a smooth broadly conical areola rising to form a boss, in whose crater-like top is the smooth rounded perforated mameleon. The miliary space is raised and is covered with large, depressed, rounded, mostly ovoid, close set tubercles. These are more elongate near the inner margin of the interambulacral plates, and elsewhere are more rounded. The ambulacra are relatively small, sinuous, and bear a few rows of inconspicuous tubercles. Dr. Boese found an interambulacral portion and a few spines in the Denton marl in a Frisco cut 2½ miles east of Kingston, Oklahoma. One small individual was found at Fort Worth near the top of the Fort Worth limestone, not in situ. Portions of a small cidarid test, certainly not the same species were found in the middle Mainstreet limestone, 2½ miles south of Denton, Texas. Cidarid spines are a conspicuous feature of the Upper Washita in North Central Texas, but these can not be assigned with any certainty to this species. The spines occur in the Weno, Pawpaw and Mainstreet formations and especially distinguish the Quarry limestone, in which they have a zone of abundance.

HORIZON: Denton marl.

### HOLECTYPUS PLANATUS Roemer

Pl. 9, fig. 2

BRIEF DIAGNOSIS: These echinoids are circular or very obscurely pentagonal, low, radially symmetrical in top view, and have a centrally located mouth (peristome). *Holectypus planatus* may be roughly distinguished from *H. limitis* by the form of the periproct. In *H. planatus* this is large, narrow-lenticular or biconvex, with both ends pointed, and approaches the margin of the test, and of the peristome more closely than in *H. limitis*. The peripcroct of *H. limitis* is more rounded, smaller, and less angular at the end. It is generally distinctly separated from the margin of the test and is separated from the peristome by almost its own length. In our material, the individuals of *H. limitis* are larger.

HORIZON: *Holectypus planatus* is occasional in the Fredericksburg limestone, near the top. We have not seen it in the Washita division.

### HOLECTYPUS LIMITIS Boese

Pl. 9, figs. 1, 3

1910: *Holectypus limitis* Boese: Inst. Geol. Mexico, Bol. 25, p. 159, pl. 36, figs. 3-6; pl. 37, figs. 1-8; pl. 38, figs. 1-2.

BRIEF DIAGNOSIS: This Holectypus may, as stated above be roughly distinguished from *H. planatus* by the shape and size of the periproct, and according to Boese, by the greater number of tubercles in individuals of the same size.

HORIZON: Upper Washita, occasional in Weno and Pawpaw formations, forming a zone in the Mainstreet formation.

### HOLASTER SIMPLEX Shumard

1853: Shumard: Pal. Expl. Red River of La. in 1852; pl. 3, fig. 2.
1916: Clark and Twitchell: U. S. G. S., Mon. LIV, p. 85, pl. 34, figs. 3a-b; pl. 38, figs. 1a-j; pl. 39, figs. 1a-g.

BRIEF DIAGNOSIS: The *Holasters* have the ambulacral pore rows flush with the surface and not lying in grooves. Their generally smooth appearance will thus distinguish them from *Hemiaster* and *Enallaster*. The anterior unpaired ambulacrum lies in part in a groove which is much shallower than that of *Enallaster*. The *Holasters* of the Weno and higher formations are probably not *H. simplex*. Clark[1] has united all of the described *Holasters* of the Washita division into one species: *H. simplex*, Shumard. Without discussing at present the merits of this procedure, it will be convenient for stratigraphic purposes to distinguish two groups of individuals as the low phase and the tall phase of *H. simplex*.

### DESCRIPTION OF LOW PHASE OF H. SIMPLEX

Pl. 9, fig. 19; Pl. 8, figs. 5-6

TEST: The height is about one-half the greatest length, and the maximum circumference is at the basal margin; the sides, therefore, slope from this margin to the apex. The curvature is even and the contour of the test in end view is a short hemi-ellipse. The outline of the margin as seen from above is elliptical-cordate. There is a broad indentation at the anterior end of the unpaired ambulacrum involving about one-third of the short diameter of the test, and a broad truncation at the posterior end. The highest point is a little posterior to the apical system which is

[1]Clark and Twitchell: loc. cit., p. 85.

nearly central. From the apical system anteriorly there is a barely perceptible median groove and, posteriorly, a slight median carina ending in a rounded projection above the peripcroct, which is elevated in the truncated area referred to above. The oral surface is usually slightly concave, and the margin sharply rounded. Near the anterior end there is an irregular transverse depression containing the peristome. The peristome is almost oval, with its long axis transverse and its posterior side somewhat flattened. Posterior to it there is usually an elevated triangular area lying between the posterolateral ambulacra and having a somewhat pointed or carinate top just behind the peristome.

The apical system is elongate; the poriferous zones, except the anterior unpaired one which lies in a shallow groove, are flush with the surface. The anterolaterals have in general two pore sizes; both pores of the anterior pore zone and the anterior pore of the posterior pore zone are short nearly equal slits. The posterior pore of the posterior zone is a more elongated slit. The pores of a pair are slightly inclined to each other. The anterior unpaired ambulacrum consists of two pore zones which consist of obliquely inclined pairs of almost circular small pores.

HORIZON: Upper Duck Creek marl and lower Fort Worth limestone. See discussion of Horizon No. 17.

### DESCRIPTION OF TALL PHASE OF H. SIMPLEX

Pl. 9, fig. 18

There is, superficially at least, a gradation in height between the low phase and the tall phase. The tall individuals are top-heavy, the height being about two-thirds of the greatest length. They have a gently convex base which curves abruptly at the margin, and there is another less abrupt curve connecting the sides with the gently arched top. The greatest perimeter is at the base in the low form and above the base in the tall form. The periproct area is triangular and truncate, and above it a blunt carina projects past the basal margin of the test.

The apical system is elongated and the ambulacra are in most respects like those of the low phase individuals.

The tall phase individuals are better preserved, have a thicker shell, and are almost never crushed the condition in which most of the low phase individuals are found.

HORIZON: High in the Fort Worth limestone. While rare this phase is a valuable horizon marker.

**HEMIASTER** species **B**

Pl. 8, figs. 7-9

1919: Hemiaster sp. B. Winton and Adkins: Univ. of Texas Bull. 1931.

BRIEF DIAGNOSIS: This small and very abundant echinoid of the Goodland limestone is distinguished from *Hemiaster whitei* Clark by its smaller size, shallower ambulacral sulci, less elevated posterior carina, less conspicuous tuberculation, and by its form, which is less rotund, more elongated, and relatively less broad anteriorly and more constricted posteriorly. This species has not been noted above the Fredericksburg division, while *H. whitei* occurs in the Lower Washita.

HORIZON: Goodland limestone, occasional. Abundant at a level just above the Upper *Salenia* horizon. In conglomerates it is associated with *Exogyra texana, Gryphea marcoui* and *Lima wacoensis.*

**HEMIASTER WHITEI** Clark

BRIEF DIAGNOSIS: This *Hemiaster* may be distinguished from *Hemiaster elegans* by its smaller size and smaller number of ambulacral pore pairs. The test is obscurely cordate with the greatest width about one-third the way back and slightly in front of the apical system. It is widened and broadly rounded anteriorly, and posteriorly is much constricted and truncate. The base is slightly concave, the sides inflated, broadly rounded, and rather tall, the aboral surface is gently arched. The tallest point of the test is on the median carina back of the apical system. The peristome is placed forwards, in the end of the anterior sulcus; the periproct is near the top of the truncated posterior end. The ambulacra lie in a groove of moderate depth and are shorter than in H. elegans. They have shorter subpetaloid zones and the posterolaterals diverge at a smaller angle than in that species.

HORIZON: Fredericksburg (Goodland) limestone, abundant at certain levels and occasional throughout. There is a higher and less noticeable zone of abundance at the *Hamites comanchensis* level, base of Duck Creek limestone; and the species above that point is scattered to the top of the Fort Worth limestone.

**HEMIASTER ELEGANS** Shumard

Pl. 8, figs. 3-4

1853: Hemiaster elegans Shumard: Pal. Expl. Red River in La., p. 210, pl. 2, figs. 4a-c.
1901: Epiaster elegans Hill: U. S. G. S., 21st Ann. Rept., pt. 7, pl. 36, fig. 4.
1915: Hemiaster elegans Clark and Twitchell: U. S. G. S., Mon. LIV, p. 88, pl. 41, figs. 1a-c; pl. 42, figs. 1a-h; pl. 43, figs. 1a-f.

BRIEF DIAGNOSIS: *Enallaster* differs from *Hemiaster* in having an anterior sulcus which is deeper and more conspicuous than the other sulci; in having the anterior ambulacra composed in part of round pores; and in having the anterior pore zone of the anterolateral ambulacra composed of pairs of small circular pores instead of elongated slits. *Holaster* differs from *Hemiaster* in having the lateral ambulacra flush with the surface instead of lying in grooves; the unpaired anterior ambulacrum of Holaster however, lies in a very shallow sulcus.

*Hemiaster elegans* is larger than the other Comanchean species and its rotund and ornamented with many small tubercles. It is practically limited to the upper portion of the Duck Creek marl and to the Fort Worth limestone. The test of *Hemiaster elegans* is inflated, large, elevated and rotund. In outline as seen from above, it is elongate cordate, with a distinct indentation of the anterior sulcus and a small posterior truncation on the mid line near the periproct. The sides are rounded and tall; the base is generally gently convex with a broadly rounded margin. The aboral side is convex and has prominent ambulacral sulci. The ambulacral pores are slit-like, similar, and, at corresponding positions on the pore zones, about equal in size. These slits are numerous and decrease in size towards each end of the pore zones. The apical system is a little in front of the center of the test. Peristome, in end of anterior sulcus about 1/5 the length of the test from anterior end; periproct, at top of small truncated area on posterior end of test and a little more than halfway up the test. Certain individuals in the upper Duck Creek marl, commonly referred to this species, are much flatter and less mineralized, and are usually seen much crushed.

HORIZON: Upper Duck Creek formation; and entire Fort Worth limestone, with a zone of abundance in upper third.

### HEMIASTER CALVINI Clark

Pl. 8, figs. 1-2

BRIEF DIAGNOSIS: This *Hemiaster* is distinguished from *H. elegans* by its smaller size, its relatively greater height, and by its more pronounced ambulacral grooves, which give to the aboral surface an angular appearance. It differs from *H. whitei* in its greater elevation and deeper ambulacral grooves, and from certain smooth small sized Hemiasters of the Upper Washita strata in the same features.

*Hemiaster calvini* is usually about an inch long, but one individual (Baylor University Museum) before us measures: length, 1.7 inches, height, 1.4 inches, width, 1.6 inches. The test of the species is elongate oval with a very slight depression in the outline at the anterior sulcus,

and a broadly truncated posterior end. This truncation is a tall oval area facing upwards and having the periproct located near its top and slightly more than half way up the test. The ambulacra lie in deep grooves, of which the posterolaterals are shortest. The pores of all the laterals are slit like and similar, and in corresponding positions in the zones are nearly equal. The unpaired ambulacral zones consist of oblique pairs of short slit like pores, the pores of a pair being placed close together and separated by a small tubercle. The apical system is compact and nearly central.

HORIZON: Upper Washita, Weno to Buda formations, sparse throughout, rather more abundant at the top of the Weno limestone.

### ENALLASTER TEXANUS Roemer

Pl. 9, figs. 12-13

BRIEF DIAGNOSIS: The Texas Comanchean *Enallasters* may be recognized by the prominently exacavated anterior groove and the circular pores of the anterior pore-zone of the anterolateral ambulacra.

*E. texanus* is a rotund inflated species which at present is not well characterized. Boese suggests that *E. texanus, mexicanus,* and *obliquatus* might be united into one rather variable species. Most of the Fredricksburg and lower Washita individuals may be referred to *E. texanus,* while in the upper Washita, *E. bravoensis* and *E. longisulcus* should be distinguished from it. *E. bravoensis* differs in being greatly constricted posteriorly, while *E. longisculcus* is low, flat topped and has the apical system near the posterior end of the test.

HORIZON: Fredericksburg, Goodland limestone, abundant at certain levels. Occasional in Walnut conglomerate. Washita: Kiamitia to Grayson, occasional. Reported from the Buda limestone. This species has practically no value for vertical orientation except in association with *Hemiaster* species B in defining the horizon of the *Hemiaster.*

### ENALLASTER LONGISULCUS n.sp.

Pl. 9, figs. 4, 8, 9, 10

1919: Enallaster sp. 2. Winton and Adkins: Univ. of Texas Bull. 1931.

BRIEF DIAGNOSIS: This *Enallaster* differs from *Enallaster bravoensis* Boese with which it might be confused, in being lower, more straight-sided and not sharply tapering at the posterior end. It has a longer anterior groove and its apical system is farther back. Briefly, it is a lower, longer, less rotund species.

HORIZON: Top of Fort Worth limestone; so far, found only in the three-foot stratum which immediately underlies the Denton shell marl.

Localities: On branch of Noland's River (Cedar Creek), two miles southeast of Blum (type); locality 409, 6 miles southwest of Fort Worth, and ½ mile southeast of Frisco track, headwaters of a small run; 3 miles north of Denison, just north of Frisco track.

Associated fossils: *Remondia*(?) *robbinsi* (White), *Nerinea* sp., *Exogyra* sp., *Plicatula* sp.

DESCRIPTION: Test: Small, elongate oval, greatest width near middle, posterior surface truncate; base slightly rounded, upper surface gently arched, the highest point being on the margin of the anterior sulcus just in front of the apical system, which is situated about two-thirds the way to the posterior end; anterior sulcus broad and deep, three-fifths the length of the test, considerably constricted just back of its anterior end, where it dents the ambitus.

The outline as seen from above is almost a perfect oval, except for a broad concavity which marks the indentation of the ambitus by the anterior sulcus, and which is about ⅓ the width of the truncated anterior end of the outline. The aboral surface is gently arched from right to left and its highest point is in front of the apical system which is situated far posteriorly; the length before and behind the center of the apical system are in the ratio of 2.5:1. Seen from the side the aboral surface is noticeably more plane than the oral surface.

The under (oral) surface is distinctly convex. Its most prominent point is just posterior to the center of the test and anterior to the center of the triangular, posterior-ventral tubercle area, which extends almost to the peristome. From the prominent point there is a slight ridge which runs anteriorly to the peristome; and a slight and gently deepening depression which runs posteriorly to the periproct. The depression widens as it passes backward between the two prominently rounded and bulging postero-ventral corners of the test, and turns rather sharply upwards, forming a medial excavated area in the basal half of the posterior surface. The periproct is situated in the upper two-fifths of this bluntly truncated and excavated posterior surface. This surface makes approximately a right angle with the portion of the aboral surface on the mid-line back of the apical system. The test as viewed from the side is prominently bulged at this central ventral point, and thence the ventral surface slopes gently forward to the anterior end. The dorsal surface shows a slight prominence at the apical system, posterior to the center of the test, and thence a gentle even slope forwards. The test is thus much taller in its posterior half than in its anterior half, and has roughly in side view a wedge-shaped appearance. This may suggest deformation by pressure but such is not

the case, as the other individuals show. Dimensions of type: Length, 24.5 mm.; height, 13 mm.; breadth, 20 mm.

ANTERIOR UNPAIRED AMBULACRUM: Lies in deep anterior sulcus. Each zone consists of about 32 pairs of pores which are small and closely spaced near the apical plates but become larger and farther apart more anteriorly. The zones diverge at an angle of 75° and become parallel near the center of the test. The two pores of a pair are subequal in size, oval and opposite. The unpaired anterior ambulacrum is very long, and as seen above, is distinctly biconvex, due to the constriction of the sides of the groove near its anterior end. The narrowest point of the groove is at this constriction, the widest point half-way between this and the apical system; these two widths are in the ratio of 2:3.

ANTEROLATERAL AMBULACRA: Diverge from each other at an angle of 180° then turn forwards and laterally, becoming almost straight. The anterior zone of each ambulacrum consists of about 28 pairs of minute, circular equal pores, the pairs being equally spaced except near the apex, where they lie closer together, and the pores of a pair being separated by the diameter of a pore; each pair of the posterior zone consists of an anterior circular pore and a posterior ovoid slit.

POSTEROLATERAL AMBULCRA: Diverge from each other at an angle of 150.° The posterolaterals are about one-third the length and three-fourths the breadth of the anterolaterals at their broadest points. Each posterolateral consists of an anterior zone of about twelve pairs of equal pores, and a posterior zone of ten pairs, each consisting of a pore and a slightly oval elongated slit.

APICAL SYSTEM: Four genital plates with distinct circular perforations, those of the posterior pair being slightly farther apart than those of the anterior pair. Oculars small, perforated.

PERISTOME: Almost circular, lies in the recurved end of anterior sulcus, far forwards.

PERIPROCT: Subcircular, situated high on the posterior truncated surface.

RELATED SPECIES: *Enallaster longisulcus* n. sp. differs from *E. texanus* Roemer and *E. mexicanus* Cotteau in its low elongated form, long anterior sulcus and posteriorly placed apical system.

*Enallaster longisulcus* differs from *E. bravoensis* Boese in the more elongate and lower test, and long constricted anterior sulcus. It differs from *Enallaster traski* Whitney in the proportions and ornamentation of the test. It differs from *Enallaster obliquatus* Clark in the curvature and angle of the antero-laterals.

The low, elongate test, long anterior sulcus, constricted forwardly, and the consequent posterior position of the apical system should easily dis-

tinguish this form from all other described species of the Texas Comanchean strata.

**ENALLASTER BRAVOENSIS** Boese

Pl. 9, fig. 11

1910: *Enallaster bravoensis* Boese: Inst. Geol. de Mexico, Bol. 25, p. 168, pl. 4, figs. 5-10; pl. 42, figs. 2-12.
1916: *Enallaster bravoensis* Whitney: Bull. Amer. Pal. No. 26, 1916, p. 16, pl. 6, figs. 3-5.

BRIEF DIAGNOSIS: This *Enallaster* occurs rarely if at all below the top of the Fort Worth limestone. It is a small sized (one inch) species with broadly rounded sides and a tapering and truncated posterior end. The widest point is in front of the apical system and about two-fifths the length of the test from the anterior end. The tallest point is behind the apical system and about three-fourths the way back. The apical system is nearly central and the posterolaterals are short and spreading. There is some variation in the Weno and Pawpaw *Enallasters* in the position of the apical system, the height and anterior slope of the test, and the components of the ambulacral pore-zones. The species is lower, less inflated and more narrowed and truncated posteriorly than *E. texanus* and *E. mexicanus*. It is taller posteriorly and relatively more elongated than *E. traski* and *E. obliquatus*.

HORIZON: Upper Washita division: Weno, occasional and locally abundant near the top; Pawpaw, occasional; Mainstreet and Grayson, rare; reported from the Buda limestone.

## PELECYPODS

**OSTREA** sp.

Pl. 16, fig. 1

BRIEF DIAGNOSIS: The Upper Washita contains scattered individuals of several species of oysters related to *O. subovata* Shumard and *O. marcoui* Boese, and also individuals of the diluviana type with zigzag margins. The zigzag Mainstreet oyster in question has a concave finely ribbed upper surface and an edge which is raised into folds, those of the two valves fitting together at the margin. The individual figured is from the Mainstreet limestone at Cleburne, Texas, and the species ranges from the Weno up. Large individuals of a species somewhat similar to that figured by Hill[1] are found in the upper strata of the Mainstreet limestone,

[1]Hill: 21st Ann. Rept. U. S. G. S., pt. 7, pl. 45, fig. 2.

while still another species with widely spaced angulations on the margin occurs in the Weno limestone and the corresponding position in the Georgetown limestone.

**OSTREA (ALECTRYONIA) CARINATA (?)** Lamarck

Pl. 16, figs. 2-5

1852: Roemer: Kr. Texas, p. 75, pl. 9, fig. 5.
1857: Conrad: Mex. Bdry. Surv., p. 156, pl. 10, fig. 6.
1884: White: U. S. G. S., 4th Ann. Rept., p. 293, pl. 43, fig. 1-4.
1898: Hill and Vaughan: U. S. G. S., 18th Ann. Rept., pt. 5, pl. 56, fig. 1.
1901: Hill: U. S. G. S., 21st Ann. Rept., pt. 7, pl. 36, fig. 2.
1910: Boese: Inst. Geol. Mex., Bol. 25, p. 104, pl. 16, figs. 13-14.
1913: Whitney: Trans. Texas Acad. Sci., p. 12, pl. 1, figs. 1-2.

BRIEF DIAGNOSIS: The widespread Texas oysters commonly referred to this species indicate stratigraphic levels from the top of the Fort Worth limestone to the Buda limestone. However, their zones of abundance give them a practical stratigraphic value, as indicated later.

The valves are elevated, curved and variable in width. The larger individuals are taller and have a hemi-elliptical cross-section; in many individuals, however, the sides of the valve are spread, resulting in a triangular or V-shaped cross-section. The ribs are prominent, coarse and oblique, starting on the midline by branching or de novo, and continuing down the sides as straight, sharp topped elevations to the margin where they terminate in a zigzag line, the projecting teeth being continuations of the valleys between the ribs. The teeth of one valve fit between those of the other valve.

HORIZON: Reported from Buda limestone (Whitney); rare in Grayson marl; occasional in a distinct zone at the base of the Mainstreet limestone in association with *Pachymya austinensis;* occasional and scattered in Pawpaw clay; Quarry limestone, zone of abundance at Red River in association with *Gryphea washitaensis,* farther south at the top of the Weno; otherwise scattered in the Weno; Denton marl, zone of great abundance in the Gryphea conglomerate layers at the top of the formation, scattered and sparse at lower levels; Fort Worth limestone, occasional in distinct zone in upper third of formation, near *Exogyra americana* level; rare at base of Fort Worth limestone; not seen by us below that level.

**OSTREA QUADRIPLICATA** Shumard

Pl. 16, figs. 6-10

1860: Ostrea quadriplicata Shumard: Trans. St. Louis Acad. Sci. Vol. 1, p. 608.
1879: White: 11th Rept. U. S. G. and G. S. Terr., pp. 275-6, pl. 5, fig. 6a.
1879: White: Contr. to Paleon. I., p. 275, pl. 5, fig. 6a; pl. 8, figs. 4a-b.
1884: White: U. S. G. S., 4th Ann. Rept., p. 299, pl. 43, figs. 5-7.
1893: Cragin: 5th Ann. Rept., Geol. Surv. Texas, pp. 20-2.
1902: Hill: U. S. G. S., 21st Ann. Rept., pt. 7, pl. 37, figs. 4a-b.
1910: Boese: Inst. Geol. Mex., Bol. 25, pp. 101-3.

BRIEF DIAGNOSIS: Shell roughly crescentic to triangular, with a few, generally four, elevated coarse ribs which start at the umbo and increasing in height terminate at the margin as conspicuous elevated projecting carinae, sharply rounded at the tips. The ribs vary in elevation. The countour of the shell is thus broadly scalloped on one margin and concave on the other. There are coarse imbricated growth lines which project ventrally upon crossing the ribs. The smaller valve is crescentic with one margin concave and the other scalloped with four conspicuous points. This valve is almost flat and bears upon its exterior surface numerous fine costellae.

HORIZON: Upper Washita, down to the top of the Fort Worth limestone. Absent in the Grayson, so far as known to us; occasional and locally numerous in the Mainstreet limestone, where strong ribbed individuals predominate; abundant in the basal Pawpaw clay; a notable zone of abundance immediately overlies the Gryphea conglomerate of the Quarry limestone group at the Red River, but this is sparse southwards; occasional throughout the Weno; occasional and locally abundant in the Denton marl; rare in the upper Fort Worth limestone; not observed by us below this level. Near Kingston, Oklahoma, very coarsely ribbed individuals occur in the Denton marl (Dr. Boese); on the Red River north of Fink, Grayson County, there are many strongly ribbed individuals in the middle Mainstreet limestone and these have one backward projecting ventral rib. Near El Paso they are abundant in subdivision 6 (equivalent of Weno-Pawpaw).

**OSTREA** sp. aff. O. Johannae Choffat

Pl. 16, figs. 11-13

The individuals figured occur below the middle of the Goodland limestone and can not be identified with certainty as *Ostrea subovata* Shumard

due to the uncertainty as to the status of this species. They have thicker and less numerous ribs, and are different in form from *Ostrea munsoni* Hill; and they agree equally little with the poor description and figure of *Ostrea subovata.* The Upper Washita formations, Weno to Mainstreet, contain *Ostrea marcoui* Boese, which is not to be confused with either of the species mentioned, while *O. subovata* is recorded from both the Fredericksburg and the Washita divisions. The present species has not been seen by us above the lower Goodland limestone where it is occasional but persistent.

This species differs from C. munsoni in having fewer, coarser and more elevated ribs, in the form, the greater thickness of the valves and the greater size of the body cavity. C. munsoni in its ribbing resembles O. delgadoi Choffat while this species more resembles the coarser ribbed O. johannae Choffat[1] of the Turonian of Portugal.

**GRYPHEA MARCOUI** Hill and Vaughan

Pl. 15, figs. 15-18

1898: *Gryphea marcoui* Hill and Vaughan: U. S. G. S., Bull. 151, p. 50, pls. 2-5.

Although the Grypheas are extremely variable it results in practice that they are relied upon considerably for stratigraphic information, partly because they are well preserved and widely ranging and partly because they occur in a definite general sequence. Only very general statements of their differences are made here, and these can not supply the details gained from an intimate familiarity with individuals from widely separated localities.

BRIEF DIAGNOSIS: The typically developed *Gryphea marcoui* of the Walnut and Goodland formations is a rather narrow shell with a straight greatly recurved beak. It has a deep sinus throughout its exterior surface and may be somewhat flared at its ventral margin. It is straight beaked, like *Gryphea mucronata* of the Grayson marl, but is less ponderous and has a deeper sinus. It differs from the typical *G. navia* of the Kiamitia marl in having the beak straight instead of twisted to the side; and it lacks the broadly flared wing seen in *G. washitaensis.* Only a series of individuals compared with a series of figures[2] is satisfactory for the identification of doubtful individual Grypheas.

In general, Gryphea marcoui is narrower and much less massive than G. mucronata.

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[1]Choffat: Rec. d'ét. pal., 1886, Vol. I, Ser. 1, pp. 54-5, pl. 1, figs. 1-7; pl. 2, figs. 18-19.
[2]U. S. G. S., Bull. 151, 1898.

HORIZON: Goodland limestone, sparse in upper half, more abundant basally; a zone of abundance near the base. Walnut conglomerate, abundant. The cap conglomerate of the Walnut formation is a mass of *G. marcoui* and other shells intermingled; this cap is less consolidated on the Red River but southwards to beyond the Brazos is conspicuous and persistent. In both formations *Exogyra texana* is the commonest associated fossil. The typically developed individuals of the species are commonest in the Goodland, while the Walnut clays in addition contain several variants.

### GRYPHEA NAVIA Hall

Pl. 15, figs. 13-14

1898: *Gryphea navia* Hill and Vaughan: U. S. G. S., Bull. 151, p. 57, pls. 17-18.

BRIEF DIAGNOSIS: This Gryphea is massive and imbricated and as typically developed has a rather sharply keeled beak which is considerably curved to the side. There is usually a depressed space along the length of the larger valve producing radiating folds. The species will be easily confused with *G. mucronata* of the Upper Washita (Grayson and Buda formations). *Gryphea navia* usually has the beak bent to one side while the beak in *Gryphea mucronata* is nearly or entirely straight. *G. navia* is generally very thick shelled and massive while *G. marcoui* and *G. washitaensis* are thinner shelled. *G. navia* has only a slightly flared ventral margin, while that of *G. washitaensis* is greatly flared producing large thin wings.

HORIZON: Kiamitia marl; we have not seen *G. navia* in any other formation. It is associated in North Central Texas with the typical inflated form of *G. corrugata* Say, which ranges above it into the Duck Creek formation.

### GRYPHEA WASHITAENSIS Hill

Pl. 15, figs. 5-12

1898: *Gryphea washitaensis* Hill and Vaughan: U. S. G. S., Bull. 151, p. 59, pls. 19-23.

BRIEF DIAGNOSIS: *Gryphea washitaensis* as typically developed in this area will be easily recognized as a thin shell with a straight and only very slightly recurved beak, and flared wings which gave a variable, usually considerable, lateral expansion to the large valve. This valve is rather narrow and sharply rounded ventrally and from this rounded

portion the wings emerge, the right hand one being larger and usually marked off by a depression from the rest of the shell.

This species will be roughly distinguished from *G. navia* and *G. mucronata* in being much thinner, less massive and more flared; from *G. marcoui* in having large wings and a slightly recurved beak; and from *G. corrugata* in having the central portion more sharply rounded and distinctly separated from the wings, thus giving the shell an entirely different contour. These statements are generalized for the bulk of the material and only approximate for the remainder.

HORIZON: Kiamitia to Mainstreet formations. Kiamitia, rare; Duck Creek, occasional; Fort Worth, occasional, but locally abundant, occurring in slabs of conglomerate; Denton marl, scattering at base, more abundant but not consolidated towards top, at top forming a conspicuous shell conglomerate, which is slabby and persistent at the Red River and southwards is less compact. In this Denton *Gryphea* conglomerate *Ostrea carinata* is conspicuous. Weno and Pawpaw, occasional and scattered. Quarry limestone on Red River, abundant and forming a conspicuous shell conglomerate containing *Ostrea carinata, O. quadriplicata* and cidarid spines and lying just below the main *Ostrea quadriplicata* zone of the Quarry limestone; basal Mainstreet, rare.

### GRYPHEA MUCRONATA Gabb

Pl. 15, figs. 1-4

1898: *Gryphea mucronata* Hill and Vaughan: U. S. G. S., Bull. 151, p. 63, pls. 24-30.

BRIEF DIAGNOSIS: Shell massive or thick, beak considerably incurved and usually not deflected to the side, lateral extensions narrow and not prominently developed. In large individuals an external furrow is often present, dividing the surface of the valve; if so the shell is sharply rounded near the beak, otherwise it may be broadly rounded. Elongate and thick set individuals are found, but the usual shape in the area under discussion is elongate, elevated, much recurved, with massive furrow.

This species resembles *G. navia* in being thick shelled and differs from it in having the beak nearly straight instead of curved to the side. It differs from *G. washitaensis, G. corrugata* and *G. marcoui* in being thick shelled. In addition the typically developed individuals differ from *G. washitaensis* in not being widely flared, from *G. corrugata* in being narrower and split externally by a furrow; and from *G. marcoui* in being more rounded basally and in having no conspicuous wing. These statements are approximate only.

HORIZON: *Gryphea mucronata* occurs in the Grayson marl in North Texas, and is reported from the Buda limestone in South Texas. Not known to occur in the Mainstreet limestone. Inflated *Grypheas* somewhat similar to *G. corrugata* occur at this level in Western Texas and New Mexico.

### **EXOGYRA TEXANA** Roemer

Pl. 13, figs. 15-16

1852: *Exogyra texana* Roemer: Kr. Texas, p. 69, pl. 10, figs. 1a-e.
1902: *Exogyra texana* Hill: U. S. G. S., 21st Ann. Rept., pt. 7, pl. 27, figs. 1a-b.
1910: *Exogyra texana* Boese: Inst. Geol. Mex., Bol. 25, p. 112, pl. 20, figs. 14-16; pl. 21, figs. 1-11; pl. 22, figs. 1-9.

BRIEF DIAGNOSIS: This Exogyra has a close coiled depressed beak and a variable small attachment scar. Both valves are elongate basin shaped with a strong angle or knee all around one edge; this edge thus presents thick appearance while the valves slant off to the other margin where their thin edges are apposed. A section of the valves is thus an elongate triangle. Each valve bears numerous irregularly crenulate simple or slightly branching ribs arranged in a short spiral. The growth lines are prominent and the laminae imbricated.

HORIZON: Goodland limestone, abundant especially at the levels of the Gryphea conglomerates. Occasional near the top of the Goodland limestone. Rare in the Kiamitia clay. Abundant in the cap conglomerate of the Walnut.

### A FOSSIL PEARL IN SHELL OF EXOGYRA TEXANA

In the collections of fossils of the Bureau of Economic Geology has been preserved an Exogyra texana Roemer bearing on the inner surface of its upper (right) valve a pearl, which was found by Mr. W. P. Bentley of Dallas and Dr. J. W. Beede, in the Walnut clay beds (of Comanchean age), in Coke County, Texas.

The pearl is firmly adherent a little dorsal and posterior to the center of the valve at the outer edge of the muscle scar, and is about one-third imbedded in the valve. It is almost spherical and has a diameter of about 2.3 millimeters. It has no pearly luster or color, the material being, like the rest of the shell, calcite of a grayish color. As a jewel the pearl is of course valueless. The two valves of the shell were preserved together, with the pearl inclosed. Surrounding the base of the pearl is a lamellar,

crater-like basin, raised about one-half the diameter of the pearl and smoothly rounded without and within its rim. The pearl adheres to the irregularly pitted bottom of this crater. The lamellae composing the crater are continuous with those of the rest of the shell and turn up at almost a right angle to its surface. The lamellar structure of the pearl is obscure, but a slight flakiness is apparent at one edge. Dr. George F. Kunz of New York writes that he has no definite knowledge of the discovery of other fossil pearls.

This pearl was found near the foot of the mountains in the northeast corner of Coke County, and about 6 miles southwest of Blackwell, Texas, in the lowest bed of abundance of Exogyra texana. In the mountains south of Robert Lee, Coke County, Texas, Mr. Cowan found a heaped up deposit of "several tons" of Exogyra texana, probably from the Walnut beds, and among them were found four other pearls which were reddish-brown and iron-stained, the largest one being kidney-shaped and about 5 mm. long. One of these was broken in removing it from the shell and showed concentric lamellae, an irregular attachment and a hollow center.

### **EXOGYRA WEATHERFORDENSIS** Cragin

Pl. 13, figs. 11-14

1893: *Exogyra weatherfordensis* Cragin: 4th Ann. Rept. Geol. Surv. Texas, p. 188, pl. 45, figs. 7-8.
1919: *Exogyra weatherfordensis* Boese: Univ. of Texas Bull. 1902, p. 5, pl. 1, figs. 1-2.

Under this name are placed small elongate shells with few broadly rounded marginal plications and obscure ribbing, which occur mainly in the Walnut conglomerate and lower beds. Dr. Boese has figured similar shells from the Fredericksburg division near El Paso.

HORIZON: Walnut cap conglomerate.

### **EXOGYRA PLEXA** Cragin

Pl. 13, figs. 7-10

1893: *Exogyra plexa* Cragin: 4th Ann. Rept. Geol. Surv. Texas, p. 187, pl. 30, figs. 3-6.
1919: *Exogyra plexa* Boese: Univ. of Texas Bull. 1902, p. 24, pl. 2, fig. 3.

BRIEF DIAGNOSIS: Cragin described from the Duck Creek limestone north of Denison and the Goodland limestone between Fort Worth and Benbrook two very distinct species, under the name of *Exogyra plexa*. One of these species (Cragin's figs. 3, 5, 6) has a depressed slightly spired

beak, a sharp angulated carina, and no plications, and resembles some of the small *Exogyras* which characterize the upper Mainstreet and lower Grayson; it is occasional in a single definite stratum of the Kiamitia marl at numerous localities, and is abundant in the Goodland limestone just below the Upper *Salenia* zone. The other species (Cragin's fig. 4, our figs. 8-10) is plicate with a more elevated beak and a more obscure carina and a different, more rounded body form. It also differs in the elevation of the beak and the juvenile stages. It is abundant in the Kiamitia marl stratum mentioned[1] and is rarer in the Goodland. Dr. Boese[2] has likewise discussed these differences as seen in Cragin's original material.

HORIZON: These two species are limited to the upper one-fourth of the Goodland limestone, the Kiamitia marl, especially stratum 16 which carries a zone of abundance; and north of Denison on Duck Creek, the basal strata of the Duck Creek limestone, which contain also *Hamites, Kingena,* and *Schloenbachia belknapi.*

### EXOGYRA AMERICANA Marcou

Pl. 14, figs. 1-2

BRIEF DIAGNOSIS: *Exogyra americana* is one of the largest Comanchean oysters; its shell weighs two or three pounds. The left valve has a distinct angulation at the thick edge and both valves taper to the opposite thin edge. The shell is coarsely imbricated and seems to lack ribs or plications. The beak is depressed and slightly coiled. Its size, shape and lack of plications will distinguish it from other Comanchean *Exogyras.*

HORIZON: Restricted zone, upper third of Fort Worth limestone, abundant and widespread. Top of Duck Creek formation, rare and local (Dr. Boese).

### EXOGYRA ARIETINA Roemer

Pl. 13, figs. 1-6

BRIEF DIAGNOSIS: *Exogyra arietina* (ram's horn) is a small coiled species with the spire variably developed in height but always rising above the body of the shell. In older individuals it makes one turn or more. The lines of growth are prominent and follow a wavy course over the gentle and broad plications of the larger valve. The species is abundant in the Mainstreet limestone and the base of the Grayson marl. In

[1]Winton and Adkins: Geology of Tarrant County: Univ. of Texas Bull. No. 1931.
[2]Boese: On a new species of Exogyra from the Del Rio clay, etc., Univ. of Texas Bull. 1902.

Southern Texas there are vast numbers in the Del Rio clay. In addition, in the Grayson marl there are other species of *Exogyra* related to *Exogyra plexa* and *E. arietina,* which are reliable markers for the formation.

HORIZON: Mainstreet limestone, basal Grayson marl.

**GERVILLIOPSIS INVAGINATA** White

Pl. 18, fig. 1

1888: *Dalliconcha invaginata* White: Proc. Acad. Nat. Sci. Philda., p. 35, pl. 2, figs. 4-5.
1902: *Gervilliopsis invaginata* (?) Shattuck: U. S. G. S. Bull. 205, p. 19, pl. 5, fig. 12.
1910: *Gervillea invaginata* Boese: Inst. Geol. Mex., Bol. 25, p. 87.

BRIEF DIAGNOSIS: This shell will be recognized by its elongation, its terminal beaks, long wing, and numerous ligament pits. The shell, shaped like a razor clam, has a central longitudinal arched ridge above which there is a long depression, marking off the wing from the main body of the shell. The interior is distinctive: there are several ligament pits of greater breadth than the elevations connecting them; and a series of oblique dental ridges. Only one muscle scar is present. The shell is frequently pearly-iridescent.

HORIZON: Reported from the Buda limestone (Shattuck); Pawpaw, rare; Weno marl, abundant in a broad horizon which terminates below in a zone of abundance near the base of the formation. Isolated individuals of the genus have been found in the Duck Creek limestone. The Weno horizon is much better developed at the Red River than farther south. These different horizons likely contain more than one species.

**PECTEN IRREGULARIS** Boese

Pl. 11, figs. 11-15

1910: *Vola irregularis* Boese: Inst. Geol. de Mexico, Bol. 25, pp. 97-8, pl. 15, figs. 10-18.
1918: *Neithea irregularis* Kniker: Univ. of Texas Bull. 1817, pp. 18-19, pl. 2, figs. 1-6.
1895: *Vola occidentalis* Cragin (not Conrad): Amer. Geol., Vol. 16, p. 375.

BRIEF DIAGNOSIS: This pecten may be roughly identified by the presence of fine tertiary ribs attached to the sides of the main ribs, and arranged as described below. It is to be noted that only one large rib has two tertiaries; the other large ribs have only one each. It has about the height and convexity of the common Texas Comanchean species, *Pecten subalpina,* but is more slender and elongated and not so flared ventrally; its umbonal angle is therefore smaller. It differs from the flat ribbed *Pecten texanus* Roemer, from *Pecten subalpina* and its intergrades, from

*Pecten georgetownensis* Kniker, and several others in having tertiary ribs; it differs from a rare basal Fredericksburg species related to *Pecten occidentalis* Conrad in having the irregular arrangement of tertiary ribs noted below instead of one tertiary on each side of each primary except the first and last; and from *Pecten roemeri* Hill (Mainstreet) and *Pecten duplicicosta* Roemer (Fredericksburg) in the form of shell and the number and arrangement of the ribs.

The description given by Boese applies to most of our material except that the tertiary rib arrangement which he describes as exceptional is typical for the material throughout North Texas. Numbering the primary ribs of the right valve seriatim from anterior to posterior as 1-6, primary No. 1 has apposed to its posterior side near the base a tertiary rib; primary No. 2 has an anterior tertiary; primary No. 3 has an anterior tertiary; primary No. 4 has an anterior and a posterior tertiary; primary No. 5 has a posterior tertiary; and primary No. 6 has an anterior tertiary. In each case a rib on the right valve corresponds to and fits into a groove on the left valve, so that either valve of irregularis is perfectly distinctive. About 20 per cent of our material deviates from the above rib arrangement in various ways and should be more closely studied. Among the deviations is the arrangement mentioned as typical in Boese's material.

HORIZON: Goodland formation, abundant near middle; Kiamitia marl, frequent; Walnut shell conglomerate, top, rare. Localities from southern Oklahoma to the Brazos. Walnut and Glenrose, near Austin (Kniker) and top of Fredericksburg near El Paso (Boese).

Figured individuals: Locality 122, Plover road, 4½ miles south of Benbrook, Texas. (Pl. 11, figs. 11-15.)

### PECTEN SUBALPINA Boese

Pl. 11, figs. 1-2; Pl. 12, fig. 16

1910: *Vola subalpina* Boese: Inst. Geol. Mex., Bol. 25, pp. 96-7, pl. 15, figs. 5, 7, 9.
1918: *Neithea subalpina* Kniker: Univ. of Texas Bull. 1817, p. 28, pl. 5, fig. 4.

BRIEF DIAGNOSIS: A considerable number of *Pectens* of the territory under discussion may be referred to this species. In Boese's material the primary ribs are thickened and elevated and apparently project beyond the ventral margin. The species has only primary and secondary ribs, there being two secondaries per interspace. The ribs vary in height and in breadth, and there seems to be a considerable series of intergrades between the typical *subalpina* and the *texana*-like individuals with broadly flared, depressed form, and depressed flat ribs with the primaries incon-

spicuous. Some of the less flared, elongate, flat-ribbed individuals may be placed in *Pecten texanus*, var. *elongatus* Boese, and many rather elongate individuals with prominent, narrow, square topped, straight sided, widely spaced ribs (the primaries not conspicuous) may be referred to *Pecten subalpina*, var. *linki* Kniker. Of the elevated individuals having the form of *georgetownensis*, some are referable to the species *P. theodori* Kniker; these are conspicuous in the Upper Washita, especially the Weno marl.

HORIZON: *Pecten subalpina* is occasional throughout the Washita division, and the other forms mentioned are abundant from the Fredericksburg to the Grayson. There is an exuberance of *Pecten subalpina* and related individuals in the Grayson marl. *Pecten georgetownensis* and related individuals characterize the Weno marl.

**PECTEN WRIGHTI** Shumard

Pl. 11, figs. 8, 10

1860: *Janira wrightii* Shumard: Trans. St. Louis Acad. Sci., Vol. 1, p. 607.
1893: *Vola wrightii* Cragin: 4th Ann. Rept. Geol. Surv. Texas, p. 217, pl. 32, figs. 2-3.
1918: *Neithea wrighti* Kniker: Univ. of Texas Bull. 1817, p. 23, pl. 4, figs. 1-3.

BRIEF DIAGNOSIS: This small *Pecten* may be distinguished by the presence of four very coarse and elevated ribs on the right valve and by the marked inequality in the ears, the anterior one being larger. The four principal ribs are tall and rather triangular in cross-section, are each surmounted by a central elevated costella and are crossed by fine striaeiform growth lines. In addition there is a small radiating rib at the posterior border of the anterior ear.

HORIZON: Rare from Main Kingena zone of the Duck Creek marl to about the middle of the Fort Worth limestone. A single individual was also found near the middle of the Mainstreet limestone, and the species is reported from the Georgetown limestone at Austin (Kniker). The small individuals (plate 11, figure 9) are occasional in the Duck Creek marl between the two Kingena zones, but do not range as high in the Fort Worth limestone as the larger individuals.

**PECTEN BELLULA** Cragin

Pl. 11, figs. 3-7

1893: *Vola bellula* Cragin: 4th Ann. Rept. Geol. Surv. Texas, p. 216.
1918: *Neithea bellula* Kniker: Univ. of Texas Bull. 1817, p. 22, pl. 3, figs. 3-11.

BRIEF DIAGNOSIS: This fine ribbed *Pecten* will be recognized by its small size, its convex and elevated form, its small ears and especially by its nearly equal, fine, numerous ribs. The umbo is sharply recurved, the hinge line straight, and the ears small, triangular and unequal. The right valve is divided into six areas corresponding to the scalloped margin of the valve and separated by variable ribs which correspond to primaries. Every sixth or seventh rib is different from the others and separates the areas; this delimiting rib is longer, or double, or elevated, or differently spaced. The variations in ribbing are numerous, but result in an obscure division of the valve as mentioned. The left valve is concave, although numerous isolated left valves seen by us are almost flat. These valves are broadened basally and show a division and ribbing similar to that of the right valve.

HORIZON: *Pecten bellula* is an important stratigraphic marker for the Fort Worth limestone. It has not been found by us lower than the Main Kingena zone near the top of the Duck Creek marl or higher than the zone of Enallaster longisulcus at the top of the Fort Worth limestone. It is occasional and scattered in the Duck Creek marl but is somewhat more abundant between the two *Kingena* zones and at the base of the Fort Worth limestone. Above the base of the limestone it is rare.

### PECTEN GEORGETOWNENSIS Kniker

Pl. 12, figs. 5-6

1918: *Neithea georgetownensis* Kniker: Univ. of Texas Bull. 1817, p. 31, pl. 6. figs. 1-3.

BRIEF DIAGNOSIS: This *Pecten* has an elevated right valve with prominently elevated ribs divided lengthwise by one or two small linear furrows; there are in addition to the six prominent primary ribs and the two lower secondaries per interspace, a variable number, usually one or two, of fine, linear ribs in the intervals between the ribs just mentioned. We have discovered no regularity to their arrangement; in some of our material they are lacking. The left valve of *P. georgetownensis* has also split ribs; in some of our material which occurs together with undoubted *georgetownensis* the ribs of the right valve only are split.

HORIZON: *Pecten georgetownensis* is a very important, and so far as we now know, invariable stratigraphic marker of the lower third of the Weno formation. It occurs locally in association with *Turritella* sp. and *Remondia acuminata,* at a level a few feet above the main *Gervilliopsis invaginata* zone of abundance in the Weno. Individuals with varying rib development from near Austin in the Georgetown limestone, horizon not stated.

**PECTEN TEXANUS** Roemer

Pl. 12, fig. 2

1852: *Pecten texanus* Roemer: Kr. Tex., p. 65, pl. 8, figs. 3a-b.
1857: *Neithea texana* Conrad: Mex. Bdry. Surv., p. 151, pl. 5, fig. 2a-b.
1910: *Vola texana* Boese: Inst. Geol. Mex., Bol. 25, p. 93-95, pl. 15, fig. 3.
1918: *Neithea texana* Kniker: Univ. of Texas Bull. 1817, p. 25, pl. 4, figs. 4-7; pl. 5, fig. 1.

BRIEF DIAGNOSIS: This rather rare *Pecten* may be distinguished by its wide, flat topped, slightly elevated ribs, by the slight difference in elevation between its primary and secondary ribs, and by its flat form. The species should be restricted to include only the *Pectens* with broad flat ribs as figured by Roemer and Conrad. If so restricted the bulk of the Washita *Pectens* of North Texas will fall under the species *Pecten subalpina* Boese; and they are so considered by us.

HORIZON: *Pecten texanus* is reported from the Georgetown limestone at Austin (Kniker) and from the Fredericksburg, Lower and Upper Washita near El Paso (Boese). In North Texas: Upper Washita, occasional in Weno and Mainstreet formations and possibly lower.

**PECTEN CLEBURNENSIS** n. sp.

Pl. 12, fig. 1

1919: Pecten sp. 2 Winton and Adkins: Univ. of Texas Bull. 1931.

BRIEF DIAGNOSIS: Shell nearly flat, subcircular, inequilateral, subequivalved, left valve convex, right valve slightly concave, each valve ornamented with many fine straight costae.

RIGHT VALVE, EXTERIOR: The anterior, ventral and posterior margins form three-fourths of the circumference of an almost perfect circle whose diameter is the antero-posterior dimension of the valve; the antero-dorsal and postero-dorsal margins form approximately two sides of a square, and are consequently subequal and make with each other almost a right angle; the side of the square and the diameter of the circle are in the ratio of 1:1.7; the umbonal angle 88.° The antero-dorsal margin is straight except for a slight concavity near its middle. The poster-dorsal margin makes a sweeping inward curvature which reaches its maximum just dorsal to the middle of the margin. The remainder of the margin is evenly rounded. The valve is convex and its greatest height is just ventral to the umbo. The dorso-ventral axis makes a total angle of about 75° with the hinge line so that the anterior portion of the valve is larger in area and more gentle in slope than the posterior portion.

The ornamentation consists of about one hundred and sixty depressed linear, unbranched costellae which are continuous from the umbo to the ventral margin and which are separated from each other by straight striaeiform depressions whose widths are the same as the adjoining costellae. The costellae are of irregular size but fall into two general sizes, whose distribution seems irregular, a small rib lying between groups of one to five large ones.

The postero-dorsal and the antero-dorsal margins are sharply rounded, the former with two narrow plications near the ventral angle of the ear, and both bordering on narrow elongated "areas" which are nearly perpendicular to the ears. The border of the valve has a narrow depressed zone and just outside it a narrow marginal elevation. There are in addition, numerous fine concentric growth lines and two coarser growth lines evenly spaced and each preceded by an impressed zone similar to that at the margin of the valve.

The ears are defective; they are flat, triangular, projecting, and the posterior one is larger. Its ventral angle is sharply concave making about a right angle with the border of the valve, which as it approaches the beak is slightly bulged inward. The posterior ear is roughly equilateral in shape and its posterior border is concave. The anterior ear is an elongated triangle, smaller and its inner margin is nearly straight. Each ear has numerous fine striae perpendicular to the dorsal margin and continuous with the growth lines of the valve.

*Left valve, exterior:* The costae are similar to those of the right valve. As on the right valve, there are numerous very fine, concentric growth lines, and at intervals about three heavier ones which correspond to those of the right valve.

*Type:* Samson collection Walker Museum No. 10670, labeled "Cleburne."

*Number of individuals:* Four.

HORIZON: Mainstreet limestone.

### LIMA WACOENSIS Roemer

Pl. 17, figs. 7-9

BRIEF DIAGNOSIS: The common *Lima* of the Goodland limestone is a rounded rectangular shell with nearly terminal beak, two straight sides and a broadly rounded ventral margin. There are about twenty linear, nonserrate sharp topped ribs, which radiate from the umbonal region, and are longest and most pronounced over the central part of the shell. Preserved as mud casts.

HORIZON: The species apparently ranges widely, from the Fredericksburg to the Buda limestone. In the Goodland limestone it is abundant and reliable as a horizon marker, although it has zones of abundance particularly at a level below the Upper *Salenia* zone. In the Lower Washita it is abundant and unreliable; in the Upper Washita it is scattering.

**INOCERAMUS COMANCHEANUS** Cragin

Pl. 17, figs. 1-3

1895: *Inoceramus comancheanus* Cragin: Colo. Coll. Stud., Vol. 5, p. 53.
1901: *Inoceramus comancheanus* Hill: 21st Ann. Rept., U. S. G. S., pt. 7, pl. 35, fig. 4.

BRIEF DIAGNOSIS: This conspicuous medium sized *Inoceramus* appears near the base of the Duck Creek limestone in association with *Hamites fremonti, H. comanchensis, Desmoceras brazoense,* and *Inoceramus munsoni.* The shell is of moderate size, and bears 15-20 raised crescentic, roughly concentric ridges of varying heights. The shell is frequently present, particularly the thick prismatic layer. There is a small Inoceramus in the basal Grayson marl.

HORIZON: Base of Duck Creek limestone.

**PHOLADOMYA SANCTI-SABAE** Roemer

Pl. 19, figs. 21-23

BRIEF DIAGNOSIS: *Pholadomya* has two sets of elevated ribs running one radially and the other concentrically. At their crossings are small, knob-like elevated areas. The central portion of the shell is rounded and inflated and the posterior portion attenuated and winglike.

HORIZON: The species is occasional in the Goodland limestone. There is a zone of abundance on the Red River at the top of the Kiamitia marl just underneath the *Hamites* zone of the Duck Creek limestone. In the Washita division it is rare.

**TRIGONIA CLAVIGERA** Cragin

Pl. 17, figs. 4-6

1893: *Trigonia clavigera* Cragin: 4th Ann. Rept. Geol. Surv. Texas, p. 212, pl. 46, figs. 12-13.

BRIEF DIAGNOSIS: This shell has the anterior end inflated, posterior end tapering, beaks nearly terminal and approximate, dorsal margin

irregularly concave, ventral margin elliptical. The shell bears about 30 radiating rows of elevated, round topped, often clubbed, compressed tubercles. The rows make an angle of about 120° at the edge of the area, turning obliquely backwards to cross the inflated sides of the valve, and then curving evenly forwards to the inferior margin. At the dorsal midline the rows make a series of V-shaped angles, and on the areas the tubercles are faint. Sufficient material of *T. emoryi* Conrad is not now at hand to decide as to its identity with the Cragin species. *Trigonias* are occasional in the Fredericksburg division, and sparse in the Lower Washita. *Trigonia emoryi* has been reported from the Buda limestone at Austin (Shattuck) and from the Weno-Pawpaw near El Paso (Boese).

HORIZON: Weno marl, above zone of abundance of *Gervilliopsis invaginata,* especially at the Red River. Common at pit of brickyard, one and three-fourths miles southeast of Gainesville, Texas.

**REMONDIA (?) ACUMINATA** Cragin

Pl. 19, figs. 13-15

1893: *Astarte* (?*Stearnsia*) *acuminata* Cragin: 4th Ann. Rept. Geol. Surv. Texas, p. 171, pl. 41, fig. 2.

BRIEF DIAGNOSIS: This concentrically ribbed species is included here on account of its stratigraphic importance as a horizon marker for the basal Weno marl. It may be roughly distinguished by having a very pointed tip with terminal, exactly apposed umbones, and an outline consisting of two straight dorsal sides and a broadly curved ventral margin. The fossil is thin and flat and bears a variable number (6-10) of widely spaced thin concentric ribs.

A smaller non-acuminate species, *Remondia robbinsi* (White), occurs in the *Enallaster longisulcus* zone at the top of the Fort Worth limestone; an acuminate but smaller species with differently shaped ribs occurs near the Upper Salenia level of the Goodland limestone; and other related scattered individuals occur in the Washita division.

HORIZON: Weno marl, basal third. Associated with *Pecten georgetownensis* and *Turritella* sp. Above the main zone of *Gervilliopsis invaginata.*

**ARCA** sp.

Pl. 19, figs. 16-20

A small pyritic *Arca* characterizes the basal Pawpaw clay over wide areas in North Texas. This species is globose, has an inflated umbonal

region, opposite remote beaks, and a wide hinge area. The hinge line is elevated, long and straight. No ornamentation has been observed. Certain small pyritic pelecypod casts seem to be the most persistent and widespread horizon markers for the basal Pawpaw in the region under discussion.

**PACHYMYA** sp.

Pl. 17, fig. 10

BRIEF DIAGNOSIS: This large and massive pelecypod, seen usually as casts, will be easily identified, even from fragments. The valves are massive and inequilateral but subequal; the beaks are nearly terminal, remote and opposite. In side view there is a distinct oblique carina beginning near the beak. The shell is bulged in the umbonal region, the beaks are incurved, and there is a large area posterior to them. Well preserved individuals have small, scattered low circular tubercles over most of the surface.

HORIZON: Mainstreet limestone, a distinct narrow zone at base, in association with *Ostrea carinata*, abundant; top of Weno limestone, rare.

**PROTOCARDIA TEXANA** Conrad

Pl. 18, fig. 7

BRIEF DIAGNOSIS: *Protocardia* may be recognized by the inflated shape of the shell, and the striations which are of two sorts: radial at one end of the valve and concentric over most of its area.

This species is variably inflated, subcircular in outline and of medium size. The umbo is nearly central and the dorsal margins make approximately a right angle with each other. The ventral margin is broadly rounded. The ribs are narrow and numerous. Preserved as mud casts. The species will be distinguished by its form and its size. It has been reported from the upper Washita.

HORIZON: Goodland and Washita. Locally abundant in the Goodland, especially below the upper *Salenia* horizon. Rare in the Kiamitia and the Duck Creek. Occasional in the Fort Worth limestone.

**CYPRIMERIA TEXANA** Roemer

Pl. 18, fig. 6

1852: Arcopagia texana Roemer: Kr. Tex., pp. 46-7, pl. 6, figs. 8a-b.
1919: Cyprimeria texana Winton and Adkins: Univ. of Texas Bull. 1931.

BRIEF DIAGNOSIS: This large flat species, preserved in the Goodland as a mud cast, will be recognized by its subcircular contour, its great thinness, nearly central beak, and possibly by slight structure in the beak region. The casts are slightly inequivalve and sometimes exhibit muscle scars, pallial line, impressions of dentition, and hinge structure.

HORIZON: Goodland limestone, middle third. A smaller species occurs near the top of the Goodland and in the base of the Washita.

## GASTROPODS

**TRICHOTROPIS SHUMARDI** Cragin

Pl. 18, figs. 4-5

1893: Cragin: 4th Ann. Rept. Geol. Surv. Texas, p. 229, pl. 42, fig. 13.

This rare gastropod is found at the upper *Salenia* level of the Goodland. It seems too exceptional to serve as a horizon marker but is inserted here as it may prove of importance on further examination of these beds.

**PLEUROTOMARIA AUSTINENSIS** Shumard

Pl. 18, figs. 2-3

BRIEF DIAGNOSIS: In the upper Duck Creek marl and the basal Fort Worth limestone there is a restricted horizon of this species, which is usually seen as fragmentary smooth individuals lacking ornamentation and having only three or four volutions (plate 18, fig. 3). Better preserved individuals have fine spiral striae, and a distinct angulation and shelf along the upper edge of the volution.

HORIZON: Upper Duck Creek marl and basal strata of the Fort Worth limestone.

## PROTOZOA

**NODOSARIA TEXANA** Conrad

Pl. 19, figs. 1-2; Pl. 21

1857: Nodosaria texana Conrad: Mex. Bdry. Surv., p. 159, pl. 14, figs. 4a-c.
1910: Nodosaria texana Boese: Inst. Geol. Mex., Bol. 25, p. 177, pl. 35, figs. 4, 6, 9.
1918: Nodosaria texana Christner and Wheeler: Univ. of Texas Bull. 1819, pl. 8.

BRIEF DIAGNOSIS: This foraminiferan shell is small, thick walled and consists of a linear series of collar-like chambers with perforated constricted junctions, the chambers increasing slightly in size toward the mouth apertures which are prominent and terminal. These protozoan shells average about 1 mm. thick and 5 mm. long. Number of chambers: average 9; maximum seen, 15.

DESCRIPTION: Test elongated, linear or slightly curved, slender, tapering. Chambers smooth, slightly inflated, externally conical-cylindrical with a nearly uniform diameter from end to end, numerous, sutures depressed, apical chamber largest and longest.

Material collected by Dr. Udden in Brewster County and by Dr. Beede in Val Verde County, and kindly put at our disposal, shows the following characters:[1]

In most individuals the terminal chamber has about twice the length of the subterminal one. About one-third the height of each chamber, except the terminal one is enclosed in the succeeding chamber, hence the prominence of the terminal chamber. Its apical end is evenly rounded, having an almost spherical surface, and bears a group of conspicuous centrally placed apertures or perforations separated from each other by narrow partitions. The number of perforations varies; the greatest number seen was eight. The shape of the group is subcircular; the shape of the separate perforations is variable, usually triangular or square, with rounded angles, but the smaller perforations are nearly circular.

The earlier chambers differ in shape from the later ones: they are successively narrower and shorter and have at their terminal ends elongated pyriform necks perforated by apertures to the following chamber. The cavities have roughly the shape of an arrowhead, which in the earlier chambers is more elongated and more acutely pointed.

The subterminal chamber in length exposed externally averages .54 the terminal one, with considerable variation. In occasional individuals the subterminal and all older chambers are noticeably short. Each older chamber is slightly smaller and shorter than its successor.

The number of perforations, although variable, increases towards the apical end. In general the larger individuals have the greater number of perforations. The appearance of the group is irregularly reticular and a central perforation is almost never present. The following are the observed numbers of perforations in chambers numbered as indicated:

[1]A convenient method of preparing calcareous sandstone slabs containing Nodosaria is to leave them in dilute hydrochloric acid for several hours.

*Number of Perforations:*

| Chamber Number | Mode | Range |
|---|---|---|
| 15 | 4 | --- |
| 14 | 4 | --- |
| 13 | 5 | --- |
| 12 | 6 | 4–8 |
| 11 | 4 | --- |
| 10 | 6 | 5–8 |
| 9 | 4 | 3–4 |
| 8 | 4 | 3–7 |
| 7 | 5 | 4–7 |
| 6 | 5 | 4–7 |
| 5 | 5 | 3–7 |
| 4 | 3 | --- |

There is no evidence of bilateral symmetry. Meandering perforations and minute perforations observed in the sides of certain chambers were considered accidental.

In various slabs containing Nodosaria 66 to 92 per cent of the shells lie parallel mainly with the apical ends pointed in one general direction due possibly to current action, as suggested by Dr. Udden.

HORIZON: This species is generally distributed and occurs in a horizon of considerable vertical thickness, beginning in the upper third of the Weno marl where it is abundant, and continuing into the Pawpaw clay, where it is rare. It is widely distributed in South Texas in the Del Rio formation in association with *Exogyra arietina* Roemer. At Cerro de Muleros, near El Paso, it occurs in subdivision 6 (equivalent of Weno and Pawpaw). It is abundant at Del Rio, in southern Brewster County, in the lower Pecos Valley, and elsewhere.

## BRACHIOPODS

### KINGENA spp.

Pl. 19, figs. 3-12

1852: *Terebratula wacoensis* Roemer: Kr. Tex., p. 81, pl. 6, figs. 2a-c.
1857: *Terebratula wacoensis* Conrad: Mex. Bdry. Surv., p. 147, pl. 3, figs. 1a-d.
1853: *Terebratula choctawensis* Shumard: Expl. Red River, La., pp. 207-8, pl. 2, figs. a-b.
1902: *Kingena wacoensis* Hill: 21st Ann. Rept., U. S. G. S., pt. 7, p. 281, pl. 37, fig. 5.

BRIEF DIAGNOSIS: These brachiopods are the only ones likely to be found in the course of ordinary field work in this region. They are rather thick, and of various outlines, some nearly circular, some truncated,

some elongated. The surface is smooth or punctate, the punctations occurring in a layer of the shell and indicating a stage of weathering, not specific differences as Shumard imagined. There is a recurved rounded beak with a circular pedicel opening. The group is in need of careful study.

HORIZON: These species have been found in limited zones considerably separated from each other. The main horizons of stratigraphic importance are: Mainstreet limestone, near base—large and small individuals of various outlines; Duck Creek marl, near top—two zones of small individuals of various outlines, of which the Lower (Main) zone is more conspicuous and important; Duck Creek limestone, base, at the Red River, where these brachiopods are associated with *Hamites, Exogyra plexa* and *Schloenbachia belknapi.*

## CORALS

### PARASMILIA AUSTINENSIS Roemer

Pl. 19, figs. 27-30

Roemer, Pal. Abh., Vol. 4, No. 4. 1888.

BRIEF DIAGNOSIS: This coral is small, simple, almost straight and approximately conical in form. It has a thin attachment stalk which is almost never preserved. Near the inflated end are often two or three circular constrictions. The septae are on the plan of six, with a regular series of secondaries and tertiaries.

HORIZON: It is the commonest species in the Coral Horizon, 20 to 28 feet below the top of the Goodland limestone. It is not known to occur elsewhere in the Comanchean. A closely related species P. texana Vaughan, is from the Buda limestone. Scattered corals, possibly *Parasmilia* have been found in the Duck Creek formation, the Fort Worth formation and higher.

### TROCHOSMILIA TEXANA Conrad

1858: *Turbinolia texana* Conrad: Mex. Bdry. Surv., Vol. 2, pt. 2, p. 144, pl. 2, figs. 3a-b.
1910: *Trochosmilia texana* Boese: Inst. Geol. Mex., Bcl. 25, pp. 51, 53, pl. 45, figs. 9, 14, 15, 18, 20, 22.

BRIEF DIAGNOSIS: This small curved simple coral, incorrectly referred to the genus Turbinolia by Conrad is abundant in the coral horizon of the Goodland limestone, 20-28 feet below the top of the formation at Fort Worth. Its horn shape, attenuated base and its equal and incon-

spicuous costae serve to distinguish it from the other corals in the horizon. Near El Paso it occurs in subdivision 2 (Fredericksburg). The associated species, *Parasmilia austinensis* and others in this horizon are less curved or very nearly straight, or else are very short and greatly inflated with an elliptical cross-section. The section of this species at all levels is circular.

HORIZON: Below Upper *Salenia* zone of the Goodland limestone.

**PLACOSMILIA (?)** sp.

Pl. 19, figs. 24-26

In the basal Pawpaw clay, locally at least, there are several species of small corals of indistinct structure, some of which may be assigned to this genus. The three individuals figured illustrate the tapered form, the circular or square cross-section, six primary septae, and the feeble development of secondary and tertiary septae, that characterize these corals. *Placosmilia mexicana* Aguilera and *P. bravoensis* Aguilera are reported from the Weno-Pawpaw (subdivision 6) near El Paso (Boese). In addition, minute very flared cup corals are found in the basal Pawpaw clay at Fort Worth.

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# PLATES 1-21

PLATE 1.

Figures 1-3. **Schloenbachia acutocarinata** (Shumard)

Occasional in Kiamitia marl; abundant in Fredericksburg (especially upper part of Goodland limestone) .....pages 15, 32

Fig. 1. Locality 122, 4 miles south of Benbrook, Texas. x 0.6

Fig. 2. Same locality. x 0.8

Fig. 3. Same locality. x 0.5

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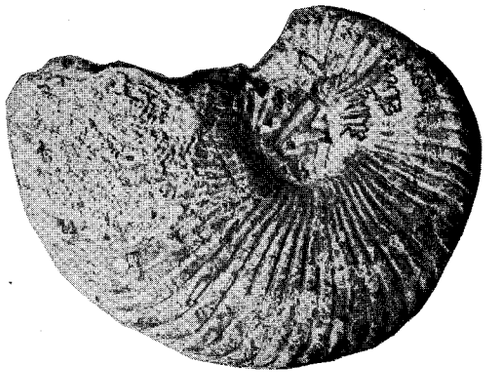

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John Davis, photo.

PLATE 2.

Figure 1. **Desmoceras brazoense** (Shumard) .....pages 18, 35
Abundant, Duck Creek limestone (top).
x 0.3. Locality: Forest Park, Fort Worth, Texas. Texas Christian University Museum.

Figure 2. **Desmoceras brazoense** (Shumard)
Duck Creek limestone, Flowing Well, 4 miles north of Gainesville, Texas.

Figure 3. **Desmoceras sp. A.**

Sparse, Duck Creek limestone.....page 35
x 0.8. Locality: Azle road, 8 miles northwest of Fort Worth, Texas.

Figure 4. **Schloenbachia belknapi** (Marcou)

Occasional, Kiamitia clay .....pages 17, 32
Locality: Stove foundry road, 4 miles west of Fort Worth, Texas. x 0.45.

Figure 5. **Schloenbachia belknapi** (Marcou)

Kiamitia clay, Stove foundry road, Fort Worth, Texas. x 0.5.

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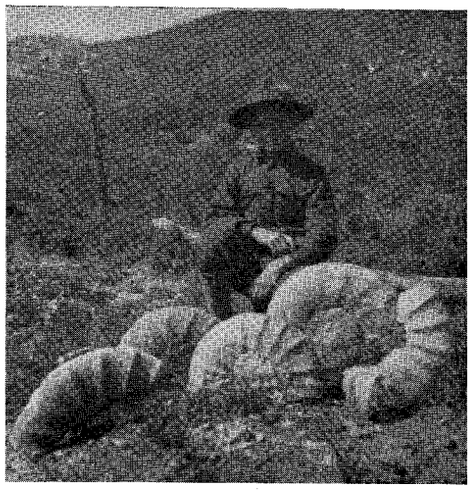

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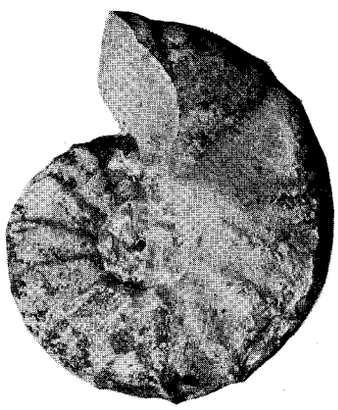

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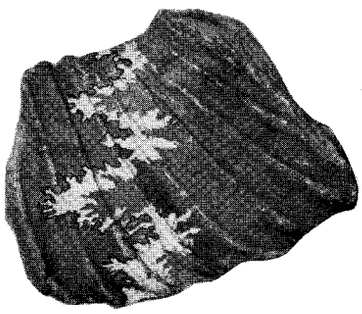

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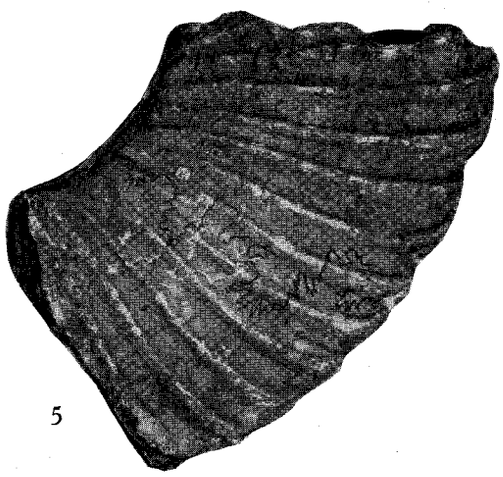

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PLATE 3.

Figures 1-3. **Schloenbachia trinodosa** Boese

Occasional, Duck Creek limestone.....pages 19, 33
Fig. 1. Azle road, 9 miles northwest of Fort Worth, Texas. x 0.7.
Fig. 2. Same individual, x 0.7.
Fig .3. Same individual, x 0.7.

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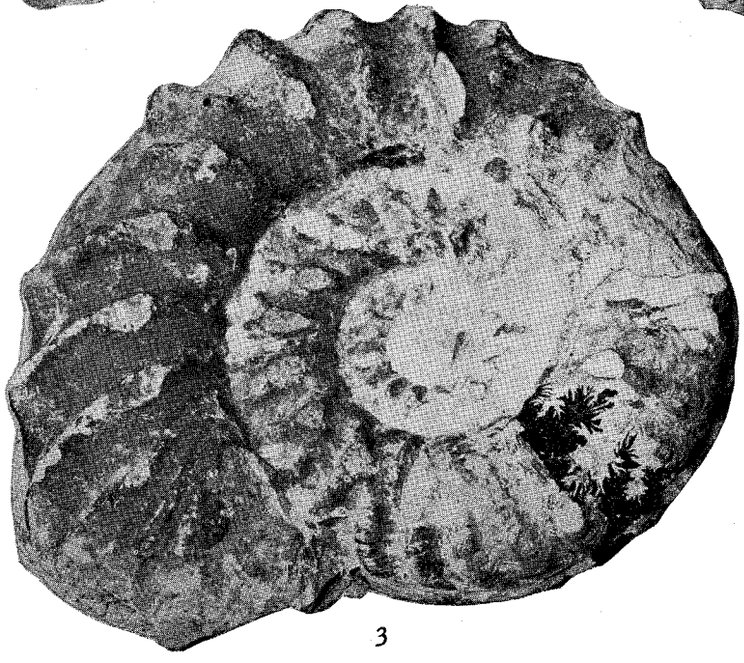

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John Davis, photo.

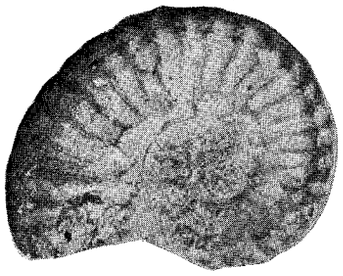
PLATE 4.

Figures 1-3. **Schloenbachia sp. I.**

Occasional, Duck Creek marl and Fort Worth limestone.....page 33
Locality: Top of Duck Creek marl, one-half mile east of Texas Christian University, Fort Worth, Texas. Fig. 1, x 0.8; fig. 2, x 0.7; fig. 3, x 0.8.

Figures 4-5. **Schloenbachia leonensis** ? Conrad

Occasional, Fort Worth limestone.....pages 22, 34
Locality: 409 one-half mile southeast of Texas Christian University, in uper half of Fort Worth limestone. Fig. 4, x 0.33; fig. 5, same individual, x 0.17. Texas Christian University Museum.



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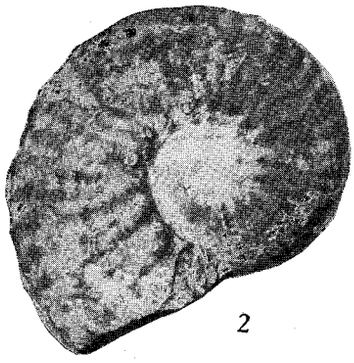

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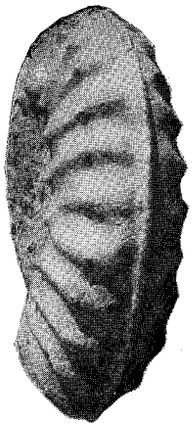

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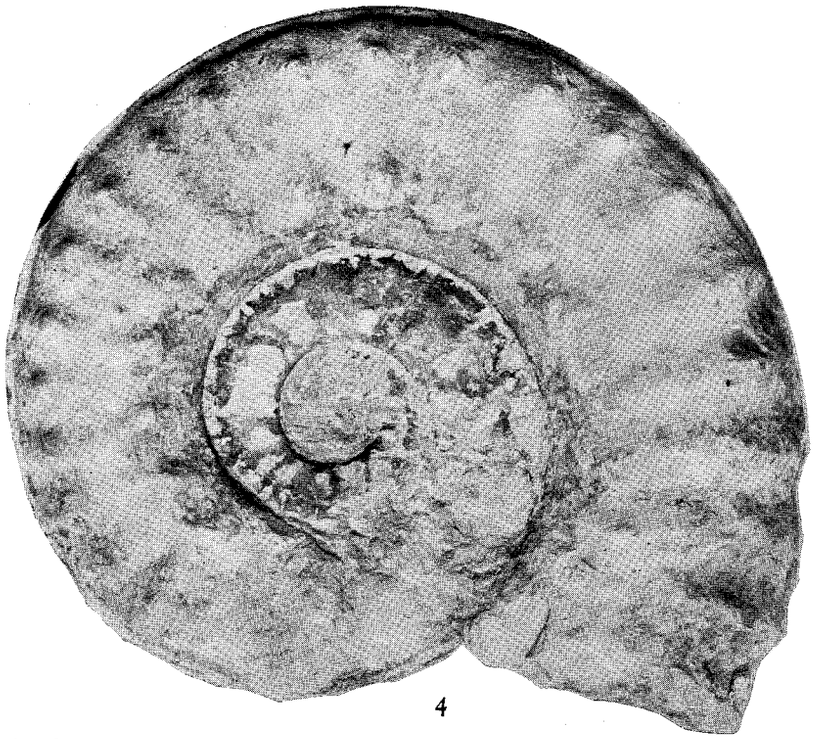

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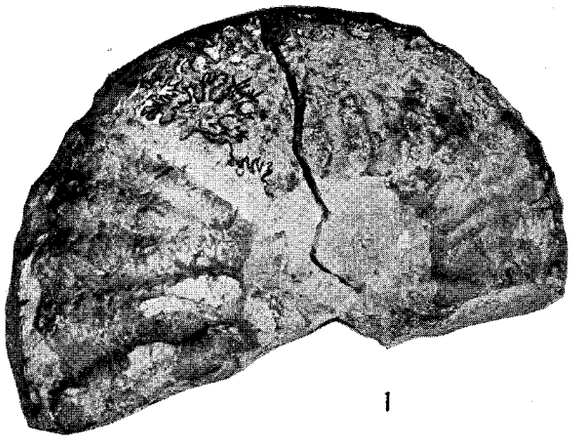
John Davis, photo.

PLATE 5.

Figures 1-4. **Schloenbachia sp. M.**

Ocasional, Weno formation .....page 34
Fig. 1. x 0.7.
Fig. 2. x 0.8.
Fig. 3. Cross section of outer volution of individual figured in Fig. 2, at same enlargement.
Fig. 4. x 0.7.



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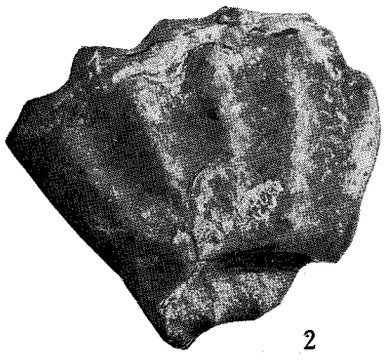

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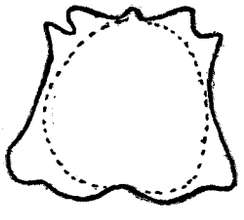

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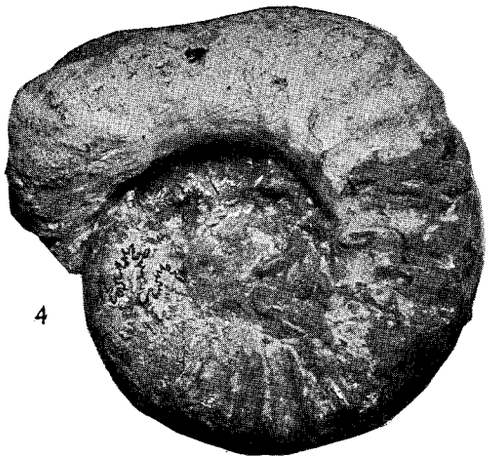

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John Davis, photo.

PLATE 6.

Figures 1-2. **Hamites tanima n. sp.**

Rare, Duck Creek marl .....page 41
Fig. 1, type, x 0.8; fig. 2, type, x 1.6.
Locality: Cut of military road, one-half mile north of Texas Christian University, Fort Worth, Texas.

Figure 3. **Hamites sp.** (fremonti Marcou?)

Occasional, base of Duck Creek limestone.....page 40
x 0.8. Locality: South side of Clear Fork, two miles southeast of Benbrook, Texas.

Figure 4. **Hamites tenawa n. sp.**

Occasional, base of Pawpaw clay.....page 43
x 1.6. Locality: Keller road, 9 miles northeast of Fort Worth, Texas. Type individual.

Figures 5-6. **Hamites nokonis n. sp.**

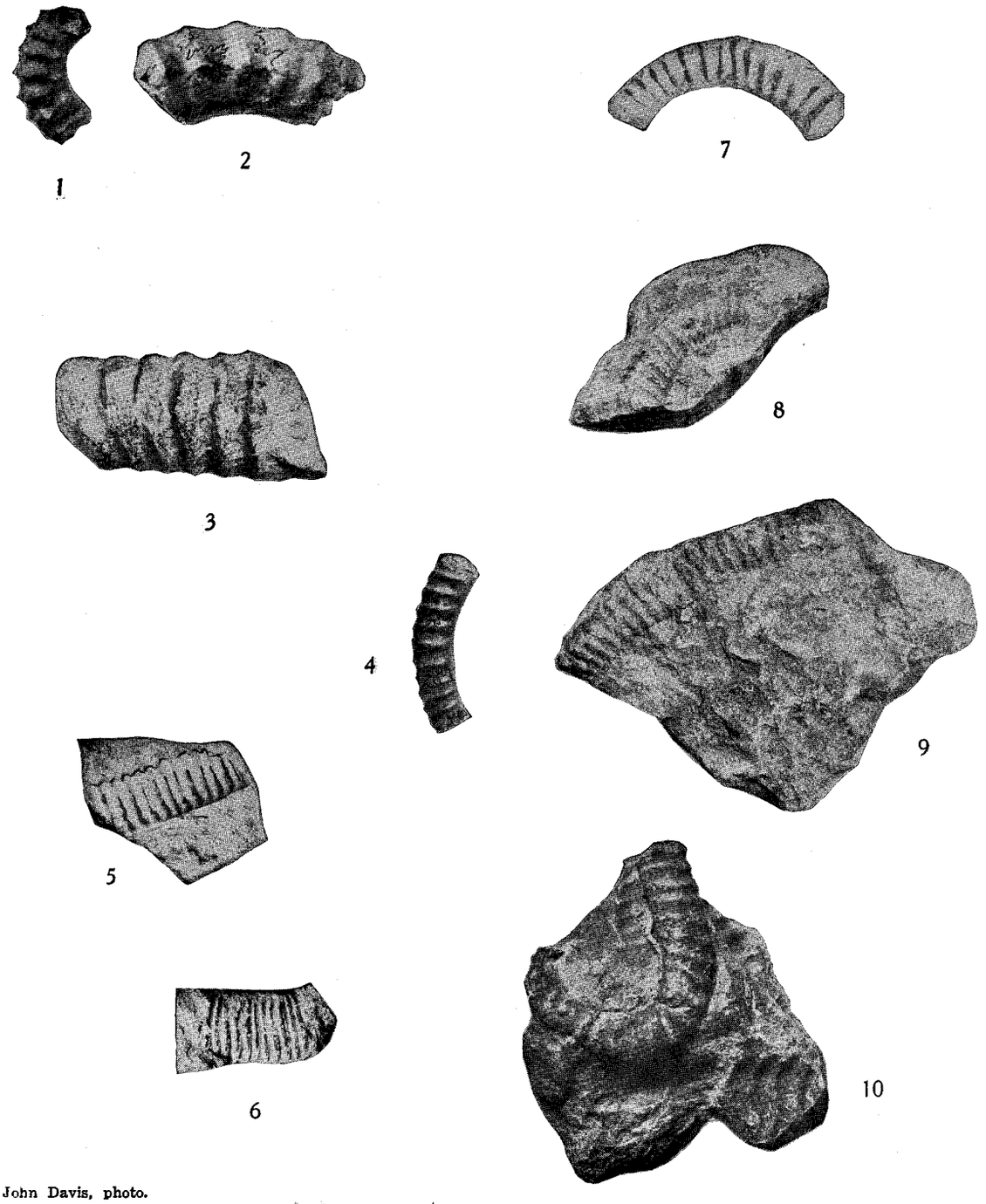
Occasional, base of Duck Creek limestone.....page 39
Fig. 5, x 0.8, eroded individual; fig. 6, x 0.6, type individual. Locality: Cut of military road one-half mile north of Texas Christian University, Fort Worth, Texas, in Hamites zone at base of Duck Creek limestone.

Figures 7-9. **Hamites sp. near comanchensis n. sp.**

Occasional, Duck Creek limestone, Hamites zone at base. Locality: 4 miles southwest of Fort Worth, Texas. x 0.8.

Figure 10. **Hamites comanchensis n. sp.**

Abundant, Hamites zone at base of Duck Creek limestone, widespread..pages 18, 38
x 0.8. Type individual. Locality of Type: North side of Lake Worth, hillside above excavation at north end of dam.




John Davis, photo.

PLATE 7.

Figures 1-2. **Scaphites worthensis n. sp.**

Occasional, Duck Creek limy marl.....pages 20, 36
Fig. 1, type individual, x 1.4; fig. 2, x 0.9. Locality: Frisco Creek, southeast corner of Forest Park, Fort Worth, Texas.

Figures 3-6. **Scaphites hilli n. sp.**

Occasional, Pawpaw clay .....pages 28, 37
Fig. 3, type individual, x 1.4; fig. 4, x 1.4; fig. 5, x 1.8; fig. 6. x 1.4. Locality: 714, on Sycamore Creek, Fort Worth, a half mile south of the International and Great Northern Railway bridge.

Figures 7-8. **Turrilites sp. B.**

Pawpaw clay, Fort Worth, Texas, x 0.9.

Figures 10, 11, 13. **Turrilites worthensis n. sp.**

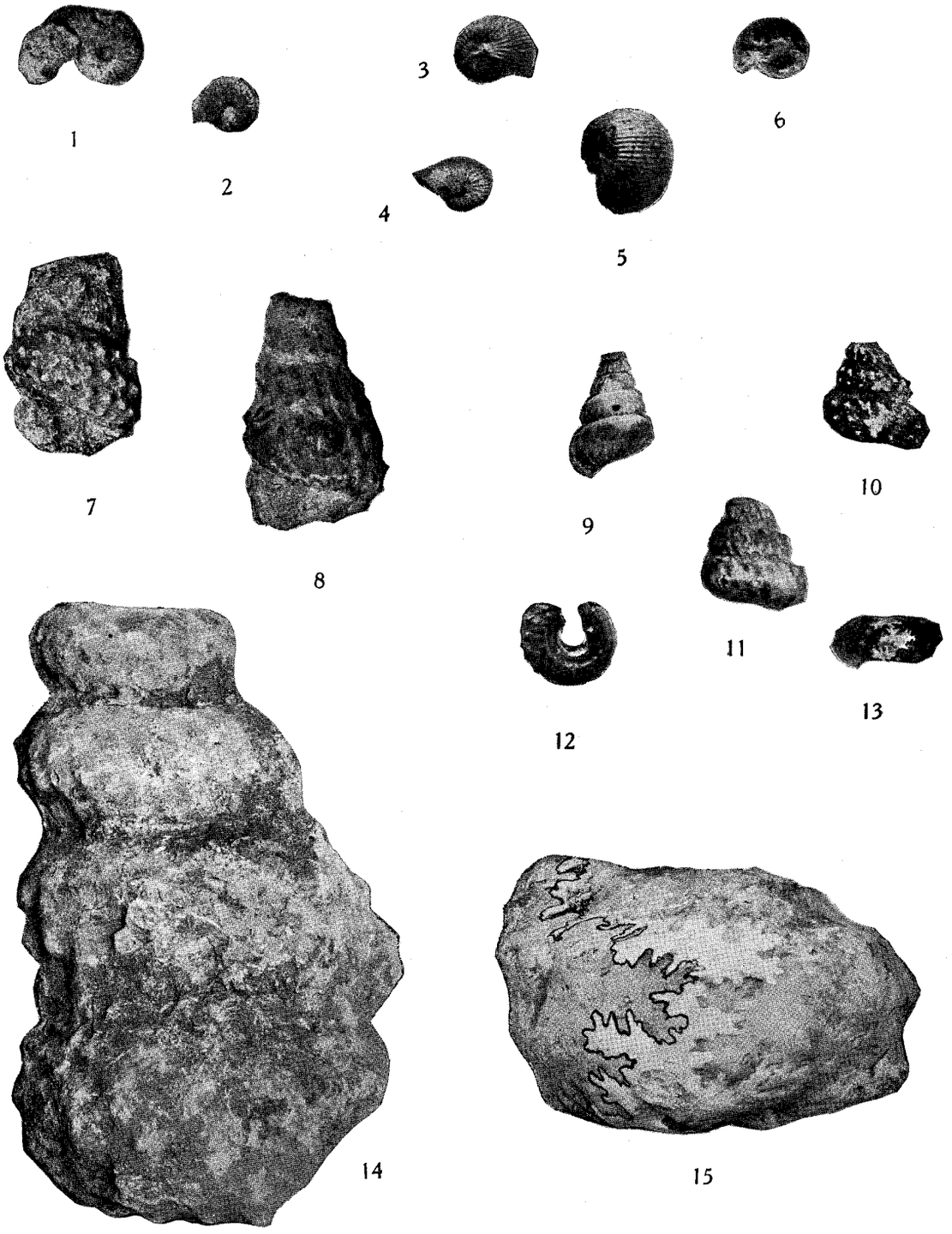
Occasional, Pawpaw clay .....pages 28, 44
x 1.5. Fig. 11, type individual, fig. 10, showing tubercles; fig. 13, showing suture. Locality: 714, Sycamore Creek, Fort Worth, Texas, one-half mile south of the International and Great Northern Railway bridge.

Figures 9, 12. **Turrilites sp.**

Pawpaw clay, Fort Worth, Texas, x 1.4.

Figures 14-15. **Turrilites brazoensis** Roemer.....pages 30, 45

Abundant, middle Mainstreet limestone, widespread. x 0.8. Locality: Water Tower Hill, about a mile southeast of Texas Christian University, Fort Worth, Texas.




John Davis, photo.

PLATE 8.

Figure 1. **Hemiaster calvini** Clark

Occasional, Weno to Buda formations.....page 54
Locality: Weno marl, branch of Little Mineral Creek, two miles north of Pottsboro, Texas. x 0.8.

Figure 2. **Hemiaster calvini** Clark

Locality unknown; Cummins collection. x 0.8.

Figures 3-4. **Hemiaster elegans** Shumard

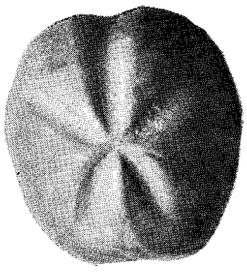
Occasional, Fort Worth limestone.....pages 22, 53
Locality: Caney Creek, about 4½ miles west of Woodville, Oklahoma. x 1.0.

Figures 5-6. **Holaster simplex** Shumard

Abundant, upper part of Duck Creek marl and in Fort Worth limestone. x 0.8. .....pages 20, 51
Locality: South end of Forest Park, Fort Worth, Texas. Texas Christian University Museum.

Figures 7-9. **Hemiaster sp. B.**

Abundant, Fredericksburg limestone.
Locality: Stove foundry road, 4 miles west of Fort Worth, Texas. x 0.7, pages 16, 53



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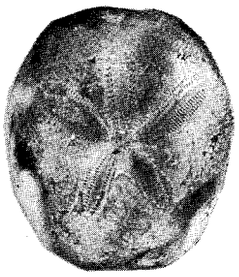

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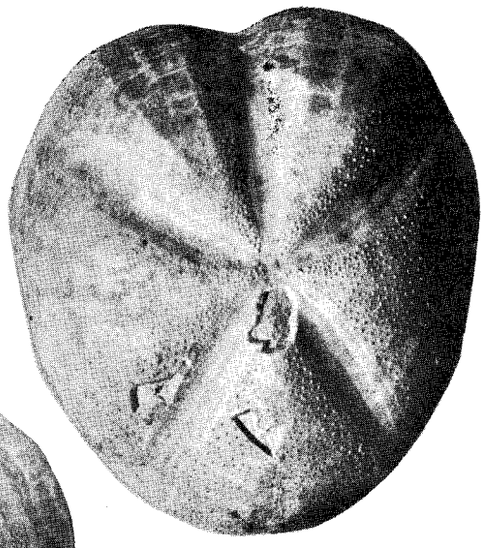

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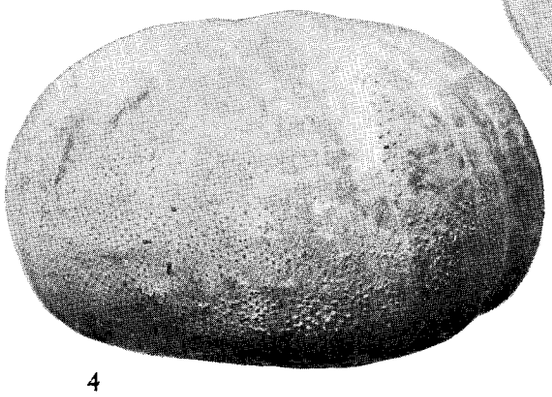

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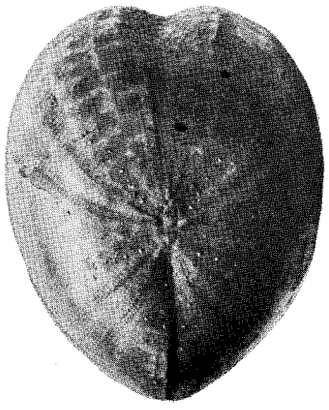

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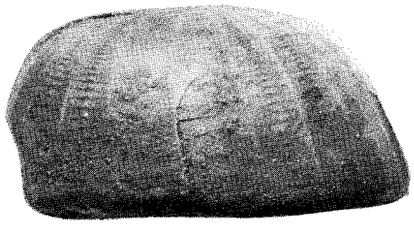

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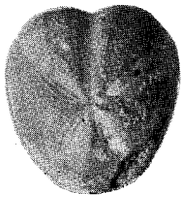

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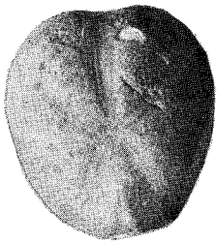

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John Davis, *photo.*

PLATE 9.

Figures 1, 3. **Holectypus limitis** Boese

Occasional, Weno, Pawpaw and Mainstreet.....pages 30, 51
x 0.7. Locality: Sycamore Creek, Fort Worth, Texas.

Figure 2. **Holectypus planatus** Roemer

Occasional, Goodland formation .....page 50
x 0.8. Locality: Stove foundry road, Fort Worth, Texas.

Figures 4, 8-10. **Enallaster longisulcus** n. sp.

Rare, top of Fort Worth limestone.....pages 23, 55
Fig. 4. Aboral side, type individual, x 0.8.
Fig. 8. Aboral side, type individual, x 1.6.
Fig. 9. Oral side, type individual, x 1.6. Locality: Blum, Teras.
Fig. 10. Aboral side, x 1.2. Locality: Fort Worth, Texas.

Figures 5, 7. **Cidarid spines.** Abundant, Quarry limestone group.....page 50

5, 7. x 1.2. Locality: Brickyards, Gainesville, Texas.

Figure 6. **Leiocidaris hemigranosus** (Shumard)

Rare, Denton marl .....pages 24, 49
x 0.8. Locality: Two and a half miles east and south of Kingston, Oklahoma. (See Pl. 20, fig. 3.)

Figure 11. **Enallaster bravoensis** Boese.

Occasional, Weno and Pawpaw; rare, Mainstreet and Grayson; Buda limestone .....page 58
x 0.8. Locality: Sycamore Creek, Fort Worth, Texas.

Figures 12-13. **Enallaster texanus** Roemer.

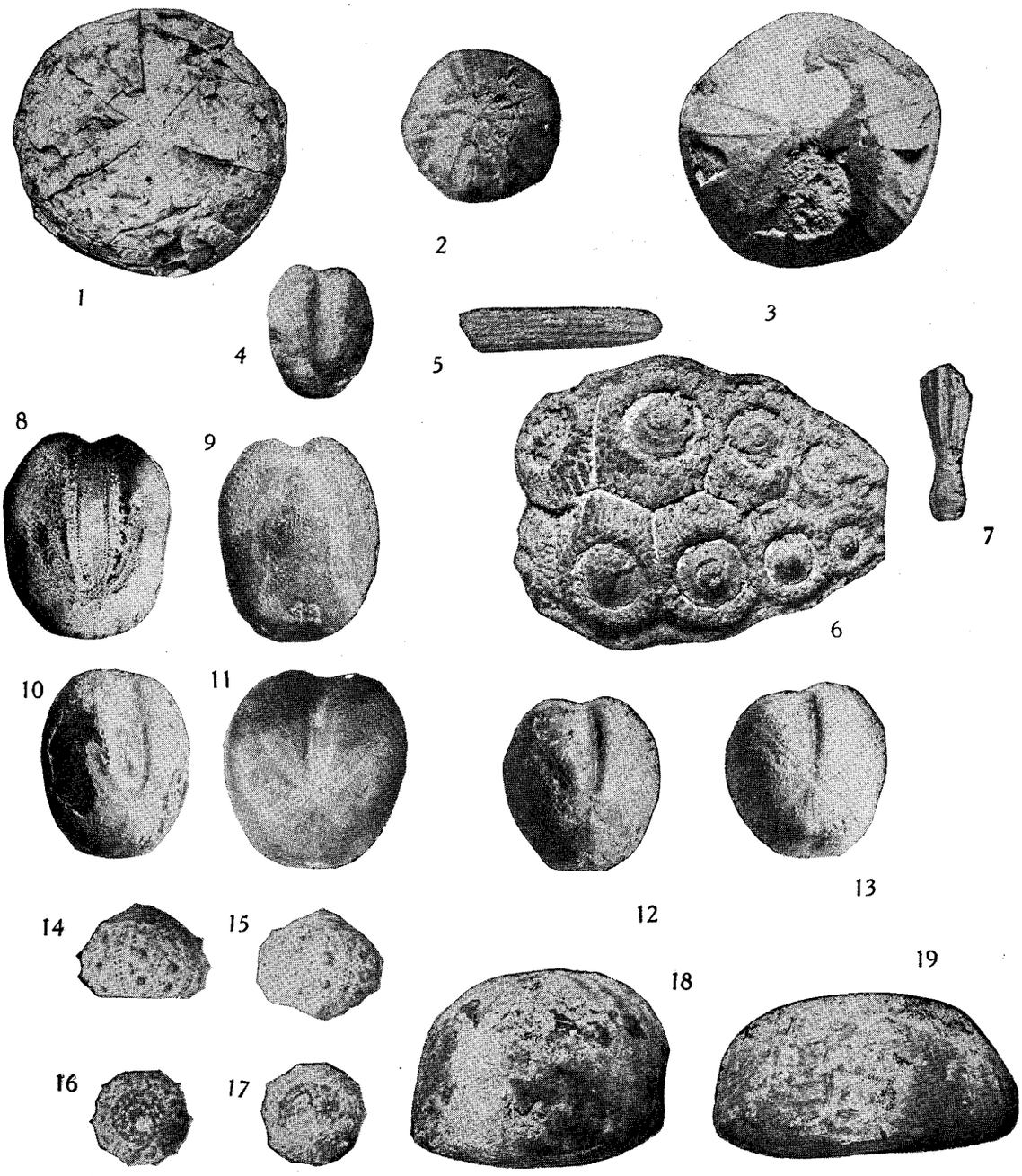
Abundant, Goodland limestone; occasional, lower Washita.....pages 16, 55
x 0.8. Locality: Stove foundry road, Fort Worth, Texas.

Figures 14-17. **Salenia mexicana** Schlueter

Occasional, Goodland limestone, Upper and Lower Salenia zones.....pages 16, 49
x 1.3. Locality: Upper zone, stove foundry road, Fort Worth, Texas.

Figures 18-19. **Holaster simplex** Shumard

Abundant, upper Duck Creek marl and Fort Worth limestone....pages 20, 23, 51-2
x 0.8. Fig. 18, tall individual; fig. 19, low individual, Duck Creek marl, 4 miles southeast of Fort Worth, Texas.




John Davis, photo.

PLATE 10.

Figure 1. **Comptonia** (?) sp.

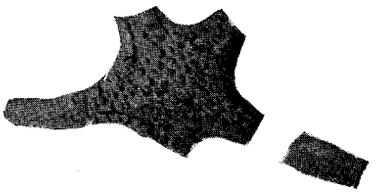
Rare, Pawpaw c'ays (base) ..... page 49
Locality: 714, Sycamore Creek, 4 miles southeast of Fort Worth, Texas. x 1.0.

Figures 2-4. **Metopaster hortensae** n. sp.

Rare, Pawpaw clays (base) ..... page 46
Fig. 2. Type, aboral side. x 1.3. Locality: 714, Sycamore Creek, Fort Worth, Texas.
Fig. 3. Aboral side. x 1.1. Locality: 715, Sycamore Creek, Fort Worth, Texas.
Fig. 4. Type, aboral side. x 1.8.

Figures 5-6. **Pentagonaster texensis** n. sp.

Rare, Weno limestone (top) ..... page 47
Fig. 5. Type, oral side. x 1.4. Locality: 613, Sycamore Creek, 4 miles southeast of Fort Worth, Texas.
Fig. 6. Aboral side. x 1.3. Same locality.



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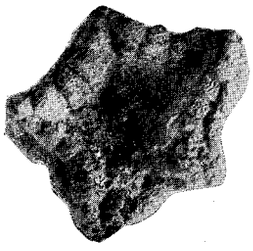

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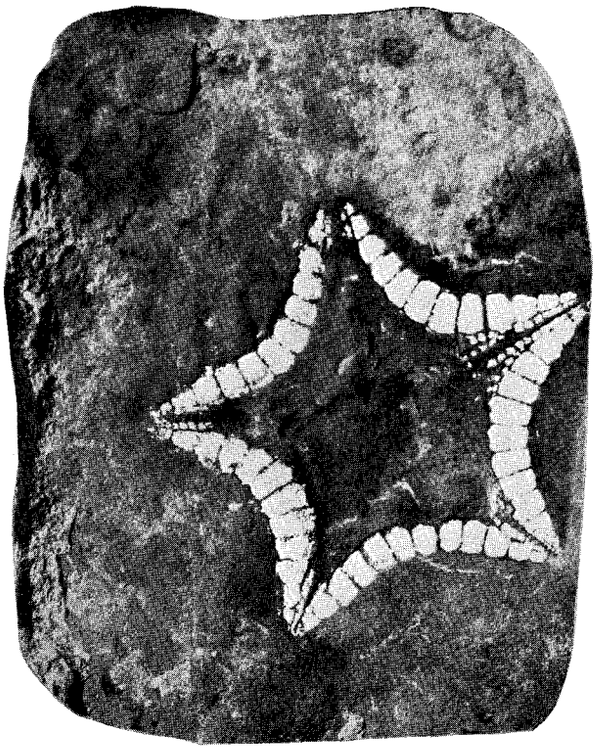

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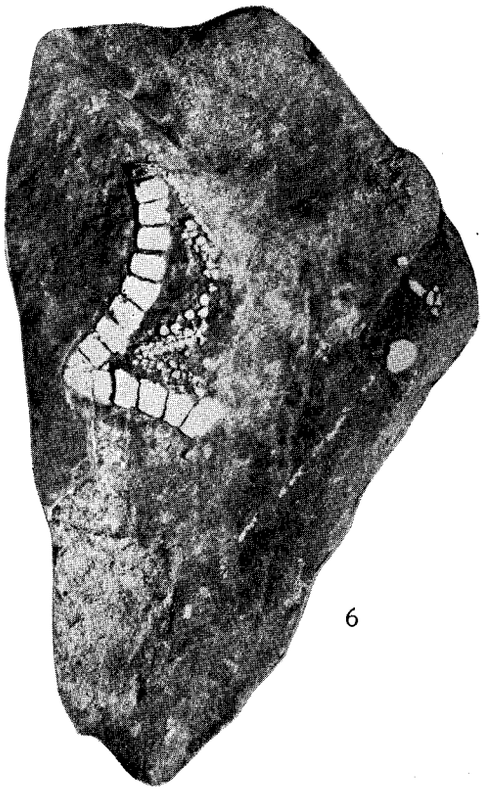

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John Davis, photo.

PLATE 11.

Figures 1-2. **Pecten subalpina** Boese

Occasional or abundant, Goodland to Grayson.....page 68
Fig. 1. Left valve, exterior. x 0.9.
Fig. 2. Left valve, interior. x 0.9.

Figures 3-7. **Pecten bellula** Cragin

Occasional, Duck Creek marl and entire Fort Worth limestone.....pages 21, 69
Figs. 3-5. x 0.9. Locality: Fort Worth limestone, one-half mile east of Texas Christian University.
Figs. 6-7. x 1.8. "Near Fort Worth, Texas." Walker Museum, Chicago.

Figure 8. **Pecten wrightii** Shumard

Rare, Fort Worth limestone and upper part of Duck Creek marl; rare, Main-street limestone .....page 69
Locality: One-half mile east of Texas Christian University, Fort Worth, Texas, top of Duck Creek marl. x 0.9.

Figure 9. **Pecten wrightii** ? Shumard

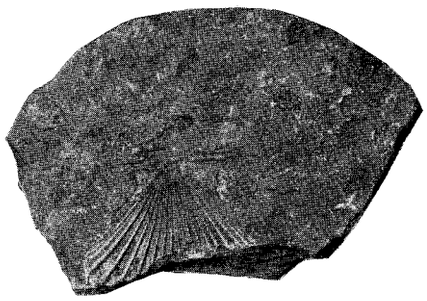
Rare, top of Duck Creek marl and base of Fort Worth limestone.....page 69
Locality: Same as preceding individual. x 0.9.

Figure 10. **Pecten wrightii** Shumard

Locality: Same as preceding. x 0.9.

Figures 11-15. **Pecten irregularis** Boese

Abundant in Fredericksburg limestone; occasional in Kiamitia marl; rare in shell conglomerate at top of Walnut.....page 67
Figs. 11-12. Locality: 122, 4 miles south of Benbrook, Texas. x 0.9.
Fig. 13. Same locality. x 0.9.
Figs. 14-15. Azle road, 9 miles northwest of Fort Worth, Texas. x 0.9.



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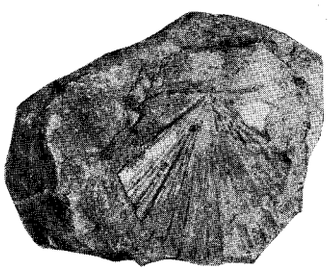

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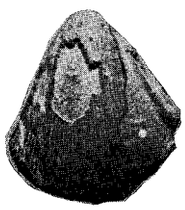

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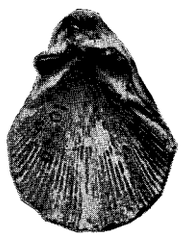

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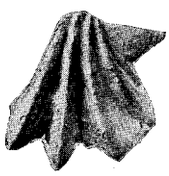

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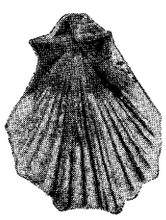

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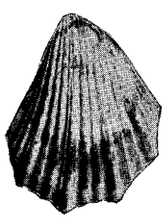

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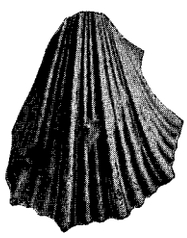

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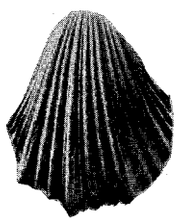

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John Davis, photo.

PLATE 12.

Figure 1. **Pecten cleburnensis** n. sp.

Occasional, basal Mainstreet limestone.....pages 30, 71
Type individual, right valve, x 0.8, Mainstreet limestone, Cleburne, Texas. Sampson collection, Walker Museum.

Figure 2. **Pecten texanus** Roemer

Occasional, Upper Washita .....page 71
x 0.7. Ribs flat, primaries not prominent, form depressed and flared. Locality: Weno marl, Sycamore Creek, Fort Worth, Texas.

Figures 3-15. **Pecten subalpina** Boese and spp.

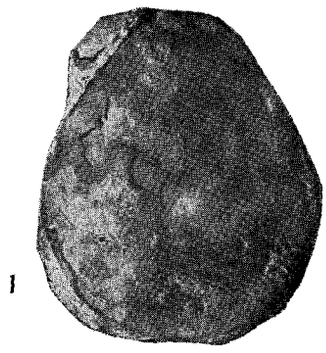
Fig. 3-4. Flat, narrow ribs, lower in 3, taller in 4, x 0.6; fig. 7, 10-14, low individuals, flared ventrally, with depressed rounded ribs and form of P. texanus; x 0.8; figs. 8-9, elevated individuals with narrow elevated ribs, the ribs lower in 8, taller in 9, x 0.7; fig. 15, interior of left valve, x 1.6. Locality: Fort Worth, Texas.

Figures 5-6. **Pecten georgetownensis** Kniker

Abundant, Weno marl .....page 70
x 0.8. Locality: Sycamore Creek, Fort Worth, Texas. Fig. 5, right valve; fig. 6, left valve.

Figure 16. **Pecten theodori** Kniker

Occasional, Weno to Mainstreet formations; rare, lower Washita.....page 69
x 0.7. Ribs elevated, primaries prominent, form elevated and elongate. Locality: Weno marl, Sycamore Creek, Fort Worth, Texas.



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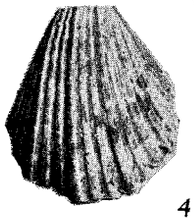

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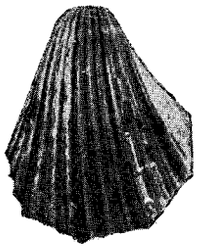

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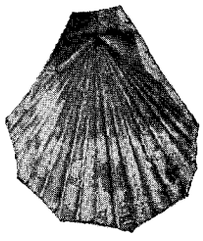

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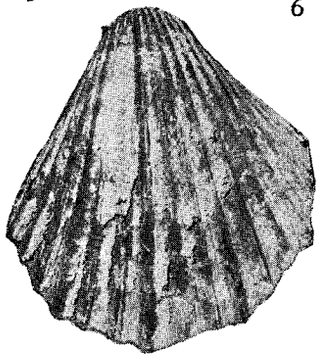

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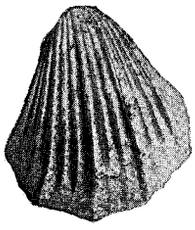

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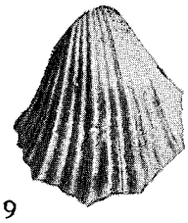

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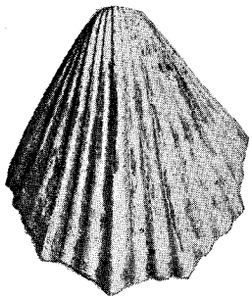

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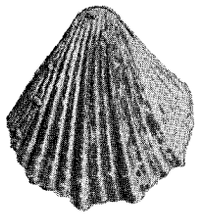

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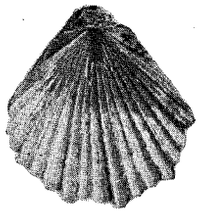

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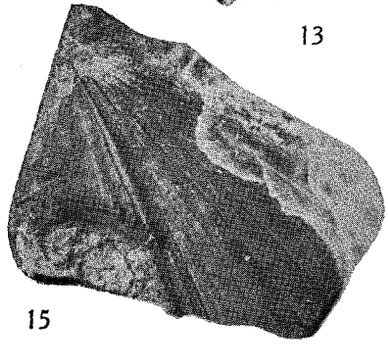

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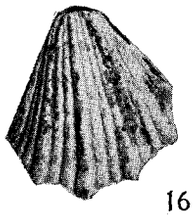

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John Davis, photo.

PLATE 13.

Figures 1-6. **Exogyra arietina** Roemer

Abundant, Mainstreet limestone; occasional, Grayson marl, base.....pages 36, 66
x 0.9. Locality: Keller, Texas and Georgetown, Texas.

Figures 7-10. **Exogyra plexa** Cragin

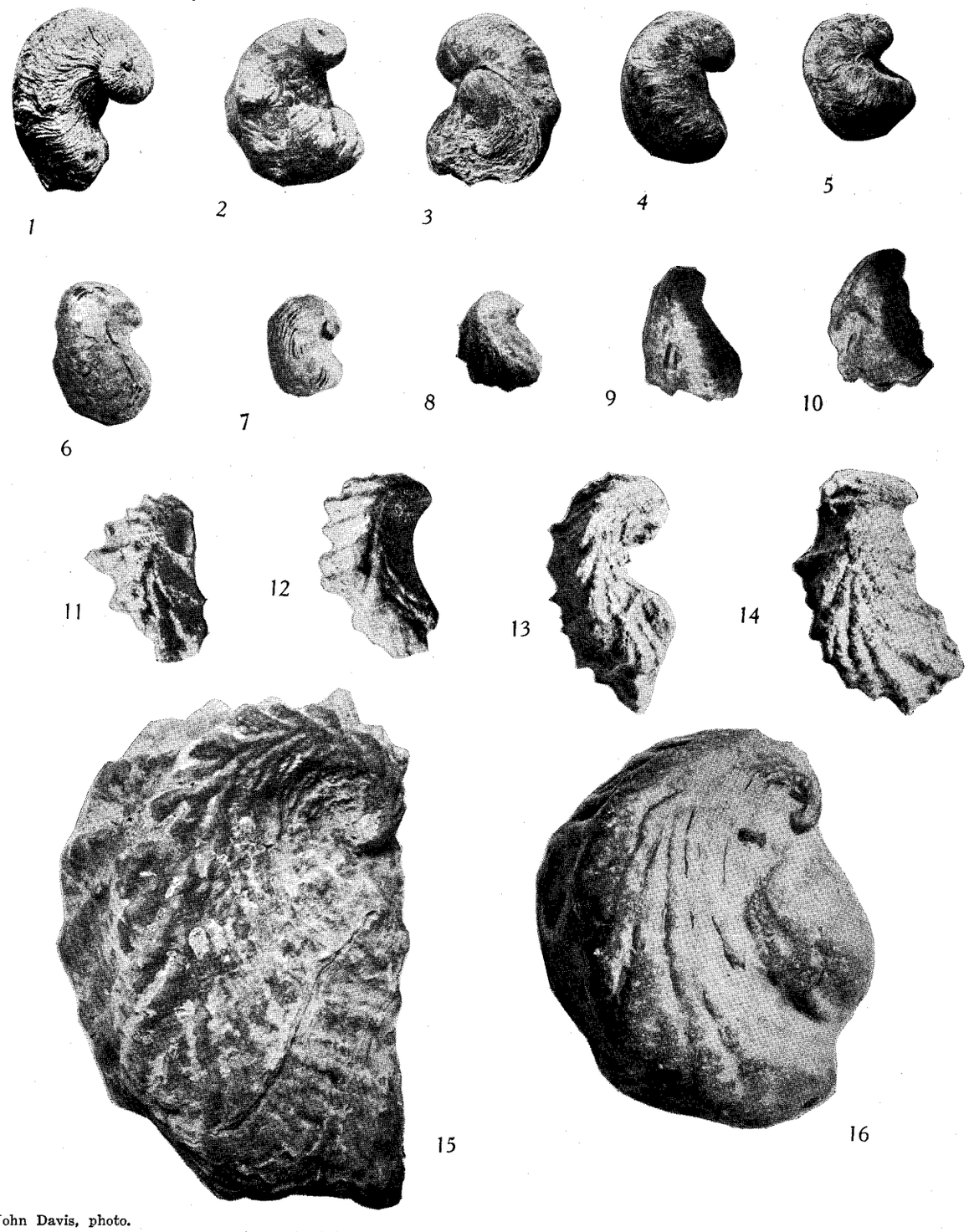
Abundant; Kiamitia clay, stratum 16; occasional in upper Goodland limestone, becoming abundant just below the Upper Salenia zone.....page 65
x 1.2. Fig. 7, smooth species; figs. 8-10, plicate species. Locality: One-half mile west of Texas Christian University, Fort Worth, Texas.

Figures 11-14. **Exogyra weatherfordensis** Cragin

Occasional, Walnut formation .....page 64
x 0.8. Locality: Newark-Azle road, 18 miles northwest of Fort Worth, Texas.

Figures 15-16. **Exogyra texana** Roemer

Abundant, Goodland and Walnut formations.....pages 15, 64
x 0.6. Locality: South side of Lake Worth. Fig. 15, flared individual; fig. 16, much eroded, river gravel.



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John Davis, photo.

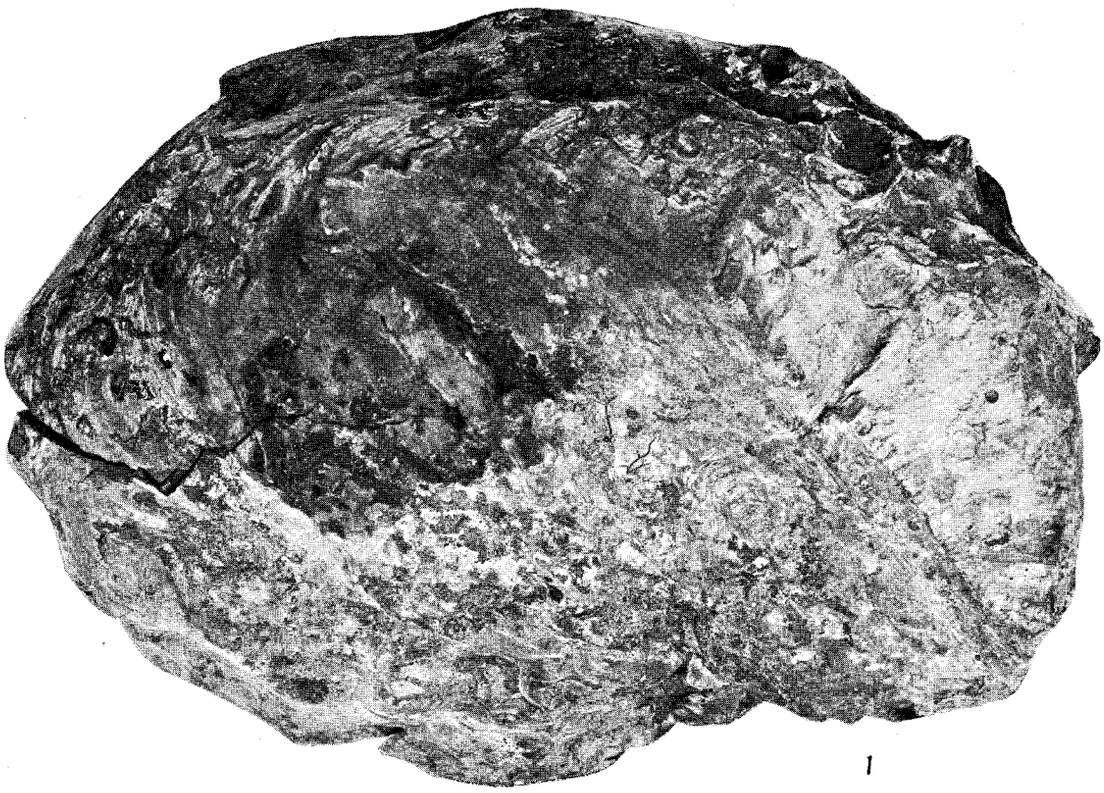
PLATE 14.

Figures 1-2. **Exogyra americana** Marcou

Occasional, Fort Worth limestone; rare, Duck Creek formation (top)..pages 23, 66

Fig. 1. Locality 412, one-half mile southeast of Texas Christian University, Fort Worth, Texas, stratum 22, Fort Worth limestone. Left valve, x 1.2.

Fig. 2. Same individual, right valve, x 2.



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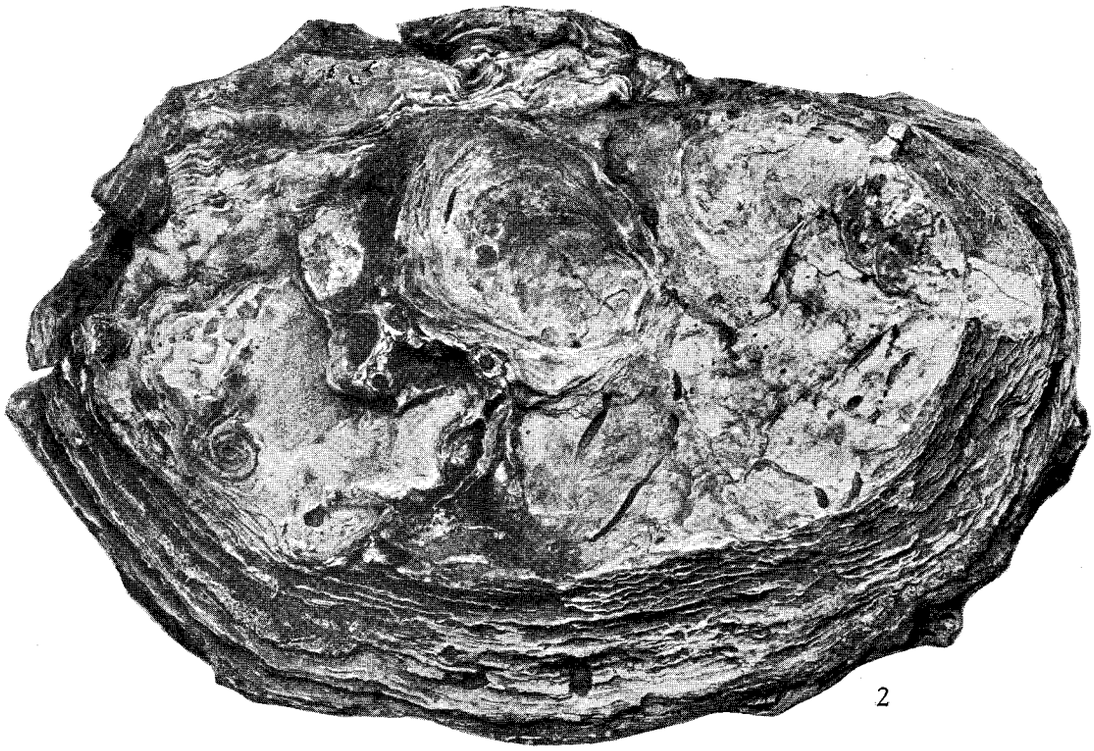

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John Davis, photo.

PLATE 15.

Figures 1-4. **Gryphea mucronata** Gabb

Abundant, Grayson marl.....pages 31, 63
x 0.6. Locality: One mile east of Burleson, Texas.

Figures 5-12. **Gryphea washitaensis** Hill

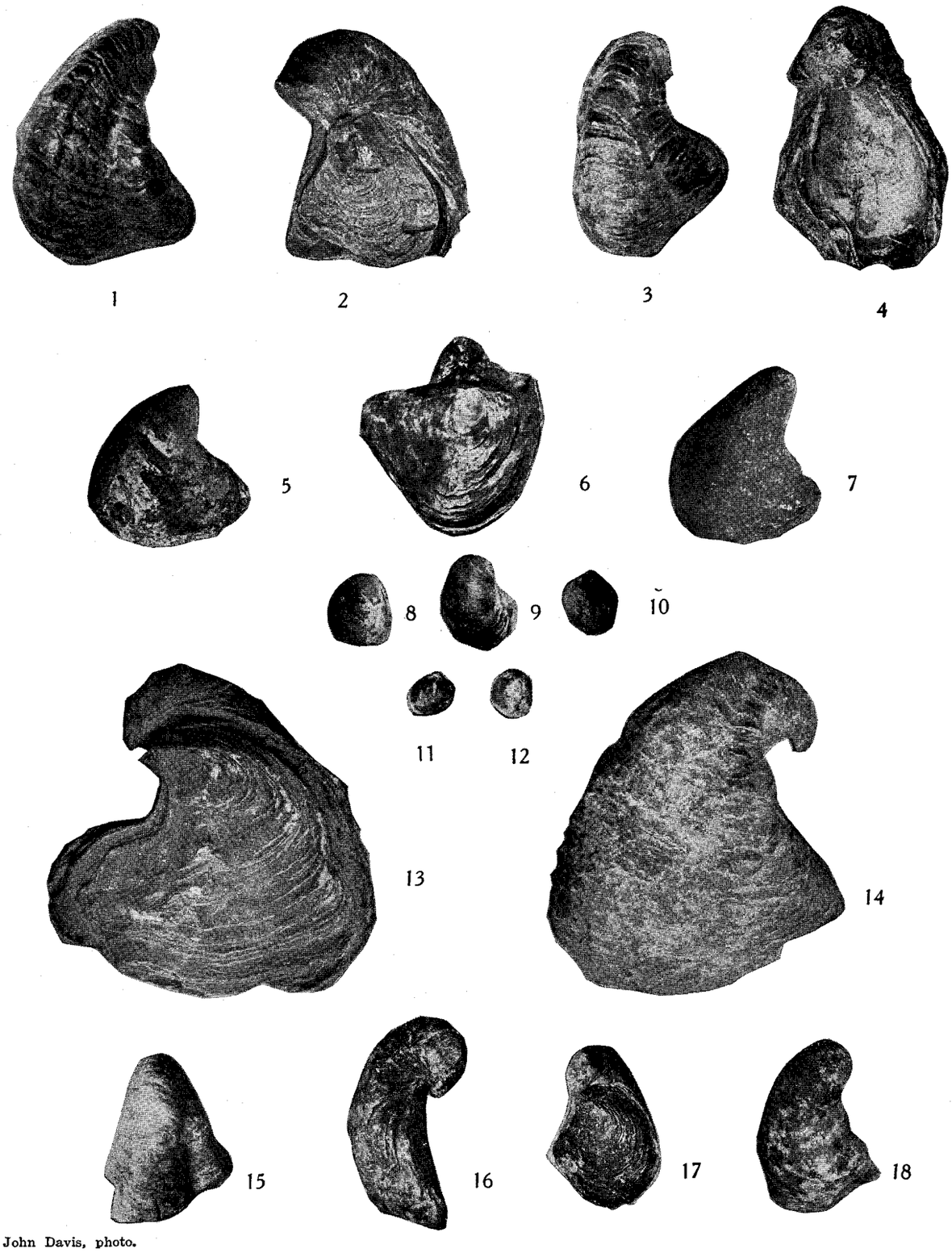
Occasional, Kiamitia, Duck Creek and Fort Worth formations; abundant in upper Denton marl, locally a conglomerate; rare, Weno and Pawpaw, except for Quarry limestone conglomerate; rare, Mainstreet.....pages 23, 62
Figs. 5-7, x 0.77; figs. 8-12, juvenile individuals, x 1.4. Locality: Noland's River, west of Cleburne, Texas, Denton marl.

Figures 1-14. **Gryphea navia** Hall

Kiamitia clay, abundant.....pages 17, 62
x 0.8. Locality: One-half mile west of Texas Christian University, Fort Worth, Texas.

Figures 15-18. **Gryphea marcoui** Hill and Vaughan

Goodland and Walnut formations, abundant.....pages 15, 61
x 0.9. Locality: Newark-Azle road, 18 miles northwest of Fort Worth, Texas.




John Davis, photo.

PLATE 16.

Figure 1. **Ostrea** sp.

Rare, Mainstreet limestone.....pages 30, 58
x 0.8. Locality: Cleburne, Texas.

Figures 2-5. **Ostrea (Alectryonia) carinata** ? Lamarck

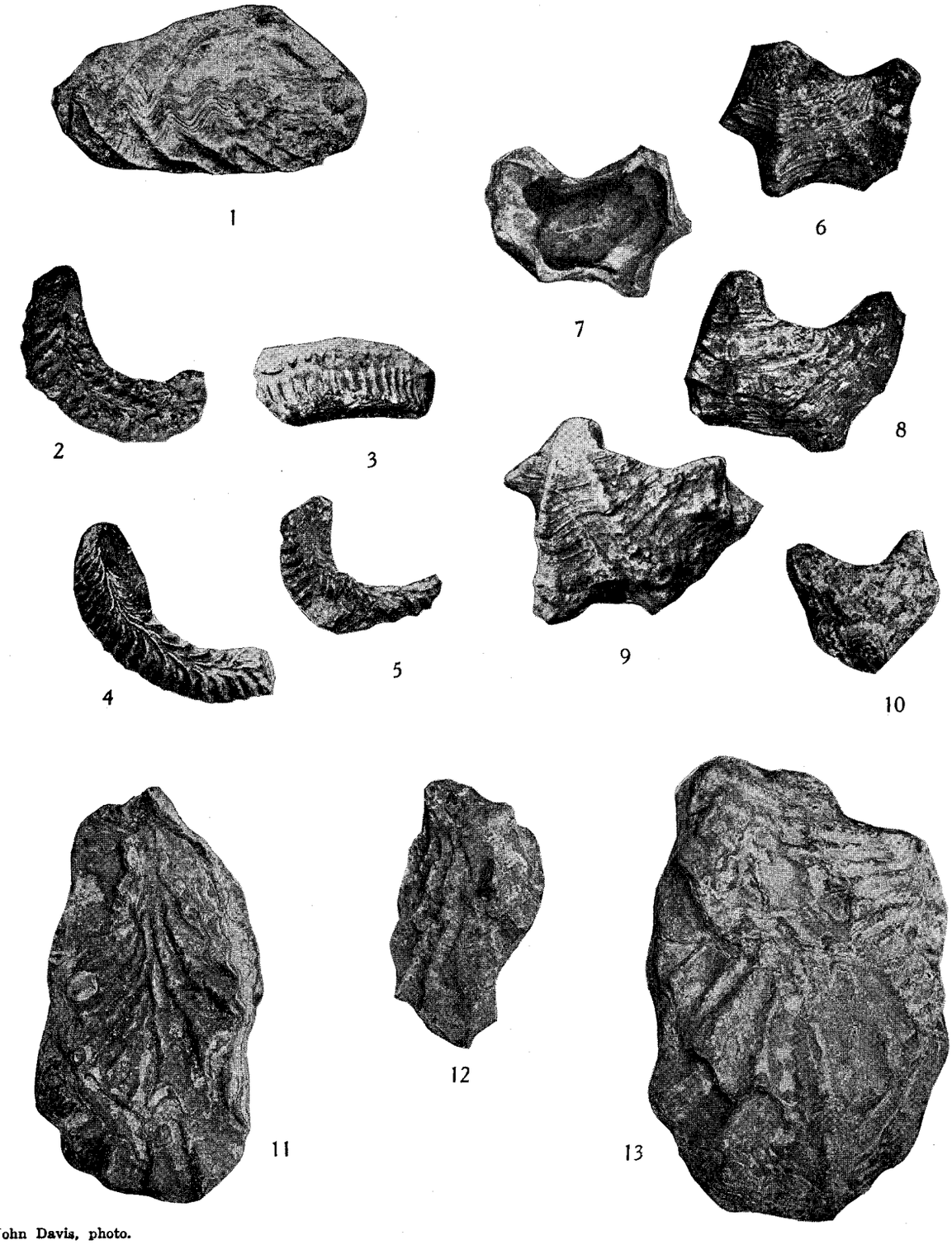
Occasional at certain levels, Fort Worth to Mainstreet formations, pages 23, 59
x 0.5. Locality: Fig. 5, Denton marl, one mile east of Gainesville, Texas; others, six miles southwest of Fort Worth, Texas.

Figures 6-10. **Ostrea quadriplicata** Shumard

Occasional, Fort Worth to Mainstreet formations; abundant in the Quarry limestone .....pages 28, 60
x 0.9. Locality: Fig. 9, Denton marl, St. Louis and San Francisco Railway track, two and one-half miles east of Kingston Oklahoma; others, rim of brickyards pit, one and three-fourths miles southeast of Gainesville, Texas.

Figures 11-13. **Ostrea sp. aff. johannae** Choffat

Occasional, Goodland limestone.....pages 15, 60
x 0.7. Locality 122, Plover road, three miles south of Benbrook, Texas.




John Davis, photo.

PLATE 17.

Figures 1-3. **Inoceramus comancheanus** Cragin

Abundant, Duck Creek limestone, base.....pages 19, 73
x 0.6. Locality: Ammonite Creek, one-half mile west of Texas Christian University, Fort Worth, Texas.

Figures 4-6. **Trigonia clavigera** Cragin

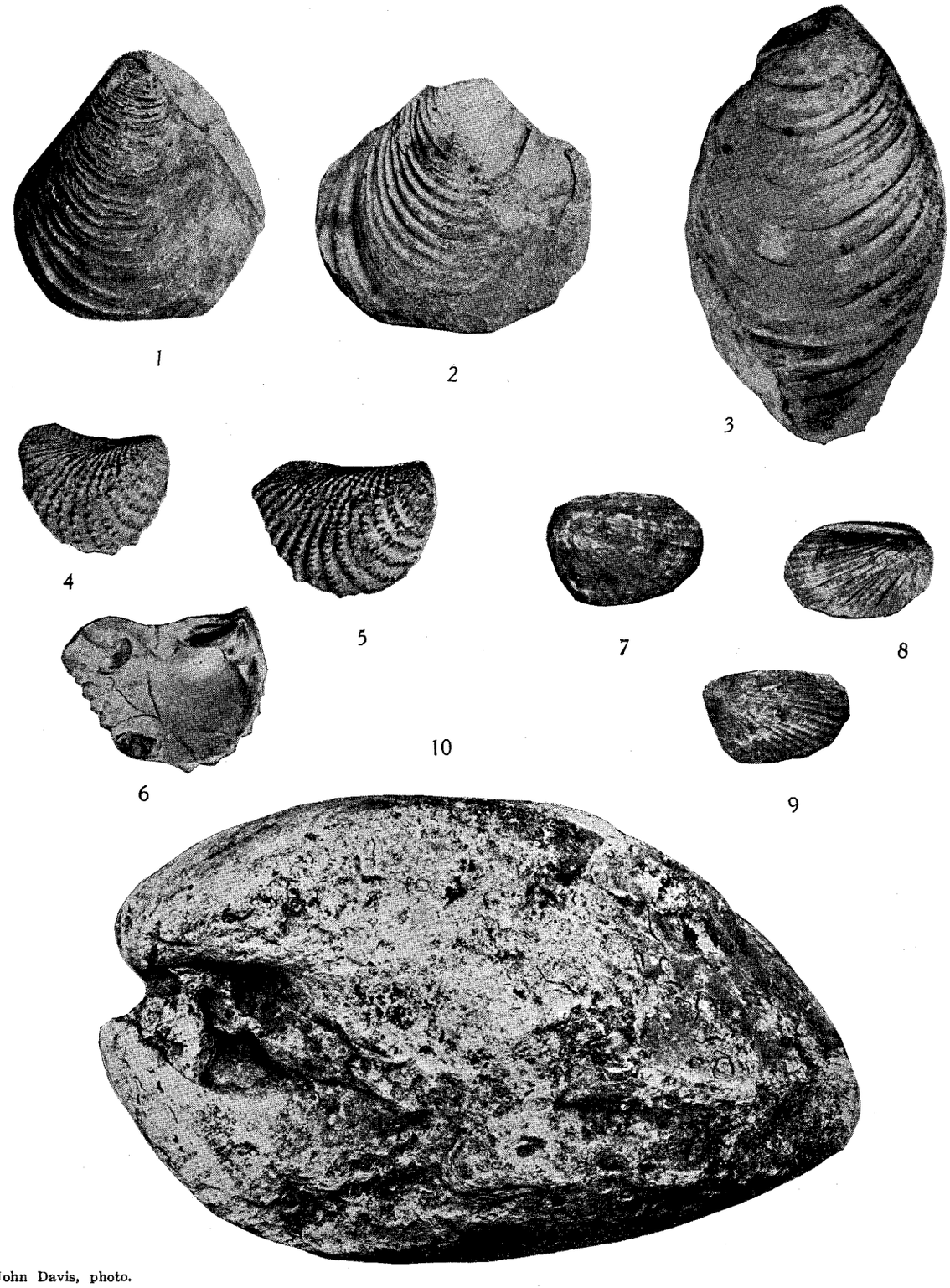
Occasional, Weno marl, middle third.....page 73
x 0.7. Locality: Brickyards, one and three-fourths miles southwest of Gainesville, Texas.

Figures 7-9. **Lima wacoensis** Roemer

Abundant, Goodland limestone; occasional, Washita division.....page 72
x 0.9. Locality: Stove foundry road, four miles west of Fort Worth, Texas.

Figure 10. **Pachymya sp. aff. austinensis** Shumard

Abundant, Mainstreet limestone, zone near base; rare, top of Weno limestone.....pages 29, 75
x 0.6. Locality: Crowley road, headwaters of Sycamore Creek, one mile north of Crowley, Texas.




John Davis, photo.

PLATE 18.

Figure 1. **Gervilliopsis invaginata** (White)

Abundant, Weno marl; rare, Duck Creek (?) and Pawpaw formations, pages 24, 67
Locality: Pit of Gainesville Brick Company, one and three-fourths miles southeast of Gainesville, Texas. Gervilliopsis zone in Weno ironstone. x 1.2.

Figures 2-3. **Pleurotomaria austinensis** Shumard

Occasional, base of Fort Worth limestone and top of Duck Creek marl....page 76
Fig. 2. Large individual, x 1.0.
Fig. 3. Worn individual, x 1.1.
Locality: Base of Fort Worth limestone, one-half mile east of Texas Christian University, Fort Worth, Texas.

Figures 4-5. **Trichotropis shumardi** Cragin

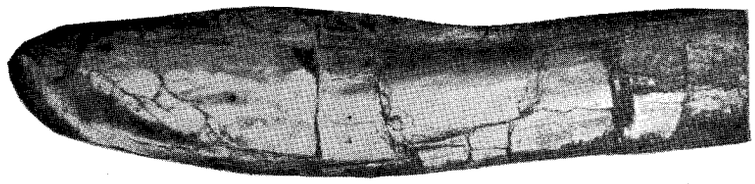
Rare, Fredericksburg limestone, Upper Salenia level.....pages 16, 76
Fig. 4. Locality: Goodland escarpment in southeastern Parker County, about 8 miles north of Cresson, Texas. Upper Salenia horizon.
x 0.9.
Fig. 5. "Near Fort Worth, Texas," Walker Museum.
x 0.9.

Figure 6. **Cyprimeria texana** (Roemer)

Abundant, Fredericksburg limestone; occasional, Kiamitia to Fort Worth formations .....page 76
x 0.9.

Figure 7. **Protocardia texana** (Conrad)

Abundant, Fredericksburg limestone; occasional as high as the Grayson (?) page 75
x 1.3.



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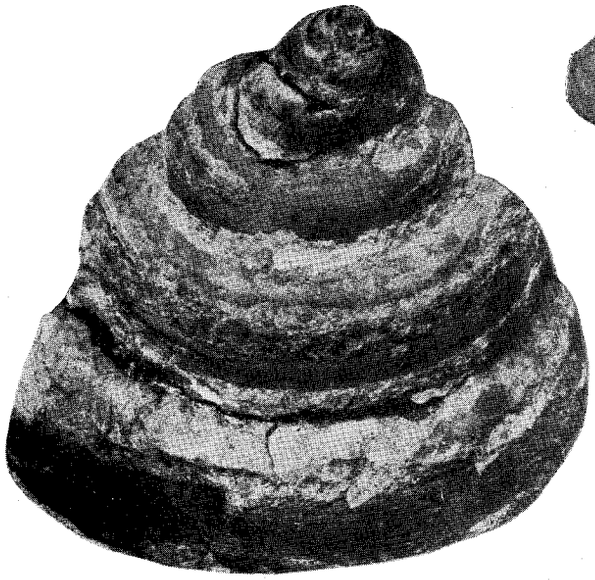

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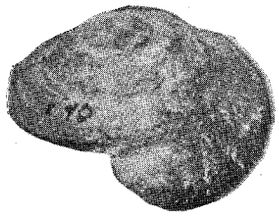

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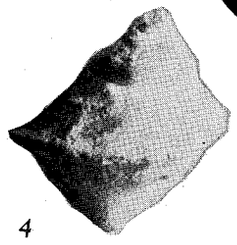

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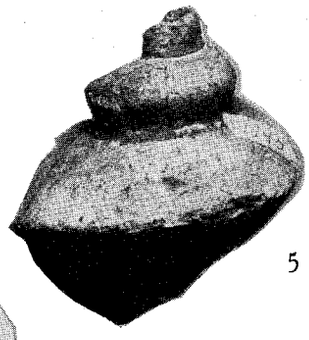

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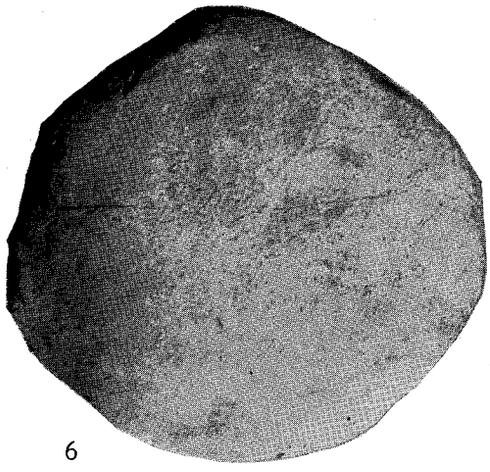

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John Davis, photo.

PLATE 19.

Figures 1-2. **Nodosaria texana** Conrad

Abundant, Weno; occasional, Pawpaw.....pages 27, 76
Fig. 1, x 1.3; fig. 2, x 4.5.
Locality: Sycamore Creek, Fort Worth, Texas. (See Pl. 21.)

Figures 3-12. **Kingena** (?) spp.

Duck Creek limestone, one zone, rare; Duck Creek marl, lower zone, abundant; upper zone, occasional; Denton marl, rare; Mainstreet limestone zone, abundant .....30, 78
Figs. 3-10, x 0.9; figs. 11-12, x 1.1.

Figures 13-15. **Remondia** (?) **acuminata** (Cragin)

Occasional, Weno marl, just above Gervilliopsis invaginata zone of abundance, p. 74
x 0.6. Locality: East of bolt factory, Fort Worth, Texas.

Figures 16-20. **Arca** sp.

Occasional, Pawpaw clay.....pages 29, 74
Locality: Sycamore Creek, Fort Worth, Texas.

Figures 21-23. **Pholadomya sancti-sabae** Roemer

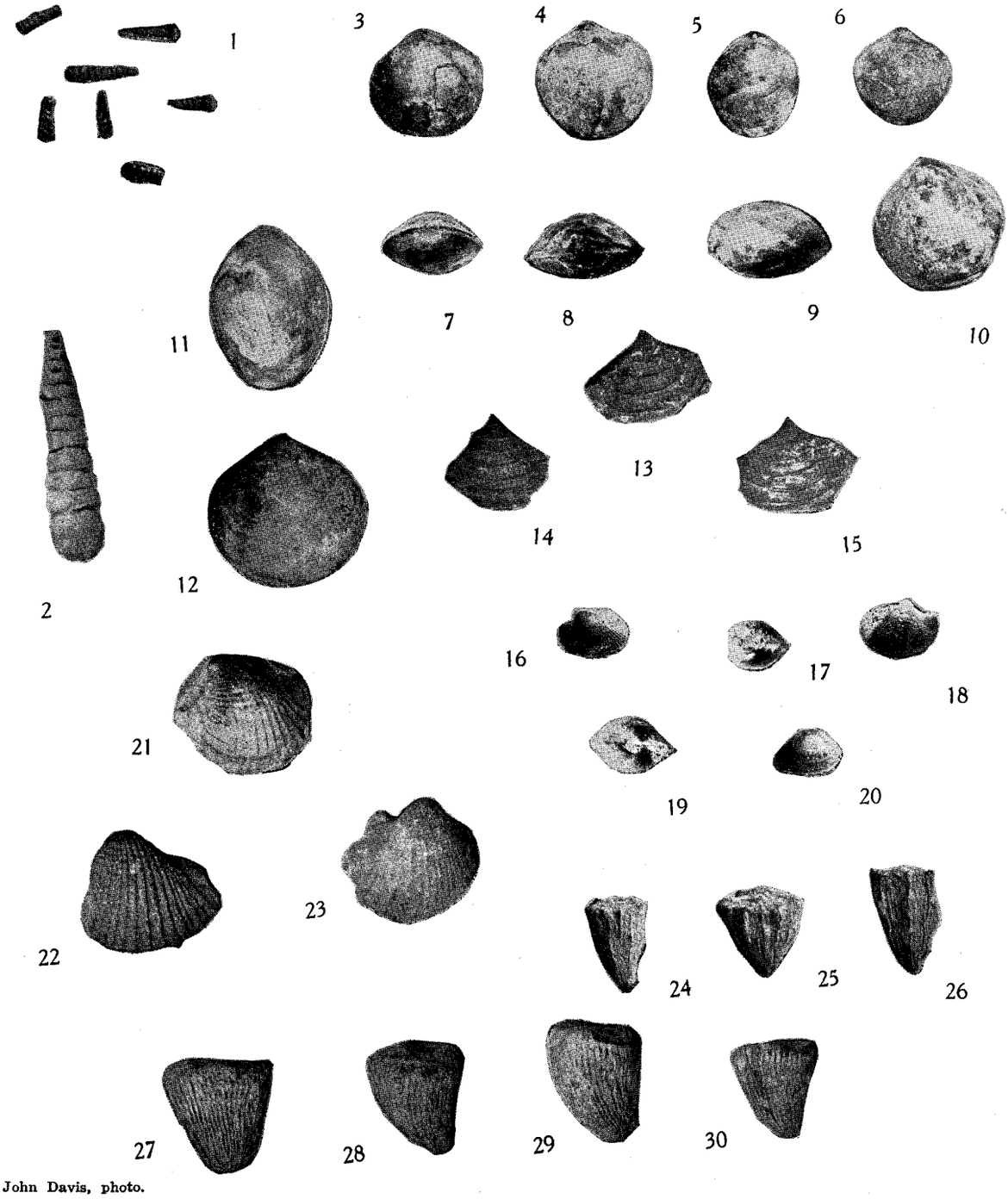
Occasional, Goodland limestone; rare, Washita division.....pages 16, 73
x 1.6. Locality 122, four miles south of Benbrook, Texas.

Figures 24-26. **Placosmilia sp.**

Occasional, Pawpaw clay.....page 80
x 1.3. Locality: Sycamore Creek, Fort Worth, Texas.

Figures 27-30. **Parasmilia austinensis** Roemer

Abundant, Goodland limestone.....pages 17, 79
0.9. Locality: Stove foundry road, Fort Worth, Texas.




John Davis, photo.

PLATE 20.

Figures 1-2. **Nautilus texanus** Shumard

Occasional, Fort Worth to Buda, more abundant in Weno (top) and Mainstreet (middle) .....page 32
Locality: Water Tower Hill, one mile southeast of Texas Christian University, Fort Worth, Texas.
x 0.9. Department of Biology Museum, Texas Christian University, Fort Worth.

Figure 3. **Leiocidaris hemigranosus** (Shumard)

Rare, Denton marl.....pages 24, 49
x 0.9. Oil Exchange, Fort Worth, Texas.
Locality: Unknown.

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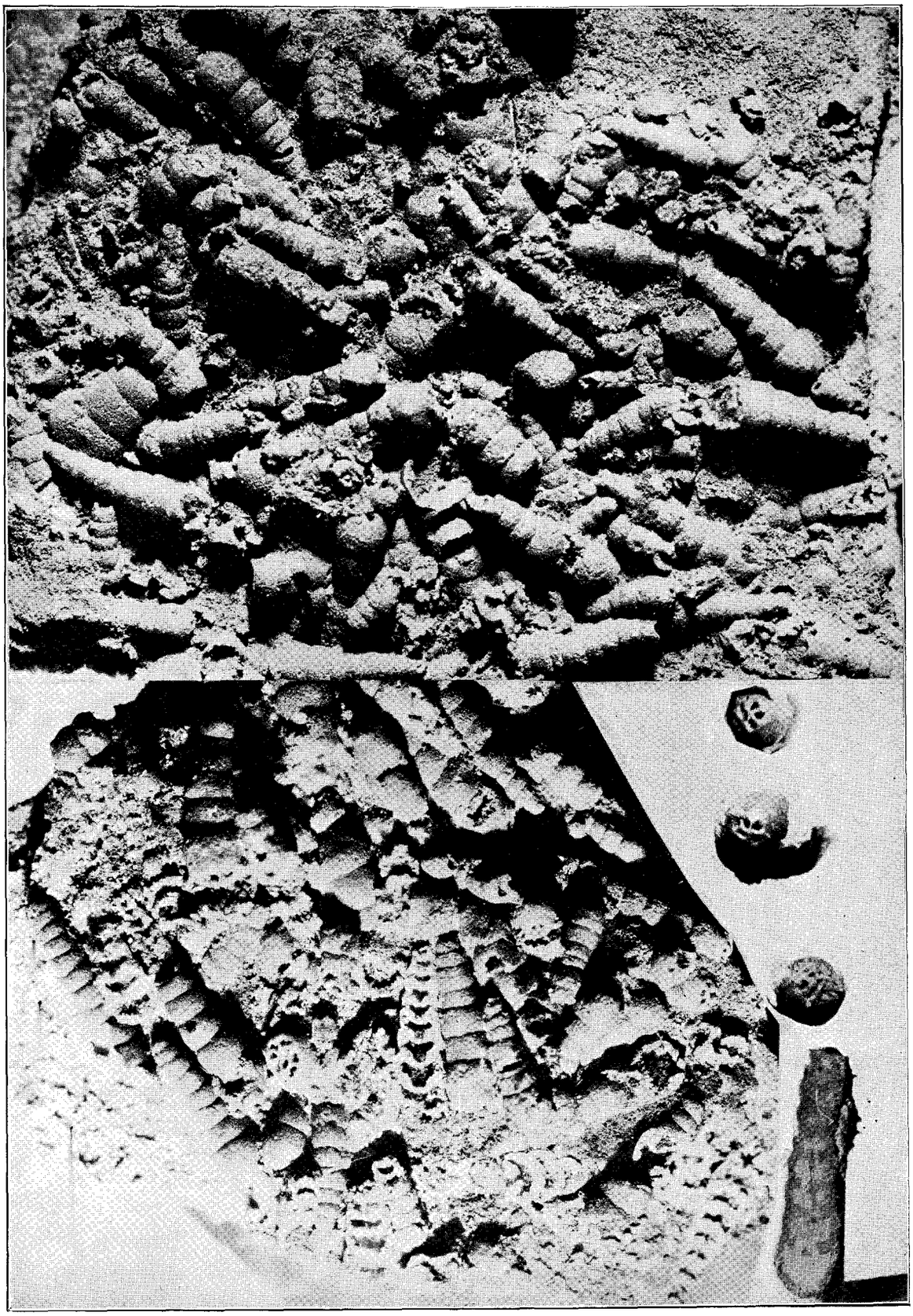
John Davis, photo.

PLATE 21.

**Nodosaria texana** Conrad

Occasional, Weno and Pawpaw formations; abundant, Del Rio clay....pages 27, 76
Terlingua, Texas. x 5.
The lower right hand figures show the apertures of the terminal chamber.



John Davis, photo.

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