University of Texas Bulletin
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FORAMINIFERA OF THE CRETACEOUS OF CENTRAL TEXAS

By

DOROTHY OGDEN CARSEY

Prepared under the direction of

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Professor of Geology and Paleontology
University of Texas

BUREAU OF ECONOMIC GEOLOGY
J. A. Udden, Director E. H. Sellards, Associate Director

PUBLISHED BY
THE UNIVERSITY OF TEXAS
AUSTIN

Publications of the University of Texas

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UNIVERSITY OF TEXAS PRESS, AUSTIN

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PUBLISHED BY THE UNIVERSITY FOUR 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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FORAMINIFERA OF THE CRETACEOUS OF CENTRAL TEXAS[1]

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INTRODUCTION

The existence of microscopic fossils has long been known, but recently interest has been greatly stimulated in the study of micropaleontology, through the realization that foraminifera may be used from an economic, as well as a scientific standpoint, for the identification of the deposits of different geologic ages of the earth's surface.

It was long believed that foraminifera were very persistent, the various species living continuously through many geologic periods and that they were of little chronologic value. Furthermore, the idea that these greater periods might be subdivided on their foraminiferal content was beyond all belief.

Only in the last few years have the facts been realized that not only do distinct species of foraminifera mark the greater periods, but that many species are restricted to the subdivisions of these periods, and that some species are even restricted to horizons in these formations. The study of hundreds of samples of rock from different parts of the country has proved this to be unmistakably true.

The most far reaching cause for the promotion of "subsurface work" came through the demand for some means whereby samples of rock taken from well cuttings and cores could be recognized. These samples are necessarily small, frequently mixed, and the characteristic lithology and larger fossils often destroyed. Under just such conditions, foraminifera are, perhaps, the best and most reliable means of identification. Only very small portions of a sample are essential for the determination of the age of a formation, and if the sample taken from a well is mixed, the species of the earliest age present are considered as identifying the formation in which the well is drilling.

[1]Manuscript submitted March, 1926, publication issued July, 1926.

The samples of rock discussed in this paper were taken from wells and surface exposures. Those coming from wells were taken from various depths and did not show complete sections of the formations encountered, but those samples taken on the surface represent in most instances each successive foot of a well defined and correctly identified section.

PREPARATION OF SAMPLES

The preparation of both well and surface samples for microscopic study is carried out in the same manner. In the case of clays and marls, a small amount of the material, three or four ounces, is put to soak in water for twenty-four hours and then repeatedly washed until all mud or silt is loosened and decanted, leaving the clean coarser particles. This residue contains the foraminifera, sand grains, and mineral particles. When the sample is dry, it is ready for microscopic examination. In order that the foraminifera may be more satisfactorily studied, they are transported on the point of a needle to a glass cell and there confined. The harder rock samples may be treated in much the same manner after the rock has been crushed, but the most satisfactory means of identification are secured by making thin sections of the material. This is done by grinding a perfectly smooth, flat surface on a small piece of rock, securely fastening it to a glass slide by means of balsam, then grinding the reverse side until only a very thin section of the rock remains. The resulting section is microscopically studied by transmitted light.

Certainly, the cross-section of a foraminifer offers, at best, a poor clue to the identification of a species, but in most instances the genus may be determined. For conservative reasons it was judged unwise to assign specific names to a few genera herein described, inasmuch as these were observed only in cross-section. Repeated attempts to secure whole specimens were in these instances futile.

Always, in the working of samples, the utmost care was taken to prevent any mixing. Every sample was kept labeled, and all containers were clean.

It will be noted that occasionally foraminifera which seemingly characterize a formation reappear several periods

later, a fact apparently contrary to the logical statement that a species once extinct never reappears. No doubt this reappearance of species is due to the fact that they existed in some other locality and returned when the temperature, depths, amount of suspended material, and other conditions were favorable in the area of deposition of the rock under consideration.

In this article descriptions were made only of foraminifera of the Comanchean and the Gulf Series of Central Texas. The author, however, has had the opportunity of examining samples of the same formations in adjoining states as well as those from other parts of Texas, and has found that the same general assemblages of species of foraminifera occur in equivalent formations in different sections of the country.

Although the present work is not exhaustive in the treatment of the subject, it is fairly complete. It was prepared to serve as a practical working basis for the study of the subsurface geology of the Cretaceous sediments of Central Texas, and, as such, the author hopes that it will fulfill its purpose.

ACKNOWLEDGMENTS

The writer especially desires to acknowledge here not only the constructive criticism, the unceasing encouragement and valuable instruction afforded her by Professor F. L. Whitney, of the Geological Department of the University of Texas, but also to express her deep appreciation of the facilities placed by him at her disposal in the use of his library, and laboratory. The plates accompanying this report were photographed and prepared by Professor Whitney. Moreover, Professor Whitney has freely given her the benefit of his field experience, information that might have been withheld for his own advancement. Further thanks is due to Dr. Frederic W. Simonds for his graciously extended counsel on matters of compilation; to Miss Hedwig T. Kniker for assistance which she has been ever ready to extend during the progress of this work; and to Mrs. Helen Jeanne Plummer for her active interest in this investigation.

DESCRIPTION OF FORMATIONS

GULF SERIES

NAVARRO FORMATION

The uppermost formation of the Gulf Series which is exposed in the area under consideration is the Navarro. Clays, some of which are marly, make up the bulk of the Navarro. These vary in color from gray to black, and on prolonged exposure weather to a greenish-yellow. The greenish color is due to the presence of the mineral, glauconite. The occurrence of moderate amounts of glauconite should not be taken, however, as an index feature of the Navarro, for very much larger quantities of this mineral are commonly found in the Midway formation just above the Navarro. These formations are frequently confused in the field, but a microscopic examination of the fauna at once reveals a decided difference between the two. The Navarro is here separated from the overlying Tertiary by a conglomerate which contains Cretaceous fossils.

In the field the formation presents an open prairie, often with rounded hills. The clay erodes easily, not infrequently forming gullies with steep sides.

Sections from Onion Creek, Travis County, and samples taken from other parts of the same county were examined.

Microscopic fauna. — A very extensive microscopic fauna, representing a number of species, is present in the Navarro. This fauna is almost entirely foraminiferal, which accords with the observation that foraminifera are most abundant in the upper stages of the Cretaceous, generally decreasing in numbers and species with the increase in age of the formations. A complete assemblage of the foraminifera is seldom found in one locality. A few smooth-shelled ostracods, fish teeth and many *Inoceramus* prisms are also present.

The preservation of the Navarro microscopic fauna is generally little short of perfect, in so far as shell texture

is concerned. Shells of this age are often porcellanous and glistening, and when calcareous, are usually clear. Arenaceous forms occur sparingly. These, too, when they do occur, are rather well preserved considering the tendency of the agglutinated shell to lose distinctness or to crumble.

A list of the species of foraminifera occurring in the formation is as follows:

Haplophragmoides diagonis n. sp.	common in localities
Textularia globulosa Ehrenberg	common
Textularia globifera Reuss	somewhat common
Textularia semicomplanata n. sp.	rare
Bolivina plaita n. sp.	common
Tritaxia tricarinata Reuss	sparingly present
Gaudryina pupoides d'Orbigny	moderately common
Gaudryina bulletta n. sp.	sparingly common
Bulimina pupoides d'Orbigny	sparingly present
Lagena hispida Reuss	rare
Nodosaria communis d'Orbigny	somewhat common
Nodosaria filiformis d'Orbigny	rare
Nodosaria obliqua Linnæus	scarce
Nodosaria larva n. sp.	sparingly common
Nodosaria consobrina d'Orbigny	rather scarce
Nodosaria fragilis n. sp.	rare
Cristellaria cultrata Montfort	very common
Cristellaria gibba d'Orbigny	moderately common
Cristellaria reniformis d'Orbigny	sparingly common
Vaginulina simondsi n. sp.	rather scarce
Vaginulina webbervillensis n. sp.	common in localities
Frondicularia alata d'Orbigny	rare
Polymorphina communis d'Orbigny	rare
Uvigerina tenuistriata Reuss	rare
Globigerina cretacea d'Orbigny	common
Globigerina rosetta n. sp.	common
Discorbis correcta n. sp.	moderately common
Rotalia cretacea n. sp.	moderately common
Anomalina pseudopapillosa n. sp.	moderately common
Anomalina grosserugosa Gümbel	moderately common
Nonionina scapha Fichtel and Moll	rare
Quinqueloculina rotunda n. sp.	rare

TAYLOR FORMATION

Blue clays, very rich in calcium carbonate, compose the Taylor formation, which is commonly spoken of as the

Taylor marl. There is no abrupt break either at the top or at the base of the Taylor where it makes contact with the Navarro and Austin formations, respectively. The upper part of the Taylor is not so marly as the lower portion and grades into the calcareous clays of the Navarro. At the base, the marl is often similar to the underlying marly parts of the Austin chalk. This basal contact, however, is sometimes identifiable by the presence of beds of *Exogyra ponderosa.*

The topography of the Taylor is not unlike that of the Navarro formation. The clays form rolling hills, and, as they wash rapidly, the country is cut by gullies. The clays lose their blue color on exposure, in some instances, and become yellowish.

Samples from Williamson County near Taylor, Texas, and from Travis County, were studied.

Microscopic fauna.—Although the Taylor formation does not have so many varieties of foraminifera as the Navarro, the individual shells are frequently larger, better developed and more abundant. Preservation varies from shells that retain their clear, hyaline texture to those which are chalky and arenaceous.

A list of all the species of foraminifera which were observed in the Taylor formation is given below with the exception of two species of *Frondicularia* which, although they are not uncommon, were not available for identification or description.

Haplophragmoides diagonis n. sp.—common in upper part
Textularia semicomplanata n. sp.—common
Textularia globulosa Ehrenberg—common
Textularia globifera Reuss—common
Bolivina latticea n. sp.—common in localities
Bolivina plaita n. sp.—sparingly common
Tritaxia tricarinata Reuss—rather common
Gaudryina pupoides d'Orbigny—very scarce
Gaudryina bulletta n. sp.—sparingly common
Bulimina compressa n. sp.—sparingly common
Bulimina pupoides d'Orbigny—sparingly common
Lagena incidenta n. sp.—rare
Nodosaria alternata n. sp.—scarce

Nodosaria vertebralis Batsch
var. *austinensis* n. var. ..... scarce
Cristellaria rotulata Lamarck ..... common
Cristellaria cultrata Montfort ..... common in localities
Globigerina cretacea d'Orbigny ..... rather common
Globigerina rosetta n. sp. ..... common in localities
Discorbis correcta n. sp. ..... rather common
Truncatulina refulgens Montfort
var. *conica* n. var. ..... common
Anomalina grosserugosa Gümbel ..... scarce
Anomalina taylorensis n. sp. ..... common
Rotalia cretacea n. sp. ..... common

AUSTIN FORMATION

The Austin formation is a conspicuous deposit appearing on exposure as persistent beds of glaring, rather pure, white chalk. The rock is moderately hard, except for occasional marly layers. Pyrite nodules are characteristic inclusions of the chalk. Well samples of the rock are not always readily recognizable, because on fresh exposure they are gray to blue in color, and frequently so hard as to be misleading. An effective identification test is to crush a small piece between the teeth. It is readily pulverized, and the absence of grit confirms its identity.

The thickness of the chalk of Central Texas varies between 200 and 500 feet. Samples from the Luling field, Caldwell County, and from various exposures in Travis County, were examined.

Microscopic fauna.—Large fossils are common in the Austin chalk, but often foraminifera are hard to find. The smaller shells are always poorly preserved, minute and often difficult to identify. One of the most characteristic features of the formation is the abundance of microscopic prisms of *Inoceramus* shells which it carries. *Orbulinas* are often abundant in the formation, appearing as tiny, globular, microscopic bodies. A few ostracods occur. Glauconite is abundantly disseminated throughout the rock in some localities.

Below is given a list of the foraminifera of the Austin formation:

Textularia globulosa Ehrenberg	common
Frondicularia christneri n. sp.	moderately scarce
Nodosaria vertebralis Batsch var. *austinensis* n. var.	scarce
Cristellaria gibba d'Orbigny	scarce
Cristellaria reniformis d'Orbigny	moderately scarce
Globigerina cretacea d'Orbigny	moderately common
Globigerina rosetta n. sp.	abundant
Orbulina universa d'Orbigny	sparingly common
Rotalia cretacea n. sp.	rare
Anomalina petita n. sp.	moderately common
Anomalina taylorensis n. sp.	rather common

EAGLE FORD FORMATION

The Eagle Ford formation is composed of a series of shales, flaggy to a greater or less degree, throughout the section. The upper portion consists of decidedly flaggy, blue, lime shales which keep their color on exposure. The lower portion of the section is a more or less sandy shale, broken by beds of bentonite, which weather to a characteristic deep yellow hue. A few thin limestone and sandstone ledges occur throughout the formation.

The rock is carbonaceous, and also carries considerable amounts of kerogen and some free oil. Phosphates are often found, and beautifully preserved fish teeth and scales are common in certain layers.

Exposures of the formation on Bouldin Creek, Travis County, were the chief sources of the samples studied.

Microscopic fauna.—Foraminifera are not abundant in the Eagle Ford formation either in species or in numbers of individuals. *Globigerina* is by far the most common fossil foraminifer, and, contrary to the usual conditions, was found to occur in the greatest abundance in a few of the samples studied.

The microscopic fauna has a most peculiar aspect of preservation, the shells presenting a waxy appearance, due probably to the presence of petroliferous material. Although, on the surface the shells look durable enough, the

oils and gases in the rock seem to have disintegrated the shell wall causing it to be easily crushed.

A few ostracods with a rim about the edge of the shell have been observed in the formation. *Inoceramus* prisms are common. The few foraminifera which were noted in the Eagle Ford formation are given below:

Textularia globulosa Ehrenberg	moderately common
Cristellaria gibba d'Orbigny	somewhat scarce
Globigerina cretacea d'Orbigny	very common
Globigerina rosetta n. sp.	scarce

COMANCHEAN SERIES

BUDA FORMATION

In the field the Buda formation appears as a resistive, cream-colored to grayish, sometimes pink blotched limestone which erodes very slowly, often forming abrupt nodular bluffs which occasionally bear ledges. The rock is intensely hard and ringing, being rather uniformly so in the upper portion, causing some difficulty in breaking samples from it. Strangely enough, while this limestone is so resistant to a hammer, it crumbles freely when subjected to an emery wheel or hone. Translucent sections of the rock are consequently hard to make. The lower part of the Buda is a soft, chalky limestone which weathers out from under the upper portion, leaving the latter as an overhanging cliff. Occasional layers of this limestone are efflorescent, forming a pulverulent material.

Microscopic aspect.—Not infrequently shells of various sizes, replaced by calcite, are found, giving the rock an irregular texture, since the calcite replacement appears as clear patches in a groundmass of fine-grained, more or less opaque, calcareous material. In thin sections, the clear transparent patches may occur in crescent shapes, cubes, circles, straight markings, or in any number of irregular forms. The larger better defined markings are usually cross-sections through gastropods and pelecypods. Not infrequently a circle with radiations occurs which is a trans-

verse section of an echinoid spine. Spongy tissue of echinoid shells is also encountered, appearing as a regularly and finely perforated mass.

Another type of limestone from the Buda is extremely fine textured. Ground, transparent layers of this show innumerable sections of microscopic shells. Of these, *Orbulinas* are perhaps the most abundant. They are distributed throughout the groundmass and are represented as extremely small, perfectly circular bodies. *Orbulinas* occur also in the coarser limestone described above, but there they are not so abundant as they are in the finer textured rock. Ostracods occur plentifully in this type of rock, appearing as very thin, clear, curved or complete oval lines, depending, of course, on the position of the section through the shell.

A third limestone typical of the Buda and unobserved in any other limestone is distinctive in its structure. This is a peculiar agglomeration of dark, rounded or oval patches occurring abundantly in the light colored groundmass. These bodies, always dark with rather well-defined outlines, may be either brown to green by transmitted light, reddish brown or dark gray-green by reflected light, depending on the amount of decomposition of the mineral contained within the area.

The identity of these small regular bodies or patches remains, as yet, undetermined. The bodies have no definite internal structure and their outlines vary to such a degree that they cannot very well be limited to one thing. It seems, however, very probable that the majority of these might be ostracods and that the organic compounds of the animal itself might possibly have some relations to the deposition of mineral matter within the shell. This mineral matter, when not too decomposed, is frequently found to be clear green and has been identified as glauconite. It is believed that the brown stain comes chiefly from the iron in the glauconite.

Glauconite is a common mineral in the Buda limestone. Although it is not found in large quantities in the forma-

tion, it is very widely distributed and is found in most thin sections. This mineral may occur in moderate sized particles which appear in the thin sections of the rock as yellowish, brownish or bluish-green patches. Decomposed glauconite is prevalent, and the brown stain that it leaves is either disseminated through the rock as the tiniest of visible particles, or as a heavier stain.

The sections examined were exposures of practically the entire formation in Shoal Creek, west of Austin, and in a ravine near Barton Creek, about a mile east of Barton Springs, Travis County, Texas. The section here is about 45 feet thick. Well samples from the Luling oil field, Caldwell County, were also studied.

Foraminifera are not abundant in the Buda limestone, one or two species of *Textularia* being the only varieties of note. These are species of moderate size and form, plainly visible in thin section. See figure 1, plate 7.

DEL RIO FORMATION

The Del Rio is the only extensive clay formation deposited in Comanchean time, and its comparatively low per cent of calcareous material is noteworthy. The clay is greenish-gray, weathering dull yellow-gray to brown. Pyrite is responsible for the greenish cast, and it also produces the brownish condition on weathering. Pyrite is plentiful in the formation, and it is frequently found replacing shells. Selenite crystals occur abundantly in the clay.

Sections were taken from this clay on Shoal Creek at Austin, Texas, the thickness of the formation measuring nearly 80 feet.

Microscopic fauna.—The Del Rio formation bears a very typical fauna and a rather extensive one. The shells have a peculiar dulled appearance as if they had been worn, which is a characteristic carried quite throughout the formation. Arenaceous forms are more common here than in any other part of either the Comanchean or Gulf Series.

The foraminifera of the Del Rio formation are as follows:

Textularia washitensis n. sp.	rather common
Textularia conica d'Orbigny	rather common
Textularia globulosa Ehrenberg	very rare
Textularia rioensis n. sp.	moderately common
Tritaxia tricarinata Reuss	very rare
Gaudryina filiformis Berthelin	scarce
Lagena sulcata Walker and Jacob	rare
Nodosaria obliqua Linnæus	very rare
Nodosaria filiformis d'Orbigny	rare
Nodosaria communis d'Orbigny	scarce
Nodosaria fragilis n. sp.	very rare
Cristellaria washitensis n. sp.	common
Globigerina cretacea d'Orbigny var. *del rioensis* n. var.	common
Globigerina washitensis n. sp.	moderately common
Globigerina rosetta n. sp.	rare
Discorbis correcta n. sp.	very rare
Rotalia cretacea n. sp.	very rare

GEORGETOWN FORMATION

The Georgetown formation consists of impure lime varying from hard limestone to marl and shale. The color on fresh exposure is blue-gray, but after weathering it becomes cream-white to yellowish. Shale partings, veins and irregular, dark inclusions are characteristic of the formation. Especially are these features noticeable in cores, presenting a readily recognizable aspect either in the field or in the laboratory. Pyrite is common. Microscopic fossils are usually plentiful and well preserved.

The materials studied were taken from exposures on the Mt. Bonnel road, Travis County, and from localities on Barton Creek, Travis County, Texas. The section in this region is about 80 feet thick.

Microscopic aspect.—The texture of the Georgetown limestone, as revealed in thin sections of the rock, is very fine and the rock may be ground to a very thin transparent layer. Thin sections exhibit very little differentiation throughout the section, the rock consisting of foraminifera, shell and crystalline fragmental material occurring thickly bedded in a very fine groundmass of lime. Echinoid spines and tissue, ostracods, and *Inoceramus* prisms are common.

Fish teeth occur rarely. Pyrite occurs rather commonly and is noticeable in thin sections as brown stains. Glauconite was observed in small quantities in the upper part of the section.

Foraminifera are not lacking except perhaps in a few feet of strata at the extreme base of the formation. This basal part of the formation varies in texture from a uniformly crypto-crystalline lime to small crystalline fragments embedded in a lime matrix.

The foraminiferal fauna is very closely related to that of the Del Rio formation.

Textularia washitensis n. sp.	moderately common
Textularia conica d'Orbigny	moderately common
Textularia rioensis n. sp.	moderately common
Gaudryina filiformis Berthelin	scarce
Globigerina washitensis n. sp.	common
Globigerina cretacea d'Orbigny var. *del rioensis* n. var.	sparingly common
Orbulina universa d'Orbigny	abundant
Rotalia cretacea n. sp.	scarce
Anomalina sp.	rare

EDWARDS FORMATION

The Edwards formation consists of about 300 feet of limestone varying from a hard, ringing rock to one of a marly nature. In color it varies from cream-white to grayish, with some layers of tan colored, rather soft dolomitic beds. The presence of dolomite is very characteristic of the Edwards. The rock is occasionally porous, assuming a honey-combed aspect on extensive weathering. Flint beds of considerable thickness are common in this formation.

Sections from several locations in Travis County and from wells in Caldwell County were studied.

Microscopic aspect.—The Edwards formation, particularly the upper portion, bears an abundance of one type of foraminifera, namely, the genus *Miliolina* of which several species are present. *Spiroloculina* is occasionally observed.

These organisms, to be sure, are absent in some layers of the formation, but where this occurs the texture of rock usually gives a clue to the identity of the formation. In the absence of this fauna, the rock is often highly dolomitic, presenting a texture which is even-crystalline to finely or moderately coarse grained. This appearance, whether the rock is in a thin section or in a lump, is not unlike that of granulated sugar, the crystals being rhomboidal. The color is tan or white, and the rock is loosely consolidated, having a semi-spongy texture.

Frequently shells are replaced or filled by dolomite, and when they are numerous a second condition of porosity occurs. This is readily noticeable in thin sections, the mineral frequently crumbling away on grinding.

This porosity offers a splendid reservoir for the accumulation of petroleum, and when structural conditions are favorable, oil is found in considerable quantities in these beds.

Both macroscopic and microscopic shells are replaced by calcite, and while this type of preservation is not restricted to the Edwards limestone, the condition occurs commonly in the formation.

Microscopic fossils of the Edwards are best seen in thin sections of the limestone. In the marly layers, which might be expected to be more fossiliferous, the foraminifera are not easily distinguishable even after careful washing of the material. In fact, these layers prove to have an underdeveloped fauna, both from the standpoint of numbers and size. The few individuals observed, with the exception of a few *Ramulinas,* were extremely small and poorly preserved.

Further concentrated study may result in the designation of specific names for the species of those which are as yet undetermined, since a shell is not readily identified from a cross-section alone.

Below is a list of the genera commonly occurring in the Edwards formation. With the exception of the *Globigerina,* none of these genera have been observed in any other formation of the Comanchean series.

Globigerina sp.----scarce
Spiroloculina sp.----sparingly common
Miliolina sp.----abundant

COMANCHE PEAK FORMATION

In the identification of formations from well logs, the Comanche Peak limestone is rarely, if ever, distinguished from the Edwards, but it is considered as a continuation of the latter. Lithologically the limestone is generally softer than that which constitutes the great bulk of the Edwards. No characteristic foraminifera have been observed.

WALNUT FORMATION

A bed of highly calcareous yellow clay, about 15 feet thick and quite persistent over extensive areas, is known as the Walnut clay. In the field this formation generally occurs in a shelf-like attitude as it rests upon the Glen Rose formation.

This clay carries a very well marked macroscopic fossil fauna. The microscopic fauna, with the exception of one genus, is not well developed.

The sections to which special study was given were taken from Rob Roy Butte, west of Austin, and from the east side of Mt. Barker, Travis County, Texas.

Microscopic aspect.—Much of the Walnut is sufficiently hard to lend itself to the making of thin sections and has been studied chiefly in this manner.

The rock, usually stained by minute particles of pyrite, is essentially a very fine grained lime, which often serves as a matrix for an agglomeration of fossil remains. Some thin sections reveal an abundance of calcitized shell fragments of pelecypods and gastropods. Others show echinoid tissue and spines. Small round sections of coral, with rather well defined septa, and a bryozoan are rather common and also restricted to the formation. Oval, apparently smooth shelled ostracods are common.

The following species of foraminifera were observed in the Walnut formation:

Textularia conica d'Orbigny	scarce
Textularia rioensis n. sp.	scarce
Orbitolina walnutensis n. sp.	abundant in parts
Rotalia sp.	scarce

GLEN ROSE FORMATION

The lithology of the Glen Rose beds is of the same general nature in different localities, but the stratification varies considerably even over moderately short distances. The formation consists of beds of limestone and marl, occasionally dolomitic, with some sand. The limes are white to yellow, sometimes tan; the clays are white to bluish.

In the vicinity of Austin the upper part of the Glen Rose consists of comparatively thin alternating beds of limestones and marls forming hills which, on weathering, give the topography a peculiar and very characteristic, terraced effect. The intermediate portion of the formation is a hard, more evenly textured limestone which weathers into bluffs. Below this the beds again become alternating, although the strata in this portion are thicker than they are at the top. Nearing the base the limes become arenaceous. The Travis County section is approximately 500 feet thick.

To the south of Travis County, in Comal and Hayes counties, the formation thickens, approaching 700 feet. Here the uppermost beds are a limestone, bearing considerable amounts of sand. These beds are followed by rather persistent layers of marls and soft chalky limestone containing enormous quantities of *Orbitolina texana.* The fossil is not only disseminated through the limestone, but also occurs in layers composed almost exclusively of its shell. The lower third of the formation consists of hard limestone. The formation usually presents a variety and an abundance of large fossils.

Microscopic aspect.—Thin sections made from the Glen Rose limestone show echinoid spines and tissue, portions of macroscopic shells and microscopic gastropods. What

might be termed an ostracod agglomerate is frequently seen. The rock is occasionally dolomitic, but layers of pure dolomite do not occur as often as they do in the Edwards formation. When the purer mineral does occur, the rock is frequently streaked with dark impurities which are probably petroliferous residues. Minute specks of brown stain, resulting from the decomposition of pyrite, are rather common.

Foraminifera are sparingly common with the exception of *Orbitolina texana* and the very large species *Orbitolina whitneyi.*

TRAVIS PEAK FORMATION

The Travis Peak is not identifiable on the basis of micropaleontology. No foraminifera have been observed, nor is it very easy to identify at once the upper part of the formation on its lithologic characteristics. The upper portion is principally massive limestone, more or less arenaceous, and occasionally bearing broken shales. This grades into red and green sands below which occurs 50 feet of basal conglomerate. The Travis Peak formation does not bear many macroscopic fossils except in the upper portion where the casts and molds of several pelecypods and a few gastropods are rather common.

DESCRIPTION OF SPECIES

FAMILY *LITUOLIDAE*

SUBFAMILY TROCHAMMININAE

HAPLOPHRAGMOIDES DIAGONIS n. sp.

Plate 3, Figure 1

Test coiled, arenaceous, shell wall consisting of coarse, well selected sand grains; chambers distinct, lying obliquely in one plane, collapsed, very gradually enlarging; sides of shell practically alike, depressed slightly at the center; aperture obscure.

Diameter about .7 mm.

This shell has been found rather commonly in horizons of the upper part of the Navarro formation, but it has also been observed in the Taylor marls.

SUBFAMILY ORBITOLININAE

ORBITOLINA TEXANA ROEMER

Plate 6, Figures 6a, 6b, 6c

Test flattened, to subconical, circular; surface smooth to slightly ringed; upper surface convex with a slight protrusion in the center; under surface concave; edge moderately thick and rounded; chambers abundant, small, lying in multilocular rings, and communicating with each other, the outer circle having a subdivision of each chamber.

Diameter varies around 7mm.

This species of *Orbitolina* is typical of the Glen Rose formation. It occurs commonly and is well distributed in limestone of this age.

ORBITOLINA WHITNEYI n. sp.

Plate 6, Figures 9a, 9b

Test thin, flattened; superior surface ornamented by concentric rings and bearing a low conical projection at the

center; opposite side smooth with a concave depression at the center, which corresponds to the conical projection of the other side; the edge of the shell is thin, fluted, and has a tendency to turn up; the chambers are abundant, small, and lie in multilocular rings; the shell wall is calcareous.

Diameter up to 14 mm.

Orbitolina whitneyi is an unusually large variety of foraminifer, and locally it is found in the Glen Rose formation in great abundance in beds of calcareous clay. In appearance it resembles *Orbitolina texana,* although it is very much larger and not so conical.

ORBITOLINA WALNUTENSIS n. sp.

Plate 7, Figures 11a, 11b

Plate 8, Figure 3

Test very finely agglutinated, quite calcareous, conical, slightly higher than broad in most instances; surface smooth; base of shell flat to slightly concave; chambers numerous, disposed in multilocular rings, each chamber porous, thus communicating with the surrounding ones, outer chambers subdivided.

Diameter up to 5 mm.

In parts of the Walnut clay this species exists in some abundance. The shell is readily distinguishable from *Orbitolina texana* due to its shape and smaller size.

FAMILY *TEXTULARIDAE*

SUBFAMILY TEXTULARINAE

TEXTULARIA CONICA D'ORBIGNY

Plate 7, Figure 1

Test decidedly conical, broadly rounded in cross-section, usually short, rather stout, often as broad as long; wall arenaceous, compactly cemented; chambers numerous, full; sutures slightly depressed, rather plainly marked; apical

end bluntly pointed; apertural end almost flat with a small, narrow, slit-like aperture at the inner margin of the final chamber.

Length from .3 mm. to .5 mm.

This species is rather common in the Washita group, more especially in the Del Rio clay.

TEXTULARIA WASHITENSIS n. sp.

Plate 7, Figure 6

Test elongate, attenuate, moderately narrow, somewhat flattened, often curved, bent or slightly twisted; chambers quite numerous, biserially arranged, very gradually enlarging, full but not noticeably inflated; giving a rather straight appearance to the sides of the shell; sutures slightly depressed, usually not clear-cut but almost always discernible; apical end often truncate; apertural end rather broadly truncate; shell agglutinated, slightly rough.

Length up to 1 mm.

Elongate *Textularias* are characteristic of the beds of the Washita group, particularly so of the Del Rio formation.

TEXTULARIA RIOENSIS n. sp.

Plate 7, Figure 2

Test rather elongate, occasionally attenuate in the earlier part, broader in later portion, sometimes slightly twisted on the long axis; cross-section rounded throughout the shell; chambers biserial, sutures only slightly depressed, visible but not always plainly marked; apical end often shows a slightly enlarged, rounded chamber at the tip; apertural end broad with the aperture at the inner margin of the last formed chamber; shell wall agglutinated, composed of very fine, well selected sand grains united with calcareous cement.

Length about .75 mm.

This species is restricted to the Washita group of the Comanchean series. It is most common in the Del Rio clay.

TEXTULARIA SEMICOMPLANATA n. sp.

Plate 3, Figure 4

Test finely arenaceous, broad, slightly flattened, biserial; chambers numerous, narrow; edges narrow, angular; shell thickest along the intermedial line of intersection of the chambers, an area which may be occasionally depressed; sutures extend from the median line obliquely backward and are usually depressed but not always plainly discernible; apical end is acutely angular; anterior end is wide and broadly angular; aperture oval, located in the terminal segment on the inner margin.

Length about .75 mm; width at widest portion about .6 mm. The shell may be smaller.

In the Cretaceous this species occurs only in the Navarro and Taylor formations and is scarce in either. The species appears to be the forerunner of a much better developed type which is more characteristic of the Tertiary.

TEXTULARIA GLOBULOSA EHRENBERG

Plate 5, Figures 2a, 2b

Test biserially symmetrical, composed of very noticeable globular chambers enlarging rapidly from very small round chambers which form a pointed initial end, to final very large bulbular segments; chambers number from ten to twelve; sutures are deeply depressed; aperture elongate, wide, with rounded ends, lying at the inner margin of the last chamber; shell calcareous.

Length up to about .7 mm.

This species is common throughout the Gulf series, showing no variation in the different formations except possibly in size. It occurs rarely in the Comanchean.

TEXTULARIA GLOBIFERA REUSS

Shell like that of *Textularia globulosa* except that the surface is ornamented by fine parallel striations running longitudinally.

Length up to about .7 mm.

This species has been observed only in the Navarro and Taylor formations.

TEXTULARIA COSTATA n. sp.

Plate 1, Figure 4

Test biserial; surface covered with coarse striations, which on either side of the shell, arise at the intermedial line of sutures and extend outward and then downward toward the apical end; chambers somewhat inflated, gradually enlarging toward the oral end except the last pair which are a little smaller than the two preceding segments; sutures moderately depressed, apertural end rounded, bearing aperture on the inner margin of the final chamber.

Length about .5 mm. to .6 mm.

This variety exists very sparingly in the Navarro formation.

BOLIVINA PLAITA n. sp.

Plate 4, Figure 2

Test elongate, slender, slightly flattened, tapering, widening with growth; apical tip rounded; ultimate end having the final pair of chambers drawn out to a somewhat rounded termination; shell wall smooth, often glistening, with sutures transparent in places; chambers numerous, regular, gradually enlarging, slightly inflated; sutures depressed, thin, plainly marked, regular, giving the shell a plaited appearance; aperture sub-oval, narrow, extending at right angles from the final suture to almost a terminal point; shell often somewhat twisted on its long axis.

Length about .7 mm.

This variety of *Bolivina* occurs commonly in the Navarro formation, and is found more sparingly in the Taylor. It is usually found well preserved and is easily identifiable.

BOLIVINA LATTICEA, n. sp.

Plate 4, Figure 9

Test calcareous, usually opaque, thus causing an obliteration of the chambers, moderately elongate, gradually enlarging toward the oral end where it is somewhat extended to tremity bluntly pointed; aperture is terminally located, small and indistinct; surface markings consist of crossed costae, presenting a lattice work effect.

Length about 1 mm.

In localities this foraminifer occurs commonly, but it is not widely distributed through the Taylor marls. *Bolivina latticea* has been observed only in the Taylor formation.

SUBFAMILY VERNEUILININAE

TRITAXIA TRICARINATA REUSS

Plate 6, Figures 4a, 4b

Test somewhat arenaceous, elongate; cross-section triangular; sides somewhat concave and marked by depressed, often indistinct, sutures; edge carinate from end to end; apertural end the larger, bluntly rounded with aperture terminal, round, and usually on a short neck or marked by a rim; opposite end not so blunt, with chambers arranged triserially for a very short distance, this portion showing more abruptly sloping edges than the rest of the shell which is uniserial and uniformly tapering.

Length about 1mm.

Both the Navarro and Taylor formations are marked by *Tritaxia tricarinata*. The shell becomes a little larger in the Taylor marl and is somewhat more common in this formation. Slightly undersized individuals have been observed very rarely in the Del Rio clay.

GAUDRYINA PUPOIDES D'ORBIGNY

Plate 4, Figure 5

Shell rather coarsely arenaceous, somewhat stout, elongate, tapering; apertural end broadly rounded; apical end form a very slightly irregular-oval termination; opposite ex-

slightly blunt to pointed; transverse section broadly oval; chambers are somewhat inflated, arranged biserially except at the apex where a triserial arrangement extends over a small portion of the test, causing a slight irregularity in the surface; sutures are marked by depressions which are not very distinct in the initial portion of the shell; the aperture lies in the final chamber on its inner margin and is roundly oval.

Length about .825 mm.

This species is moderately common in the Navarro formation and rather rare in the Taylor marls.

GAUDRYINA BULLETTA n. sp.

Plate 4, Figure 4

Test elongate, stout, straight, sides smooth; transverse section round; initial chambers triserial, remaining chambers biserial; apertural end usually somewhat flattened, broad, with edges rounded; aperture an open slit on the inner margin of the terminal chamber; apical end tapered to a blunt point; chambers full but not inflated; sutures are straight lines, neither raised nor depressed, difficultly discernible in the initial portion of the shell, more distinct in the later portion, in which they form, on the surface, an angular median line.

Length .7 or .8 mm.

Both the Navarro and Taylor formations bear this species of Gaudryina.

GAUDRYINA FILIFORMIS BERTHELIN

Plate 7, Figure 7

Test elongate, very noticeably long, tapering sometimes slightly arcuate, wall arenaceous, smoothly cemented; chambers inflated, enlarging very gradually, arranged triserially in the very short initial portion, biserial in the remainder of shell; sutures depressed; apical end bluntly pointed; apertural end wider with final chamber rounded to angular;

aperture oval, located at the inner margin of the final chamber; surface of shell is fairly smooth.

Length varies up to a little more than 1 mm.

Gaudryina filiformis occurs sparingly in the Del Rio clay, but since this is a very noticeable form it is a good marker for this formation. In thin sections of rock from the Georgetown limestone, there has been observed, although rarely, forms which are probably *Gaudryina filiformis.*

SUBFAMILY BULIMININAE

BULIMINA PUPOIDES D'ORBIGNY

Plate 4, Figure 3

Test very smooth, elongate-oval; apical end bluntly pointed, tapering: apertural end broader; aperture a narrow slit bearing a plate-like tooth and occurring at the extremity of the shell in a division of the final chamber; chambers distributed with some irregularity around the longitudinal axis of the shell, initial ones somewhat compressed, later ones more elongate and spreading, all very slightly inflated; sutures are lines of slight depression; shell is calcareous, often somewhat glistening.

Length varies around .75 mm.

It has been observed that the foraminifera of the Taylor formation are as a rule a little better developed than those of the Navarro. A good example of this condition is noticeable in *Bulimina pupoides.* The Taylor variety is longer and a little better preserved than the Navarro form. This species has not been observed elsewhere in the Gulf series nor at any horizon of the Comanchean series.

BULIMINA COMPRESSA n. sp.

Plate 4, Figure 14

Test suboval, calcareous, with segments arranged irregularly around a longitudinal axis; later portion of shell much the broader; apertural end rounded, bearing an oval

aperture which extends downward from the inner margin of the final chamber; apical end rather abruptly tapering to a rounded point; chambers inflated, the last two forming fully two-thirds of the visible portion of the shell and often having a tendency to overhang the smaller apical portion.

Length about .6 mm.

This species has been observed only in parts of the Taylor marls, but in these horizons the shell is rather common.

FAMILY *LAGENIDAE*

SUBFAMILY LAGENINAE

LAGENA HISPIDA REUSS

Plate 4, Figure 8

Test monothalamous, small, spherical; surface roughened by fine papillae, or short spines, uniformly distributed over the shell; aperture ectosolenian, the neck slender, sometimes long.

Size, .2 to .4 mm. through.

This species is rare in the Navarro. Related forms have been observed in the Taylor formation.

LAGENA INCIDENTA n. sp.

Plate 4, Figure 12

Shell rounded to oval, covered uniformly with short, blunt spines or small nodes, and having two projecting tubular necks, both with a terminal collar, one neck being much longer than the other; aperture small and round.

Entire length about .75 mm.

This form resembles *Lagena hispida* from the Navarro, except for its bearing such prominent necks and its much larger size. *Lagena incidenta* was observed only in the Taylor formation.

LAGENA SULCATA WALKER AND JACOB

Plate 7, Figure 4

Test subglobular to pyriform; surface ornamented with parallel striations extending the length of the shell; apertural extremity extended into a moderate lengthened neck, bearing a round mouth; apical end usually rounded but occasionally slightly protruded.

Entire length about .25 mm.

Lagena sulcata has been observed in the Del Rio formation, but it is of rare occurrence.

SUBFAMILY NODOSARIINAE

NODOSARIA VERTEBRALIS BATSCH var. *AUSTINENSIS* n. var.

Plate 7, Figure 12

Test straight, linear, heavily ribbed; ribs prominent, thin, rather sharp; sutures restricted and chambers inflated in later portion only; aperture terminal, radiate to toothed; apical end uniformly tapered to a sharp point, not bearing the enlarged initial chamber typical of *Nodosaria vertebralis* Batsch.

Length about 4 mm.

The shell occurs sparingly in the Taylor formation, but it is quite noticeable inasmuch as it is the largest foraminifer observed in this marl. The shell also occurs in the Austin formation.

NODOSARIA LARVA n. sp.

Plate 2, Figure 2

Shell elongate, linear, straight, rounded transversally, white, always smooth, often glistening; apical end composed of two or more indistinct segments, tapered, very bluntly pointed; apertural end having one rather highly inflated chamber bearing a distinct, radiate, somewhat pro-

tuberant opening; intermediate chambers often smaller than terminal ones, not entirely regular in size; sutures smooth, distinct, depressed lines, running straight around the shell; shell porcellanous, opaque, except by strong transmitted light.

This foraminifer occurs not infrequently in different stages of growth, having from two to seven chambers. The younger specimens are essentially like the older forms, although they do not have a sufficient number of chambers to exhibit their somewhat irregular inflation.

Length up to 1 mm.

In the Navarro formation *Nodosaria larva* occurs as a rather noticeable shell, although it is sparingly present there. It has not been observed in other formations of Cretaceous age.

NODOSARIA LAEVIGATA NILSSON

Plate 4, Figure 13

Shell small, short, somewhat pyriform, smooth; apical end acutely pointed; apertural end rounded; chambers not inflated, somewhat involute, each successive one nearly but not completely enveloping the preceding one so that all but the final chamber are seen at the surface merely as small bands in the apical part of the shell; sutures are flush with the surface, visible as fine lines running around the shell; aperture terminal.

Length up to about .65 mm.

Nodosaria laevigata occurs very sparingly in the Navarro and Taylor formations.

NODOSARIA CONSOBRINA D'ORBIGNY

Plate 2, Figure 5

Test smooth, elongate, linear, arcuate, tapering, chambers about as short as they are wide, slightly inflated, becoming more so with growth, rather stout, and gradually enlarging; sutures are lines of slight constriction, and are

straight; the initial end is decidedly rounded; aperture radiate, terminal, eccentric, protruded from terminal chamber; shell calcareous, sometimes rather hyaline.

Length usually about 2 mm.

A few specimens of this variety occur in the Navarro formation. It was not observed in the Taylor marl. Poorly preserved forms resembling this species were found in the Del Rio clay, but these did not occur with any frequency.

NODOSARIA INTRASEGMA n. sp.

Plate 4, Figure 10

Test elongate, attenuate, somewhat hyaline in appearance; chambers elongate-oval, joined by striated necks which are about two-thirds the length of the chambers.

The length of two chambers is about 1 mm.

Since the chambers of this shell are joined by such thin delicate necks, the segments are easily broken apart, making a perfect specimen almost unobtainable. This species occurs very sparingly in the Taylor marls.

NODOSARIA FILIFORMIS D'ORBIGNY

Plate 7, Figure 8

Test long, slender, smooth, clear, somewhat curved; composed of a number of oval chambers arranged in linear series and separated by slightly depressed sutures which are sometimes very moderately oblique; chambers increased in length toward the apertural end becoming more than twice as long as wide; aperture terminal, radiate and slightly eccentric.

Length 1.5 mm. to 2 mm.

Only fragments of this shell have been observed in the Navarro, and those are very rare. A few have been observed in the Del Rio.

NODOSARIA FARCIMEN SOLDANI

Plate 4, Figure 11

Shell calcareous, elongate, tapering, somewhat curved; chambers round to slightly oval, inflated, separated by fairly wide restricted areas, enlarging rapidly, the final segment quite large, usually twice the size of the foregoing one and rather pear-shaped; aperture terminal, projecting, radiate; oral end abruptly tapering, bluntly pointed; aboral end rounded.

Length about 1 mm.

The Taylor marl is the only formation in which *Nodosaria farcimen* was observed, and it occurs very rarely in the beds of this age.

NODOSARIA COMMUNIS D'ORBIGNY

Plate 7, Figure 5

Test elongate, tapering, somewhat curved, smooth; composed of numerous chambers becoming more inflated toward the apical end; aperture terminal, radiate, slightly elongate and eccentric; sutures oblique. *Nodosaria communis* differs from *Nodosaria filiformis* in being usually more curved, and always having distinctly oblique sutures.

Length about 1 mm.

The species is somewhat common in the Navarro. A few individuals have been observed in the Taylor and Del Rio formations.

NODOSARIA MARLA n. sp.

Plate 4, Figure 6

Test linear, short, stout, usually white, calcareous; surface ornamented with moderately coarse, rather thick ribs; chambers inflated, gradually enlarging; sutures plainly observed as areas of depression throughout the length of the shell.

Length about .7 mm.

This species is noted as one of rare occurrence in the Taylor formation.

NODOSARIA FRAGILIS n. sp.

Plate 4, Figure 1

Test elongate, small, delicate, with rather coarse ribs reaching from end to end; initial extremity sharply pointed; ultimate end also rather pointed with a centrally located aperture; chambers few, the last one noticeably the longest; sutures are vague rings of depressions which do not interrupt the surface ribs.

Length about .75 mm. or less.

This species is rare in the Navarro, Taylor and Del Rio formations.

NODOSARIA ALTERNATA n. sp.

Plate 4, Figure 7

Test straight, medium sized, linear, bearing two types of ribs, one variety being prominent, thin, hyaline, with a sharp, usually chipped edge, the other type of ribs, one, three or five of which are visible occur between the prominent ones and are far less pronounced; earlier chambers only very slightly, if at all inflated; later chambers somewhat more inflated; sutures are areas of restriction more receding between later chambers; apical end somewhat rounded; aperture terminal.

Length about 1.7 mm.

Nodosaria alternata occurs only in the Taylor formation in which it is rather scarce.

NODOSARIA OBLIQUA LINNÆUS

Plate 2, Figure 6

Test elongate, slender, tapering, linear, sometimes curved, varying in size up to rather large; surface covered with numerous, moderately coarse, longitudinal ribs, a few of

which may not be continuous; sutures appear as restrictions; chambers are somewhat inflated, particularly the later, larger ones; the initial chamber is often slightly larger than those immediately following, and it is terminated by a short spine; aperture radiate, terminal, a little eccentric, occurring on a slight protrusion of the final chamber; shell calcareous.

Length about 2 mm.

Nodosaria obliqua is rare in the Navarro and Del Rio formations. It was not observed in intermediate beds.

NODOSARIA TEXANA CONRAD

Plate 6, Figure 10

Test large, elongate, usually straight; chambers gradually enlarging, each younger one enveloping the anterior portion of the immediately preceding one; initial extremity slightly pointed, ultimate end broadly rounded to slightly protruded; aperture terminal, consisting of rounded to subovate orifices regularly arranged in a semi-radiating manner around a central opening of about the same size; surface of shell marked by rather closely set depressed suture lines.

Length usually not exceeding 9 mm., occasionally much longer.

Nodosaria texana occurs rather commonly in parts of the Del Rio formation and has been occasionally observed in the Buda limestone.

CRISTELLARIA LINEARA n. sp.

Plate 2, Figure 3

Test smooth, elongate, of medium length, consisting of seven or eight chambers, noncarinate, width about the same throughout; initial end somewhat bent, suggesting a tendency to coil; most of the chambers are short, broader than long, oval in cross-section, the final one somewhat elongate, slightly oblique, a little inflated and not so wide as the

adjoining chamber; sutures are well marked, clear lines, faintly raised; aperture is terminal, radiate and forms a protrusion at the outer edge of the ultimate chamber.

Length usually about 1 mm.

This species is not abundant, but it is of rather frequent occurrence in the Navarro formation.

CRISTELLARIA GIBBA D'ORBIGNY

Plate 5, Figures 4a, 4b

Test medium sized, calcareous, entirely involute; chambers not very numerous, usually about seven or eight are visible, triangular, inflated; sutures are almost straight, clearly marked heavy lines, depressed, arising from a round, clear central node and terminating on the periphery in a noticeable, clear, triangular enlargement, plainly marking previous apertures; periphery carinate, slightly indented on each chamber immediately following the termination of the suture; aperture radiate, located at the extremity of the final chamber.

Diameter usually about .75 mm.

This species is moderately common in the Navarro and Taylor formations, and it appears sparingly as a poorly preserved form in the Austin chalk. The form in the latter formation is small.

CRISTELLARIA RENIFORMIS D'ORBIGNY

Plate 3, Figure 2

Test smooth, sublenticular, subcarinate, bilaterally symmetrical, equally biconvex, somewhat compressed laterally, causing the shell to be thinner than is usually found in *Cristellaria;* shell coiled, yet having a slight suggestion toward straightening in the last few chambers which sometimes do not reach the center but extend toward the periphery until the inner margin of the ultimate chamber is flush with the keel, forming an almost straight angle; chambers numerous, full but not noticeably inflated except for

the inflation of the final one or two; the ultimate chamber is much attenuated and bears the radiate, somewhat protruding aperture at the acute angle which the inner edge of the final chamber makes with the periphery; sutures slightly thickened and raised in initial part, lines of depression in later portion, all extending from a central, usually clear, raised node; shell hyaline to calcareous.

Size varies from about .6 mm. to .75 mm. across the largest dimension.

The shell is found sparingly in the Navarro and Taylor formations, and it occurs still more rarely in the Austin chalk.

CRISTELLARIA WASHITENSIS n. sp.

Plate 7, Figure 9

Test smooth, lenticular, equally convex on both sides, center more or less raised, subcarinate to unkeeled; chambers numerous, the final one often extended at the base until it makes almost a straight angle with the periphery of the previous whorl; sutures are only slightly curved, usually not raised, indistinct but occasionally having a depressed appearance; aperture terminal, radiate, on the outer angle of the final segment. The shell is always calcareous and practically opaque in direct light, while in transmitted light it is only translucent at best.

Size of the shell usually varies from .5 mm. to 1.25 mm. across the largest part.

This species is common in the Del Rio formation.

CRISTELLARIA CULTRATA MONTFORT

Plate 6, Figure 3

Test planospiral, lenticular, biconvex, smooth; shell durable, but rather thin giving a fragile appearance; usually grayish in color; margin carinate, the keel being uniformly wide, thin and sharp; sutures extending from a rather large, clear, central node to the keel as slightly raised, curved,

clear, tapering lines expanding slightly on approximation to the keel; whorls completely involute; aperture radiate, terminal, on the outer edge of the final whorl.

Size up to 2 mm. in diameter.

This species is very common in the Navarro formation and is usually considered as typical of that formation, however, the shell has been found in great abundance in the upper parts of the Taylor marls.

CRISTELLARIA ROTULATA LAMARCK

Plate 6, Figure 2

Test smooth, lenticular, equally convex on both sides, rather large, nautiloid, completely involute; chambers numerous, narrow; sutures curved, moderately heavy, sometimes slightly raised, sweeping, extending from a central, faintly raised, large node to the periphery where the positions of previous apertures are still apparent; periphery angular to narrowly carinate, keel usually quite thin, aperture radiate, located at the peripheral extremity of the final chamber.

Diameter up to 1.3 mm.

This *Cristellaria* is the most common species of this genus to be found in the Taylor formation.

VAGINULINA WEBBERVILLENSIS n. sp.

Plate 2, Figure 7

Test blade-like, flat; dorsal edge straight, bicarinate; ventral edge curved, smooth; both edges square with the sides of the shell; sutures marked by plain, curved, faintly depressed lines, running obliquely backward from a regular spacing on the dorsal margin to the ventral edge where they sometimes meet; aboral end attenuated, terminated by a bulbular enlargement, which is ornamented by a few moderately heavy ribs and pointed at the extremity; the aperture is terminal, round and toothed; shell calcareous but often transparent.

Length up to 6 mm. but more commonly about 4 mm.

Frequently, these shells are observed in the Navarro clays without the aid of a hand lens because of their large size. They are rather common in some parts of this formation, and they may be considered as an index foraminifer of it. There is, however, a variety of this species which occurs sparingly in the Taylor. This type was not available for description.

VAGINULINA SIMONDSI n. sp.

Plate 2, Figure 4

Test complanate, slender, blade-like; dorsal edge straight, bicarinate; ventral edge curved, broken somewhat by ridges or striations which extend over it and across the shell in the direction of the aperture; the surface markings extend at an angle across the line of direction of the chambers, are somewhat irregular and the later ones are not continuous from edge to edge; chambers and sutures are not distinct, but extend from the dorsal edge obliquely backwards; the initial end is tapered, somewhat attenuate, has a suggestion of enlarging at the end, which terminates with an abruptly pointed tip; the ultimate end somewhat pointed, with a round, somewhat toothed or radiate mouth at the extremity; shell calcareous and translucent only by strong transmitted light.

Length about 2 mm.

This shell is noticeably smaller and more slender than *Vaginulina webbervillensis* and is readily distinguishable from the latter by the surface markings. It, too, is restricted to the Navarro formation, but it is not so common as *Vaginulina webbervillensis.*

FRONDICULARIA ALATA D'ORBIGNY

Plate 2, Figure 1

Test ovate, rather elongate, smooth; oral end acute; aboral end slightly rounded, bearing a ribbed, bulb-like

enlargement and one or two projecting spines; the chambers, which are narrow, grow longer with age, diverge from a median line and extend apically, ending almost in line with the initial chamber; sutures are plainly marked lines, slightly depressed; the aperture is round, terminal, on the acute end of the shell; shell wall hyaline, unusually clear.

Length about 1 mm.

This species was observed only in the Navarro formation and here it occurred very rarely.

FRONDICULARIA PROJECTA n. sp.

Plate 6, Figure 5

Test triangular, arrow-shaped, complanate; chambers numerous, bifurcating, except in the apical portion where they show a slight coil and occur as a projection beyond the rather straight apical edge; sutures are raised ridges and between them are surface ornamentations of small nodes either in lines or scattered; the apical end is broad and the shell tapers toward the apertural end which is pointed, and which bears at its extremity an aperture, slightly protruding and of moderate size.

Length from 1 mm. to 1.5 mm.

This shell is very attractive, consequently noticeable, and is generally well preserved. It occurs in the Taylor marls.

FRONDICULARIA CHRISTNERI n. sp.

Plate 6, Figure 7

Shell calcareous, somewhat flattened, although a bit convex on either side; initial chambers rather irregular, following chambers diverging at their forward extremity and extending backward around the initial portion; final chambers extending backward only part way; all visible on surface; sutures raised, moderately thin, smooth ridges meeting in a sinuous line which extends from the initial portion almost to the aperture which is terminal.

Size varies up to about 2.25 mm.

Frondicularia christneri is sparingly common in the Taylor formation near its base, but the shell is more characteristic of the Austin chalk.

SUBFAMILY POLYMORPHININAE

POLYMORPHINA COMMUNIS D'ORBIGNY

Plate 1, Figure 5

Test ovate, pyriform, smooth, inflated; chambers few; apertural end somewhat bluntly pointed; apical end broadly rounded and bearing more chambers; sutures are smooth lines of depression, sometimes rather difficult to discern; aperture terminal, radiate, protruding; shell calcareous, although often translucent.

Length seldom more than .5 mm. or .6 mm., usually about .4 mm.

Polymorphina communis occurs rarely in the Navarro formation.

SUBFAMILY UVIGERININAE

UVIGERINA TENUISTRIATA REUSS

Plate 1, Figure 1

Test small, elongate, broadly triangular in cross-section; chambers arranged about a longitudinal axis, slightly inflated, partially overlapping, rather indistinct; aboral end rather pointed; oral end more broadly pointed, the final chamber bearing a short neck which embraces the smooth, round aperture; shell wall calcareous, ornamented with more or less prominent costae.

Size .1 mm. to .2 mm. long.

This shell is scarce in the Navarro, and since it is so small, is not very noticeable. The species has not been observed in other formations.

SUBFAMILY RAMULININAE

RAMULINA EDWARDSENSIS n. sp.

Plate 6, Figure 8

Test tubular, elongate, often curving and branching; shell wall calcareous, roughened on the surface by small rounded, granular protrusions; interior smooth.

The shell is delicate and seldom found whole. The fragments are rarely more than 2 mm. long.

This shell was observed only in the marly layers of the Edwards formation. It does not occur here in any abundance.

FAMILY *GLOBIGERININAE*

GLOBIGERINA CRETACEA D'ORBIGNY

Plate 5, Figures 5a, 5b

Test rotaliform, comprised of about three whorls all of which are visible from the dorsal side, only the last whorl is visible on the ventral side, dorsal side usually flattened, ventral side depressed toward the center; chambers globular, highly inflated and rapidly enlarging from a few very small initial ones; sutures much depressed; shell coarsely perforate, sometimes marked with small projections; aperture in margin of final chamber, opening into umbilical depression.

Diameter about .5 mm.

Globigerina cretacea is by far the most widely distributed foraminifer in the Cretaceous period. It occurs rather commonly in each formation of the Gulf series but is scarce in the Comanchean series except in the Del Rio clay. This formation bears a variety of the species, *Globigerina cretacea* var. *del rioensis* n. var.

GLOBIGERINA CRETACEA D'ORBIGNY var. *DEL RIOENSIS* n. var.

Shell resembles that of *Globigerina cretacea* very closely except that the final chamber is more inflated and protrudes

ventrally beyond the plane in which the foregoing part of the shell lies.

This shell is common in the Del Rio formation but it also occurs sparingly in the Georgetown limestone and marls.

GLOBIGERINA WASHITENSIS n. sp.

Plate 7, Figure 10

Plate 8, Figure 2

Shell calcareous, usually white; surface very coarsely and regularly pitted; chambers well inflated, rapidly enlarging, arranged subspirally, dorsal side shows two or more whorls; ventral side shows only one whorl which consists of the last three or four chambers rather loosely joined about a depressed center; aperture at the inner margin of the final chamber.

The diameter of the shell is about .5 mm.

This species is moderately common in the Del Rio and Georgetown formations, and it serves as a splendid horizon marker of the Washita division of the Comanchean series.

GLOBIGERINA ROSETTA n. sp.

Plate 5, Figures 3a, 3b, 3c

Test coiled, flattened to slightly convex with surface of chambers flattened seldom inflated, but occasionally resting at an angle to the dorsal plane causing the anterior margin of each to be slightly raised; sutures sweep from the center and roundly curve on the periphery giving a subpetaloid appearance, are distinctly marked, slightly broadened and frequently ornamented by tubercles which are coarser toward the center. The periphery, formed by the extremity of the sutures, is scalloped or lobed, subcarinate and ornamented by fine excrescences. The ventral side is convex to protruded with usually only one whorl visible, and the

chambers on this side are somewhat inflated with sutures marked by lines of depression sometimes curving and extending from the perpihery to the broad umbilicus. Umbilical margin of the chambers is marked on each by an extended lip; apertures open from the chambers in the final whorl into the receding umbilical vestibule; shell very finely perforate.

The width of the shell varies from .3 mm. to .7 mm., but the size is usually intermediate.

*Globigerina rosetta** is first noticeable in the Del Rio formation where it occurs very rarely; in the Austin chalk it is sparingly represented while in the Taylor and Navarro formations it is common.

Variations noted in the structure of this shell lead to the belief that if this one type were given extensive study several varieties of the species might be determined to good advantage.

ORBULINA UNIVERSA D'ORBIGNY

Test thin walled, spherical, usually consisting of a single globular chamber but occasionally composed of two adjoining ones; exterior and interior of shell smooth. No definite orifice which might serve as an aperture has been observed in the shell wall.

Diameter not exceeding .04 mm.

Orbulina universa is present in great abundance throughout most of the Georgetown formation.

FAMILY *ROTALIIDAE*

SUBFAMILY ROTALINAE

DISCORBIS CORRECTA n. sp.

Plate 3, Figures 5a, 5b

Test coiled, chambers rather numerous; dorsal side convex, showing from two to three whorls; ventral side

*This species although undescribed has generally been designated among paleontologists as *Pulvinulina rosetta*. The author is indebted to Mrs. Helen Jeanne Plummer for calling attention to the fact that the genus is *Globigerina*.

flattened to concave; somewhat umbilicate, with only one whorl visible; chambers only slightly inflated, final one large but not thickened; sutures plainly marked, curved, often sweeping, depressed; shell calcareous covered with fine perforations.

Diameter varies from about .3 mm. to .75 mm.

This shell serves as a good marker for the Navarro and upper part of the Taylor formations. A few rare forerunners of it occur as low as the Del Rio clay.

TRUNCATULINA REFULGENS MONTFORT var.. *CONICA* n. var.

Plate 4, Figures 15a, 15b

Test conical, calcareous, finely perforate, smooth, coiled, chambers numerous; dorsal side flat to concave with very smooth surface and having from two to three whorls with oblique sutures which are somewhat curved and faintly visible; ventral side conical, showing only one whorl with a deep, narrow umbilicus and slightly curved, seldom visible suture; inner face of final chamber somewhat squared; sutures on dorsal side are moderately broad lines flush with the surface of the shell; the aperture is a narrow, elongate slit on the inner margin of the final chamber.

The diameter is about .6 mm. across the widest part of the shell.

This shell is an index fossil of the Taylor marls in which it occurs rather commonly.

ANOMALINA GROSSERUGOSA GÜMBEL

Plate 3, Figures 3a, 3b

Test subnautiloid, ventral side convex, dorsal side a depressed spire; chambers numerous, inflated, in three or more coils, all of which are visible from the dorsal side; only the final whorl is visible on the ventral side; surface is rather coarsely perforate; sutures are smooth, depressed

lines; periphery broadly rounded; aperture is a narrow, curved slit lying somewhat ventrally at the base of the final chamber.

Size about 1 mm.

Anomalina grosserugosa is a common foraminifer of the Navarro formation. The same species occurs more sparingly in the Taylor marl.

ANOMALINA PSEUDOPAPILLOSA, n. sp.

Plate I, Figures 6a, 6b

Test nautiloid, medium size, inflated, about two whorls visible on the dorsal surface which sometimes shows a slightly enlarged initial chamber; ventral surface not completely involute; chambers narrow, enlarging gradually; sutures raised, heavy, coarser on the inferior surface, particularly on approaching the umbilicus where they stop abruptly and leave a small portion of the center exposed, thereby revealing the extremities of preceding truncated sutures, giving the umbilical region a papillose appearance. The aperture is a narrow, curved, small slit lying at the inner margin of the final chamber. The shell is regularly perforate, the foramina being of moderately coarse size.

Diameter usually not more than .4 mm.

This shell is rather common in the upper part of the Navarro and may be accepted as a good marker for this formation.

ANOMALINA TAYLORENSIS n. sp. (See note)

Plate 6, Figures 1a, 1b

Shell nautiloid, distinctly porous, slightly flattened, large, subcarinate, chambers numerous; dorsal side slightly

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NOTE.—*Anomalina taylorensis* is mentioned by E. T. Dumble and E. R. Applin in the article "Subsurface Geology of Idolo Island, Vera Cruz, Mexico," which occurs in The Pan-American Geologist, Volume XLI, June, 1924.

convex, showing one and one-half to two whorls and having a large prominently raised node in the center; ventral side much more convex, depressed slightly at the umbilicus in which either an irregular node or a coil of shell material occurs. The sutures are raised, plainly marked, moderately heavy lines. The chambers are slightly inflated or flush with the surface; aperture is an arched slit on the inner margin of the final chamber near the periphery.

The diameter of the shell is about 1 mm.

Anomalina taylorensis is one of the most noticeable shells in the Taylor marl, however, it originates in the Austin formation in parts of which it occurs commonly. The Taylor type reaches a larger size than does the one from the Austin formation.

ANOMALINA PETITA n. sp.

Plate 7, Figure 3

Test coiled, usually small; dorsal side showing one whorl with a subconical central node; ventral side having one and a part of a second whorl visible and generally exhibiting a small coil of calcareous material at the center; chambers gradually enlarging; shell calcareous, rather smooth; color usually white.

This shell is moderately common in some horizons of the Del Rio formation.

ROTALIA CRETACEA n. sp.

Plate 5, Figures 1a, 1b

Test coiled, somewhat rotund, surface very smooth; dorsal side slightly convex showing two or three whorls; ventral surface with only one visible whorl and quite convex; chambers inflated and sutures depressed on the ventral side and in the final portion of the dorsal side; sutures clearly marked, usually curved dorsally and straightened ventrally;

periphery rounded; umbilical region filled with shell material which sometimes forms a rounded node lying in a slight depression; aperture is a very narrow slit on the ventral portion of the inner margin of the final segment; shell calcareous.

The diameter of the shell is generally not over .5 mm.

This species is common in the Navarro formation, occurs very sparingly in the Taylor marls, and has a few rare forerunners in the Del Rio clay. The shell is typically well preserved.

FAMILY *NUMMULITIDAE*

NONIONINA SCAPHA FICHTEL AND MOLL

Plate 1, Figures 2a, 2b, 2c

Test elongate to somewhat oval, approximately equilaterally compressed, slightly flattened on the face of the final chamber; involute, the final whorl usually embracing all previous volutions, although more than one whorl may show on one side; the sutures are distinct lines of depression, only slightly curved, extending continuously across the periphery which is without a keel and is rather broadly rounded; segments are a bit inflated, increasing very rapidly in size toward the final chamber which is by far the largest, comprising more than half the length of the shell. The chambers are oval in cross-section, a feature particularly noticeable in the ultimate one; final whorl overlapping at the umbilical depression so that the umbilicus is covered. The aperture, located at the inner margin of the final chamber, is a very small, concentric slit. The shell is usually glistening and is very finely perforate.

The shell measures about .4 mm. across the widest part.

Nonionina scapha is found in the Navarro formation, in which it occurs with some degree of rarity.

FAMILY *MILIOLIDAE*

SUBFAMILY CORNUSPIRININAE

SPIROLOCULINA sp.

Plate 8, Figure 4

Test coiled planospirally, concave on either side due to a gradual enlarging of the shell from the early or central portion outwardly; surface apparently smooth; shell wall rather thick.

Diameter of shell is about .75 mm.

The above description is based on a study of cross-sections made from Edwards limestone in which the shell occurs sparingly.

SUBFAMILY *QUINQUELOCULININAE*

QUINQUELOCULINA ROTUNDA n. sp.

Plate 1, Figures 3a, 3b

Test smooth, clear, broadly oval to almost round, transverse section roughly oval to rounded; chambers curved longitudinally, full, enlarging with growth, inflated, arranged in an irregular, bilateral fashion, five chambers always visible on the exterior; sutures are very deeply depressed, receding, usually filled with some foreign material; the extremities of the shell are much alike, except for the aperture at the termination or oral end of the final chamber.

Widest part of shell not over .4 mm.

As stated in the description, the shell is clear or transparent. It is possible that the specimen studied was reworked, the shell was destroyed, and a calcite cast left, which gives the clear or hyaline appearance.

The species was observed in the Navarro formation.

MILIOLINA sp.

Plate 8, Figure 5

Shell calcareous, with smooth surface and broadly rounded in transverse section. The chambers are numerous, gradually enlarging, and are coiled about a longitudinal axis in such a way that from three to five chambers are visible on the exterior.

Diameter usually about .65 mm.

The genus was observed only in the Edwards limestone. It occurs here in great abundance.

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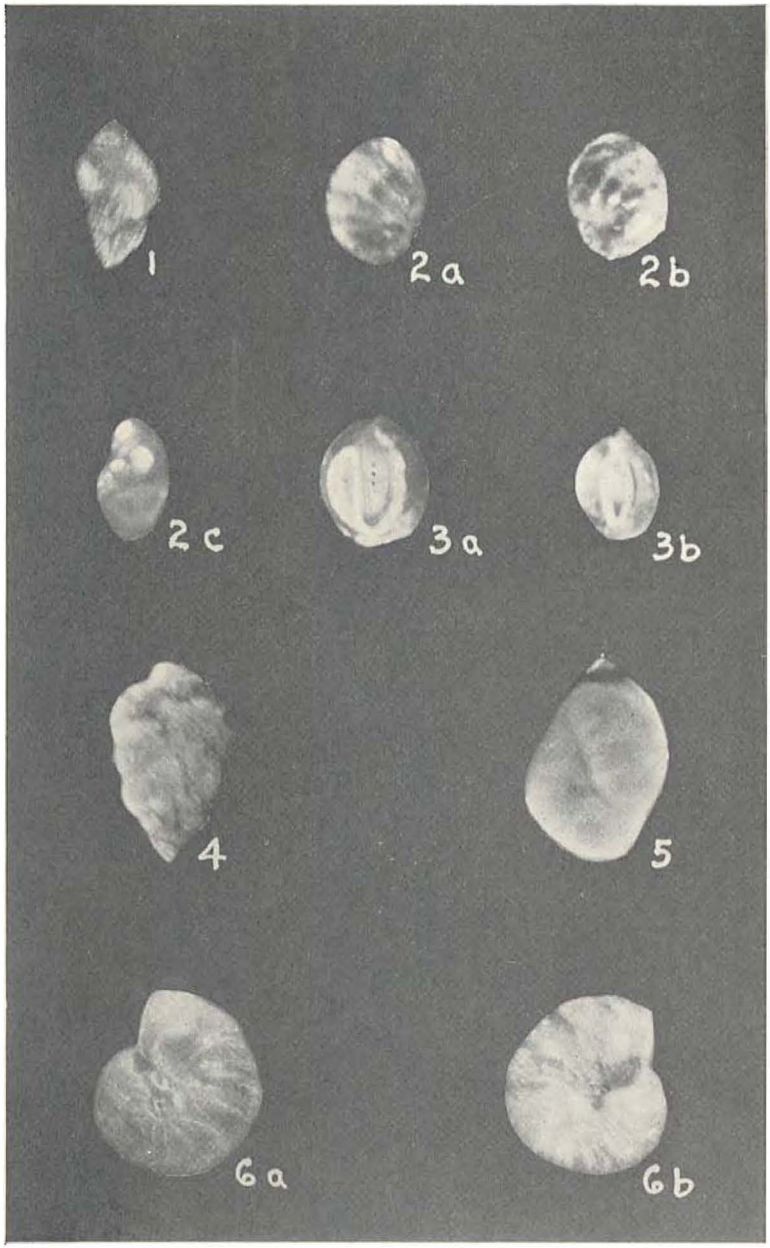
Fig. 6 *Anomalina pseudopapillosa* n. sp., (a), ventral view; (b), dorsal view, x 60, Navarro, near Delvalle on Onnion Creek.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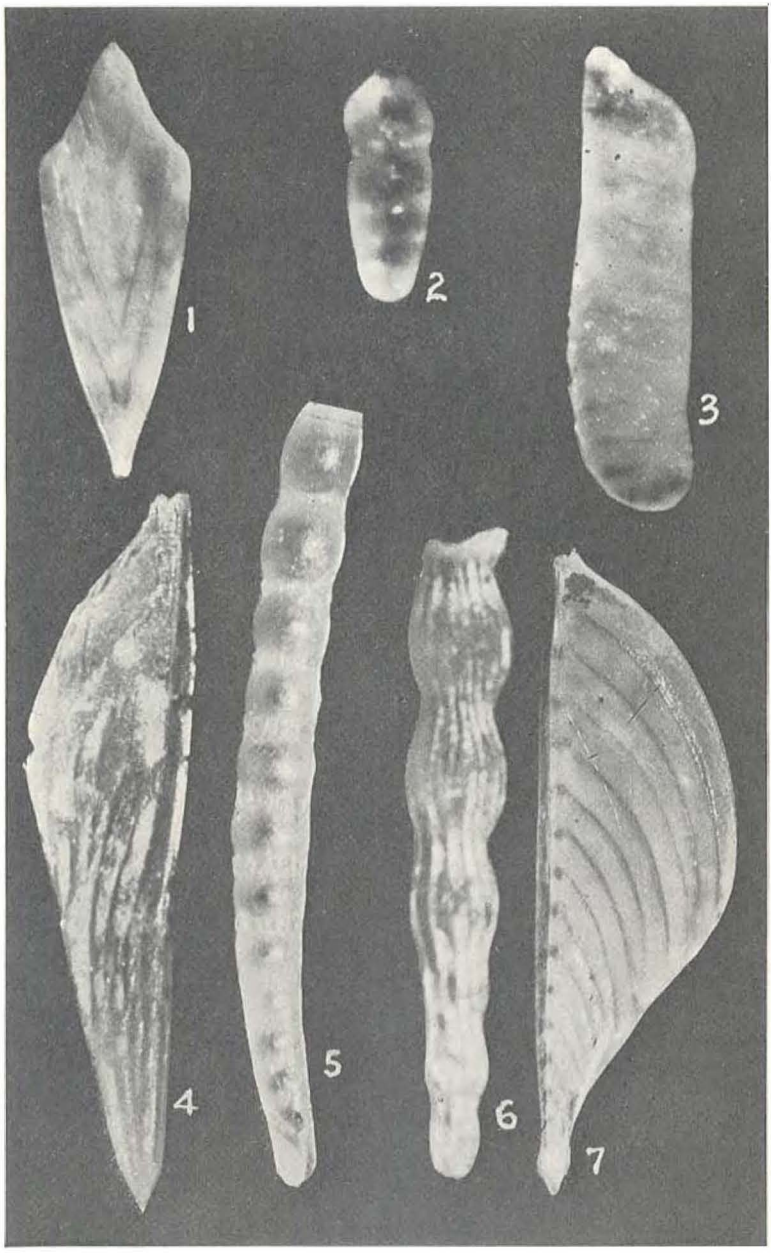
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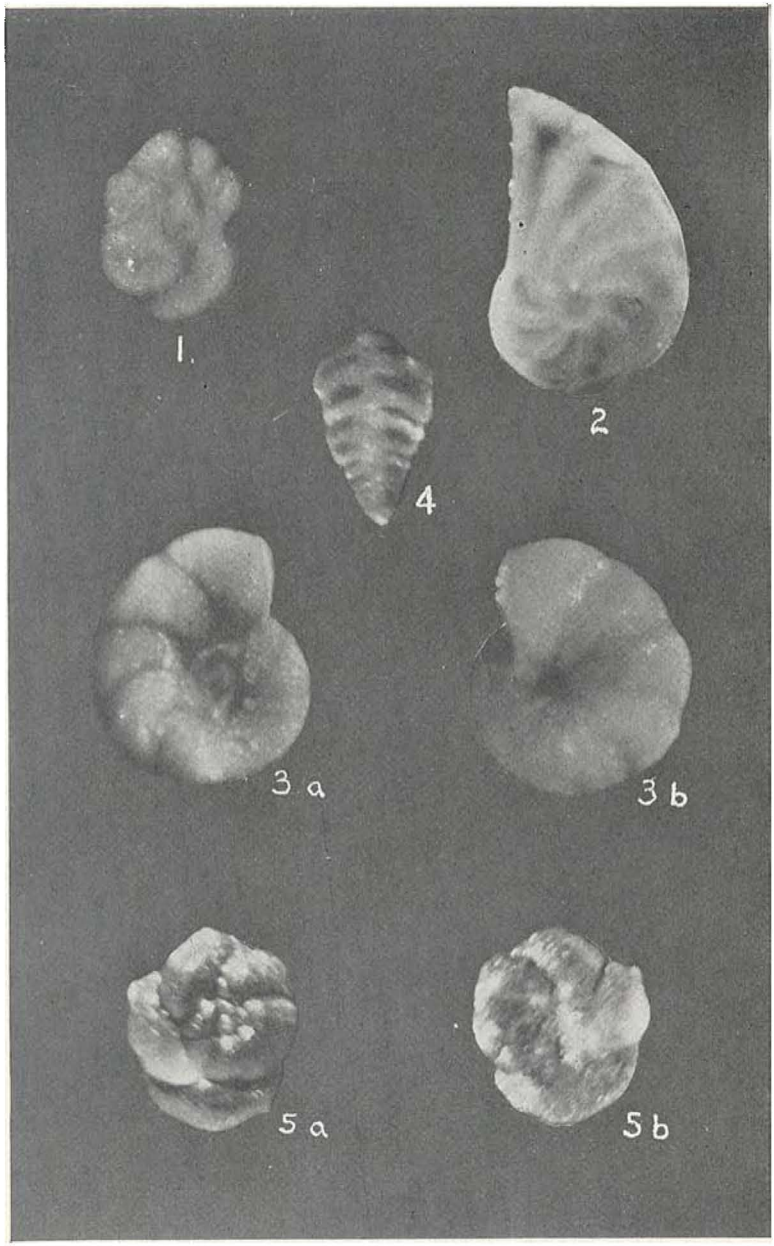
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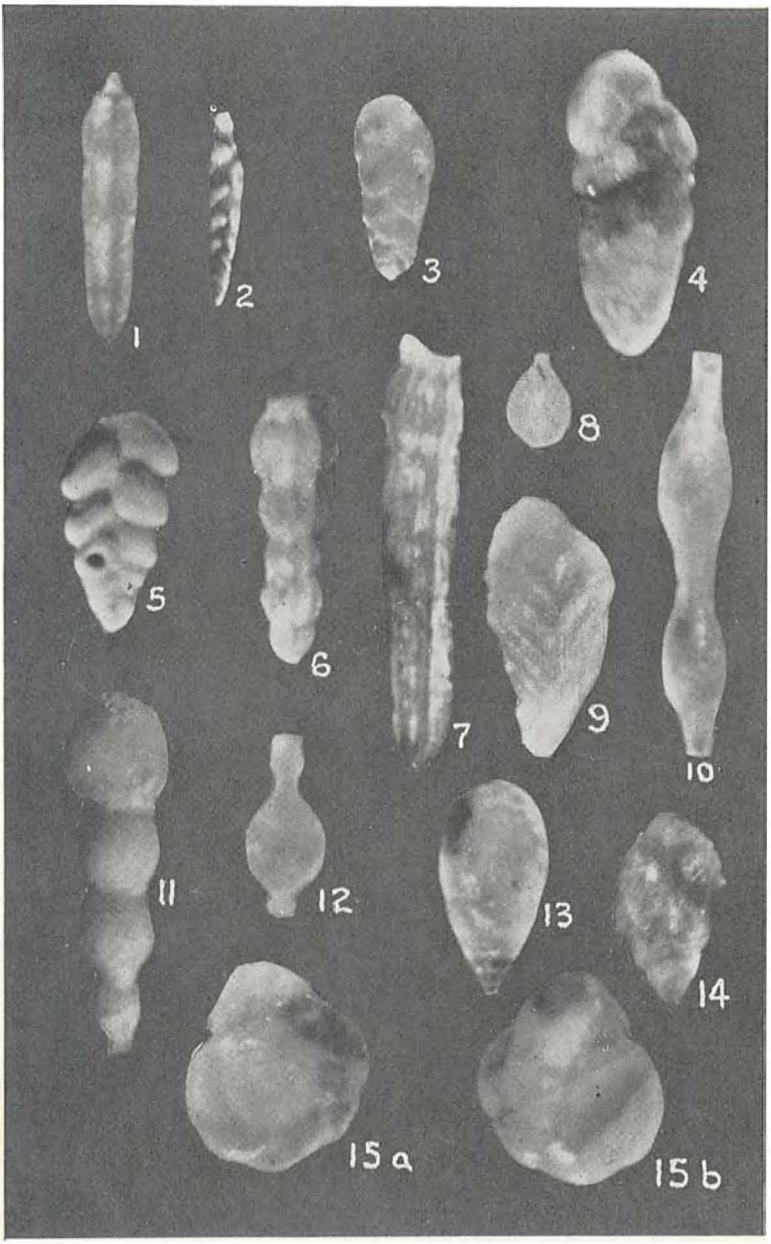
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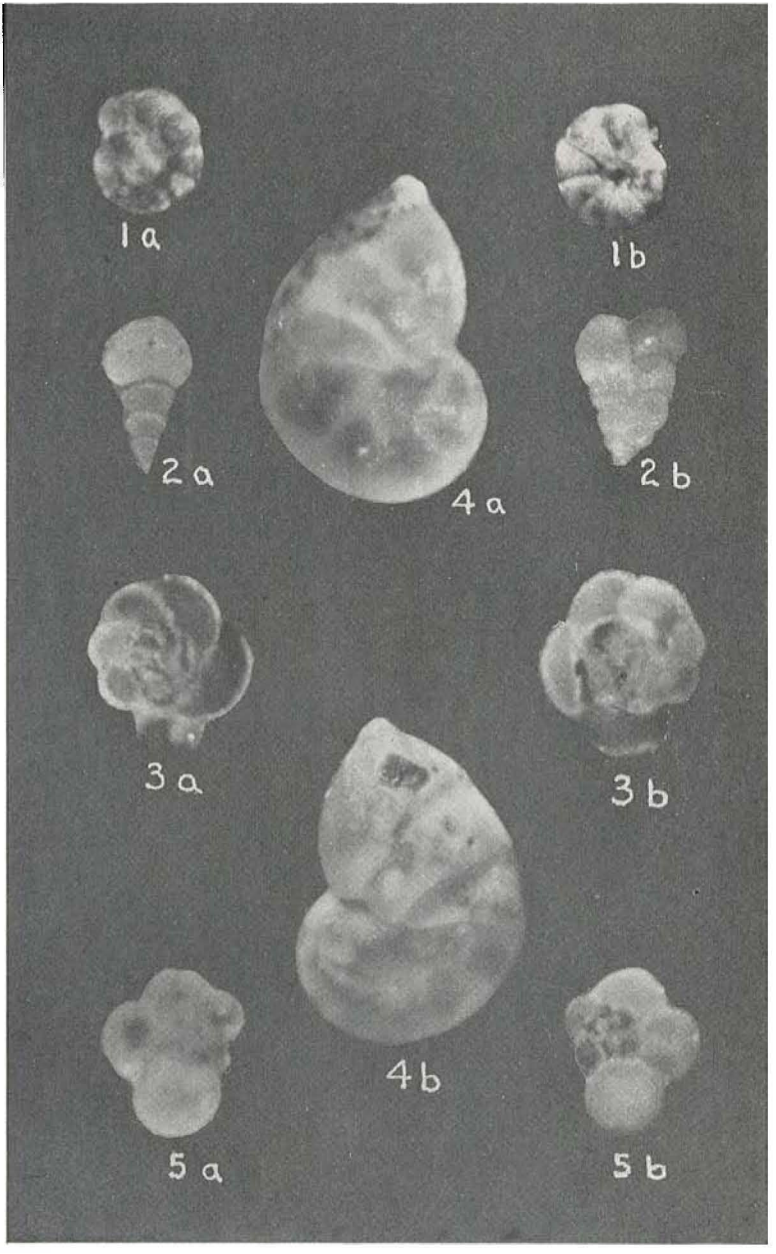
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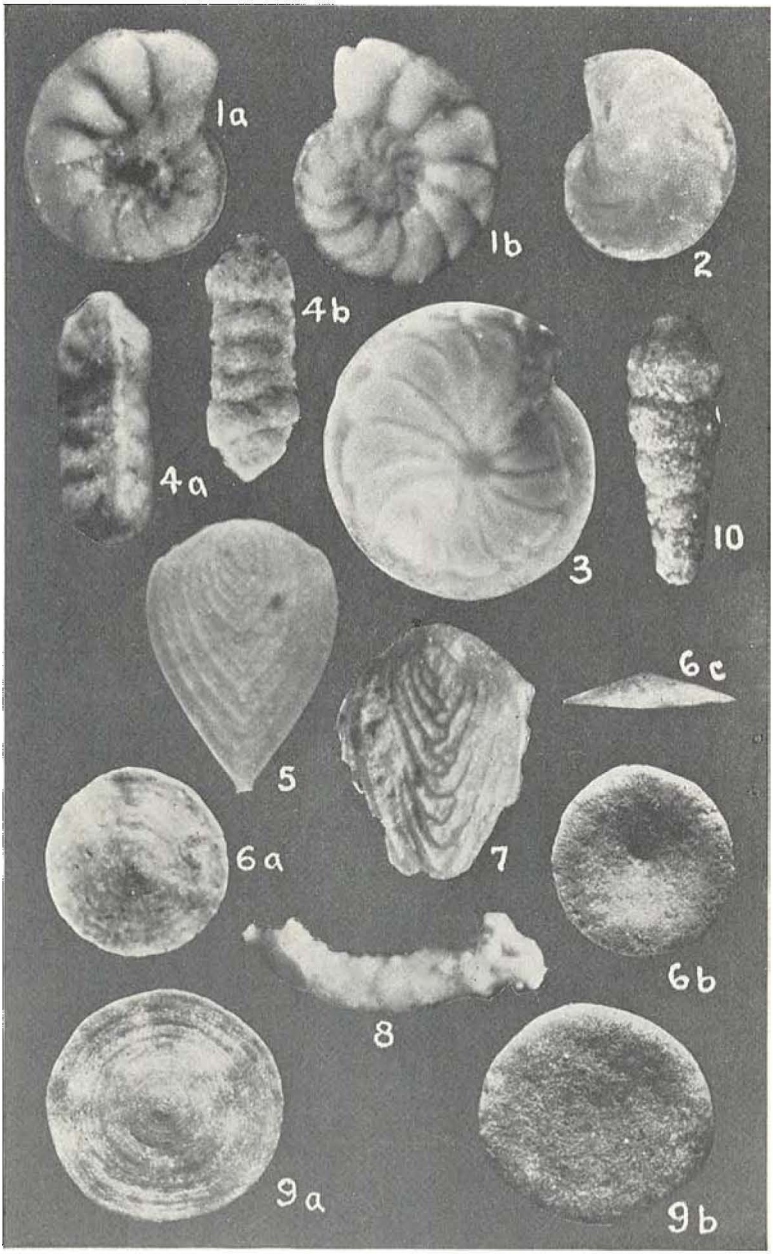
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Fig. 1 *Textularia conica* d'Orbigny, x 55, Washita group, Shoal Creek at Austin.

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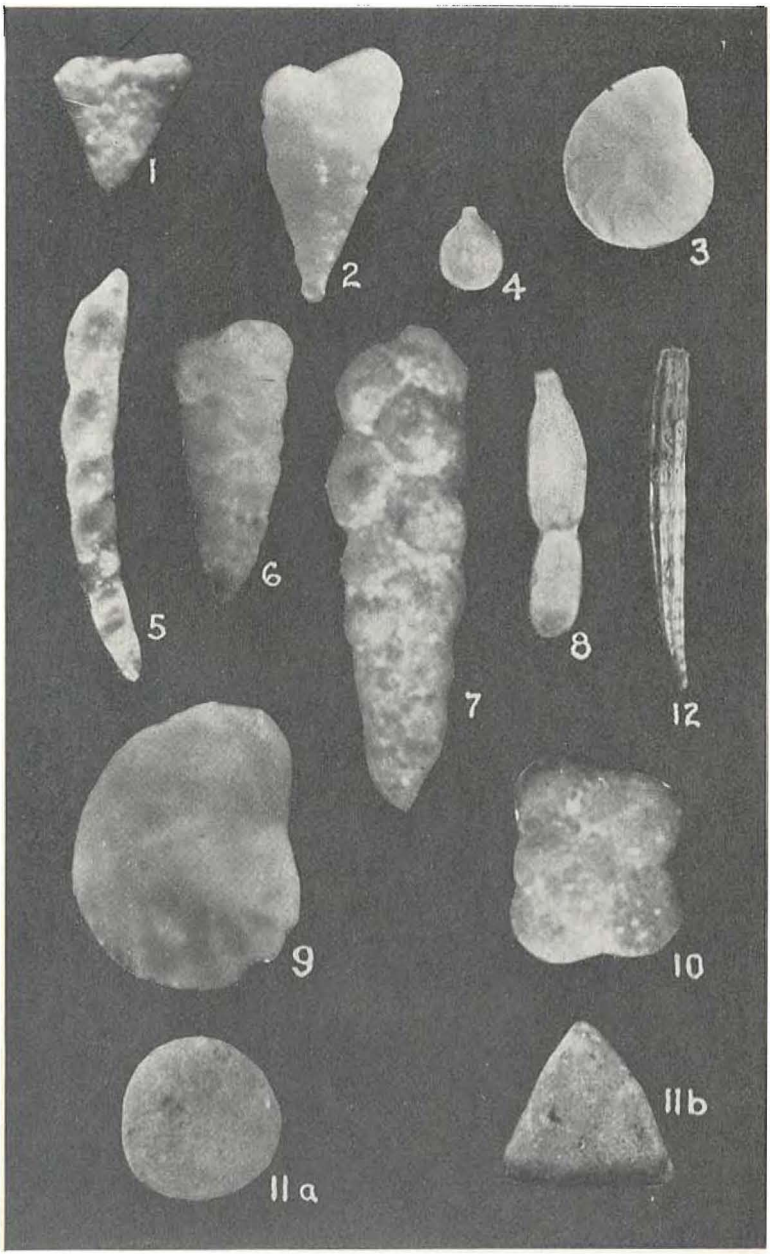
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Fig. 1 Buda limestone showing the cross-section of a *Textularia*, x 55.

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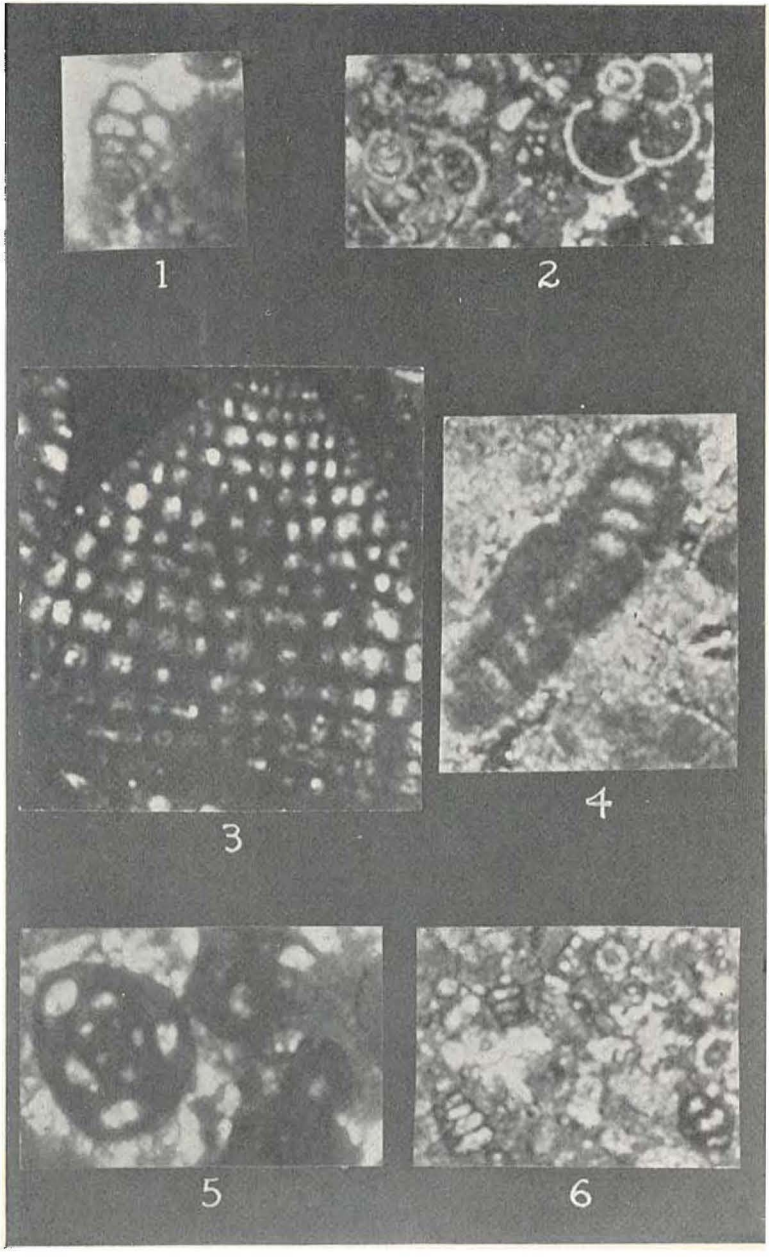
Fig. 4 Edwards limestone bearing a *Spiroloculina*, x 55.

Fig. 5 Edwards limestone containing typical shells of *Miliolina* sp., x 55.

Fig. 6 Georgetown limestone containing *Textularia*, x 55.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