

PLANKTONIC FORAMINIFERA FROM THE COMANCHEAN SERIES (CRETACEOUS) OF TEXAS

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ABSTRACT

A study of the Comanchean planktonic foraminifera from the Washita Group of North Central Texas indicates that the Albian portion of the Washita Group can be subdivided into the *Favusella washitensis* Assemblage Zone and three subzones: the *Hedbergella implicata* Subzone, the *H. punctata* Subzone, and the *H. delrioensis* Subzone. The early Cenomanian portion of the Washita Group is included in the *Rotalipora* s.s. Assemblage Zone, *Rotalipora evoluta* Subzone.

A new genus, *Favusella*, is proposed to include all

species with cancellate ornamentation, once known as *Globigerina washitensis* Carsey, and later included in the Genus *Hedbergella* by Loeblich and Tappan. Twelve new species are described.

The problem of the Albian-Cenomanian boundary is discussed. The writer agrees with Renz, *et al.* (1963, 1965) and Pessagno (1969) in regarding the Vraconian as the uppermost substage of the Albian and thence the top of the Lower Cretaceous.

INTRODUCTION

This paper deals with the stratigraphic distribution of planktonic foraminifera from the Comanchean Series (Lower Cretaceous) of North Central Texas. A detailed system of zonation is presented to facilitate the correlation of these strata with those in the European type area. This is the first comprehensive study of planktonic foraminifera from the Comanchean Series of Texas. To date, most of the literature dealing with the microfossils of the Comanchean strata focused on the benthonic foraminifera.

The system of zonation proposed herein has been integrated with that of the ammonites. Hopefully, it will offer a biostratigraphic framework that can be utilized to study other groups of fossils.

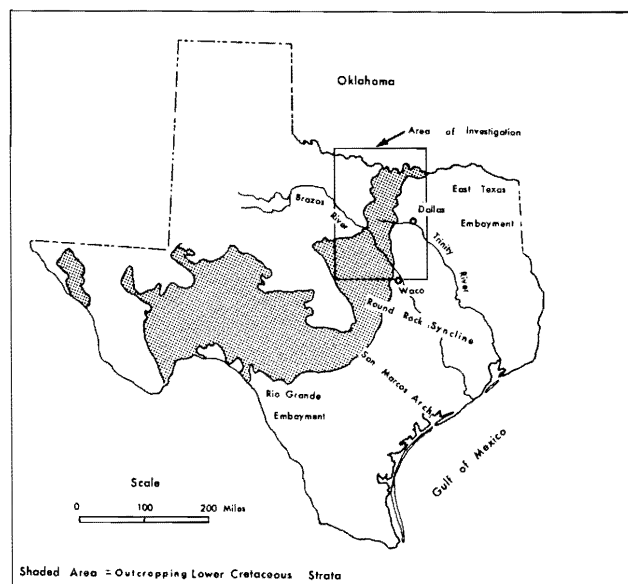
GEOLOGIC SETTING

The Cretaceous of Texas is divided into two series: the Gulfian Series and the Comanchean Series. The Comanchean Series includes a significant portion of

the Cretaceous of Texas. Comanchean deposits crop out across the central portion of the state from its northern boundary (Cook County) and extend to trans-Pecos Texas nearly to El Paso (text fig. 1). Southward, Comanchean strata can be traced in the subsurface to depths beyond the reach of the drill.

In recent years numerous investigators (e.g. Sellards *et al.*, 1932, Lozo, 1944, 1949, 1959, Young, 1959, Perkins, 1960, and Hendricks, 1967) have focused their study on the geology of North Central Texas.

The deposits examined in this report include those of the Trinity, Fredericksburg and the Washita Groups. The Trinity Group includes the Bluff Dale, Glen Rose and the Paluxy Formations (from oldest to youngest). The Fredericksburg Group includes the Walnut Marl, the Goodland Formation and the Kiamichi Formation. The Washita Group includes the Duck Creek, Fort Worth, Denton, Weno, Pawpaw, Main Street, and the Grayson Formations. Thicknesses and lithological characteristics of these formational units are summarized in text fig. 2. On the basis of lithic char-



TEXT FIGURE 1

Simplified map showing the Lower Cretaceous outcrop in Texas.

acteristics and faunal content of these formations in the North-Central Texas area an inner neritic environment is indicated for the Washita Group, while a more near shore (shallow-neritic to littoral) environment is indicated for both the Fredericksburg and Trinity Groups. The reader is referred to Perkins (1960) and Murray (1961) for detailed discussion of the lithostratigraphy of the Comanchean.

METHOD OF STUDY

Over 400 samples were collected at 21 localities in the North Central Texas area from Comanchean formations. Sample intervals were generally a maximum of five feet. However, in cases of rapid lithofacies changes, samples were often taken at intervals as close as a few inches apart. The procedure given by Pessagno (1967, p. 375) for processing samples was used. Selected specimens were mounted on plugs, shadow coated with carbon and then with gold-palladium, utilizing a Denton DV-502 vacuum evaporator. Ultimately, specimens were examined by means of JEOLCO-JSM-1 Scanning Electron Microscope.

The preservation of the planktonic foraminifera in the area of study was generally poor. Illustrated fossils in plates 1–7 are from seven localities only where the preservation was good enough.

The holotypes and the paratypes have been deposited at the U. S. National Museum, Washington, D. C. An additional set of paratypes is at the University of Texas at Dallas, Pessagno Collection.

ACKNOWLEDGEMENTS

The writer wishes to express his gratitude to both the geology department of Southern Methodist University and the Geosciences Division of The University of Texas at Dallas. The use of the Scanning Electron Microscope at The University of Texas at Dallas greatly facilitated this investigation.

Particular thanks are due to Dr. Emile A. Pessagno, Jr., of The University of Texas at Dallas for his continuous encouragement and patient guidance throughout the whole study. Special thanks are also due to Dr. Thomas E. Williams of Southern Methodist University who helped in reviewing the manuscript.

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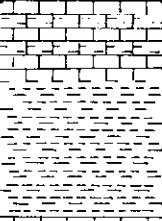
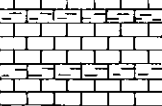
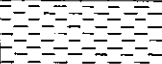
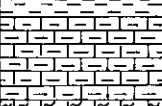
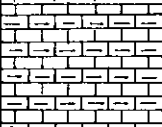
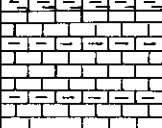
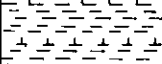
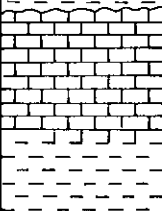
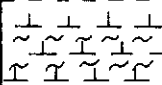
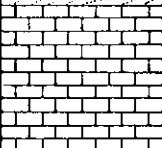
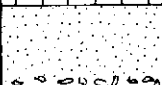
Finally, the writer wishes to express his appreciation to all of his colleagues for numerous fruitful discussions.

ZONATION OF THE COMANCHEAN STRATA

A summary of the proposed system of zonation and the stratigraphic distribution of the different foraminiferal species is shown in text fig. 3. The assemblage zone and its subdivisions are used here in the sense given by both the *Code of Stratigraphic Nomenclature* (American Commission on Stratigraphic Nomenclature, 1961, pp. 655–657) and in *Stratigraphic Classification and Terminology* (International Subcommittee on Stratigraphic Terminology, 1961, pp. 7–38). Two zones with four subzones can be recognized within Comanchean strata. These are (from oldest to youngest): the *Favusella washitensis* Assemblage Zone with three subzones: the *Hedbergella implicata*, *H. punctata* and *H. delrioensis* Subzones (late Albian) and the *Rotalipora* s.s. Assemblage Zone, *Rotalipora evoluta* Subzone (early Cenomanian). The relation of these zones to zonations of other workers is shown in text fig. 4.

THE *FAVUSELLA WASHITENSIS* ASSEMBLAGE ZONE

The *Favusella washitensis* Assemblage Zone (middle to late Albian) is characterized chiefly by species of *Favusella*, n. genus, together with *Hedbergella punctata*, n. sp., *H. implicata*, n. sp., and *H. delrioensis* (Carsey)

Stage	Group	Formation	Thick- ness in Feet	Phase	Lithology	Diagnostic Character
Lower Cenomanian	Washita	Grayson	70	Trans- gression		Brownish gray shale and marls with limestone in upper parts.
		Main Street	30		Regress- ion	
Pawpaw		15		Shales and fine sands with some pyritized layers.		
Weno		30		Alternating limestone and calcareous shale.		
Denton		40	Trans- gression			Marls and calcareous clay with shell aggregate on top.
Fort Worth		40			Dense gray limestone and marls.	
Duck Creek		45			Calcareous mudstones and chalky marls.	
Kiamichi		25			Bluish silty clay with thin limestone interbeds.	
Middle Albian		Fredericksburg	Goodland	110	Regression	
	Walnut		22			Marls, marly clays with shell aggregate.
	Paluxy		150			Poorly consolidated to cross-bedded sands.
Lower Albian	Trinity	Glen Rose	150	Trans- gression		Massive chalky limestone.
		Bluff Dale	90	Regress- ion		Sands, sandstones and conglomerates.

Stratigraphic distribution of Globigerinacea in the Comanchean Series and zonal framework for North Central Texas.

Co-type Localities: There is no one locality where the entire assemblage zone can be found. Localities Tex 2, Tex 4, Tex 6, Tex 7, Tex 8, and Tex 11 represent a composite section including this assemblage zone (text figs. 5, 6 and 7).

This is the lowest subzone in the *Favusella washitensis* Assemblage Zone. It is characterized by an assemblage

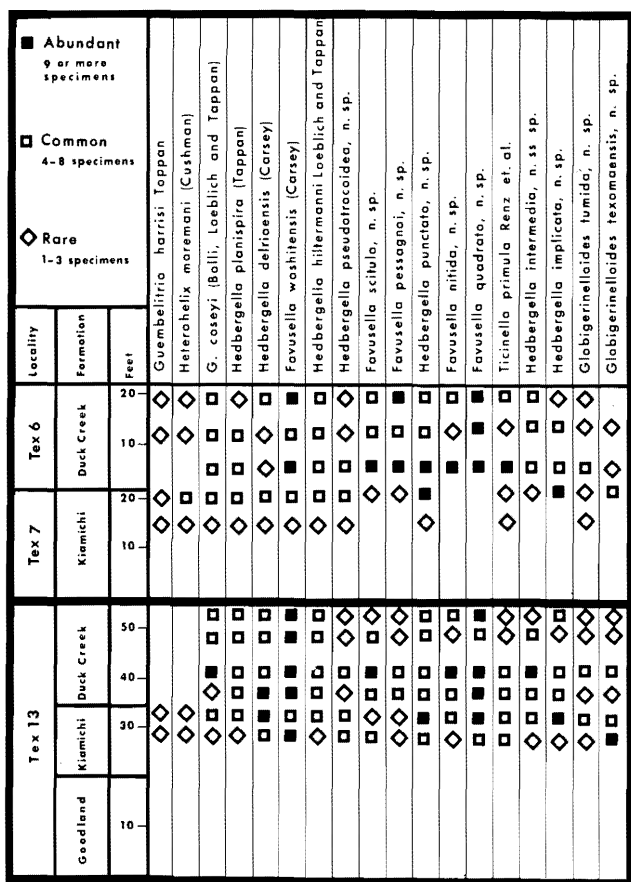
Generalized composite section of the Comanche Series in North Central Texas.

Tex 1				Abundant 9 or more specimens	
Main Street	Grayson	Locality	Formation		
					Feet
10				Ratalipora evoluta Sigal	
30				Praeglabotruncana delrioensis (Plummer)	
40				Schackoina primitiva Tappan	
50				Clavibedbergella subretacea (Tappan)	
				Gubkinella graysonensis [Tappan]	
				Guembeliriella graysonensis Tappan	
				Glaberinelloides bentonensis [Morrow]	
				Guembelitria harrisi Tappan	
				Heterohelix moremani [Cushman]	
				G. caseyi (Bolli, Loeblich and Tappan)	
				Hedbergella planispira (Tappan)	
				Hedbergella delrioensis (Carsey)	
				Favusella washitensis (Carsey)	
				Hedbergella hilfermanni Loeblich and Tappan	

Foraminiferal assemblage of locality Tex 1.

TEXT FIGURE 4

Correlation chart showing the zonation of the Albian by different investigators.



TEXT FIGURE 6

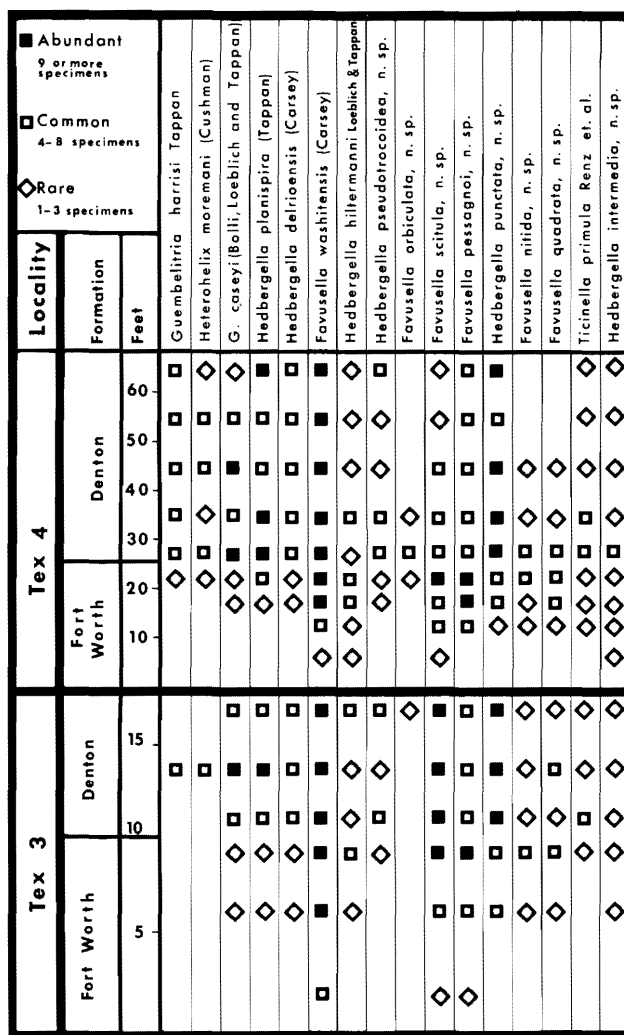
Foraminiferal assemblage of localities Tex 6, 7, and 13.

Co-type localities: Duck Creek and Kiamichi Formations, Westover Hills, Fort Worth, Tarrant County. Localities Tex 6, and Tex 7 (text fig. 6).

THE *HEDBERGELLA PUNCTATA* SUBZONE

The *H. punctata* Subzone is characterized by an assemblage including *Hedbergella punctata*, n. sp., *H. pseudotrocoidea*, n. sp., *Favusella pessagnoii*, n. sp., and *Ticinella primula* Luterbacher. All of these species make their final appearance in the *H. punctata* Subzone. *Favusella nitida*, n. sp., and *F. quadrata*, n. sp., tend to be rare in this subzone. The Denton and Fort Worth Formations occur within this subzone in the North Central Texas area.

Type locality: A complete section of the Fort Worth and Denton Formations is exposed 2 miles east of Justin, Denton County, locality Tex 4 (text fig. 7).



TEXT FIGURE 7

Foraminiferal assemblage of localities Tex 3 and Tex 4.

THE *HEDBERGELLA DELRIOENSIS* SUBZONE

Species characterizing this subzone are *H. delrioensis* (Carsey), *H. planispira* (Tappan), *Favusella washitensis* (Carsey), and *F. hiltermanni* Loeblich and Tappan. Species characteristic of the *R. evoluta* Subzone above and *H. punctata* Subzone below are absent. This is the upper-most subzone of the Albion portion of the Comanchean Series. It includes the Weno, Pawpaw, Main Street and the lowermost part of the Grayson Formation.

Co-type Localities: A composite section representing the subzone occurs at the following localities: Tex 10, Tex 2 (Cook County) and Tex 1 (Denton County) (text fig. 5).

THE *ROTALIPORA* S.S. ASSEMBLAGE ZONE

The definition of this zone given by Pessagno (1969, pp. 7–8) is followed herein. This zone of early Cenomanian age is characterized mainly by species of *Rotalipora* s.s. Pessagno (1969, p. 8) subdivided this zone into two subzones, a lower *R. evoluta* Subzone and an upper *R. cushmani-greenhornensis* Subzone. Most of the Grayson Formation is included in the lower part of the *R. evoluta* Subzone.

BIOSTRATIGRAPHY OF THE COMANCHEAN SERIES

A primary objective of this study was to establish a system of planktonic foraminiferal zonation and integrate this system of zonation with that of the ammonites. There are two basic problems that greatly influence any attempt at correlating the Lower Cretaceous strata of North Central Texas with those in the type European area: 1) The type sections in Europe are poorly defined and 2) The planktonic foraminifera and their stratigraphic distribution in the type areas are not well documented.

These two problems were discussed in detail by different authors during the "Colloque sur le Crétacé Inférieur" which was held in Lyon, September 1963. A resume of the results and discussions of this colloquium was given by Collignon (1963, pp. 292–297). In almost all of these publications the zonation of the Lower Cretaceous was based primarily on ammonites and virtually no attempt was made to integrate the ammonite zones with foraminiferal zones. Furthermore, no planktonic foraminiferal zonation was proposed for the Lower Cretaceous. In his conclusions and discussions of the colloquium, Collignon (1965, pp. 313–318), indicated the Albian should be subdivided into lower, middle, and upper divisions. The Lower Albian was subdivided into a lower *Leymeriella tardefurcata* Zone and an upper *Douvilleiceras mammillatum* Zone. The middle Albian was subdivided into two zones, a lower *Hoplites dentatus*-*Lyelliceras lyelli* Zone, and an upper *Euhoplites lautus* or *E. nitidus* Zone. The upper Albian was subdivided, in ascending order, into three zones: *Dipoloceras cristatum*, *Mortonicerias inflatum* and *Stoliczkaia dispar*. The uppermost zone, that of *Stoliczkaia dispar*, was considered equivalent to the Vraconian. The independent character of the fauna of the Vraconian was not questioned by the colloquium, but it was considered dangerous to give it separate stage status as it might further confuse the definition of the Albian *sensu strictu*. Because the colloquium on the Upper Cretaceous (Colloque sur le Crétacé Supérieur

Francais, Paris, 1959), considered the Cenomanian to be the lower most stage of the Upper Cretaceous, it was the decision of the colloquium on the Lower Cretaceous to consider the Vraconian as defined by Renevier to be part of the Upper Albian *Stoliczkaia dispar* Zone.

A resume of the decisions of the colloquium by Sigal (1963, pp. 293–296) showed the necessity of organizing a commission to study in detail the type sections of not only the Albian, but also the Berriasian-Barremian. In 1963 Sigal (p. 294) presented a foraminiferal distribution chart in which he included the range zones of various foraminiferal species and in which he mentioned that the tabulation of these range zones was a function of the zones adopted in the conclusions of the colloquium. This chart was compiled by Sigal and Moullade. Later Sigal (1965b, p. 500) recorded the distribution of the Lower Cretaceous Foraminifera of France and other countries. There is a difference between the two charts in the range zones of some species (text fig. 4). It is interesting to note that in the resume of the colloquium (Sigal, 1963, p. 296) the Upper Albian was subdivided, in ascending order, into the following zones: *Dipoloceras cristatum*, *Mortonicerias inflatum*, *Stoliczkaia blancheti* and *S. dispar* (zone of "*Mortonicerias*" *perimflatum*). The last two zones, *S. blancheti* Zone and *S. dispar* Zone, correspond to the Vraconian.

The stratigraphy and paleontology of some Albian and Cenomanian deposits in the Jura Mountains within the Canton de Neuchâtel (Western Switzerland) has been discussed by Renz *et al.* (1963, pp. 1074–1083) and is one of the few papers that combines both ammonite and foraminiferal zonation. These workers followed the decisions of the colloquium and subdivided the Albian into three substages that include four ammonite zones, the uppermost considered to represent the Vraconian (text fig. 4), while the upper part of the early Cenomanian *Mantelliceras mantelli* Zone includes keeled forms (*Rotalipora*).

Later, Renz *et al.* (1965, p. 77) restudied the rich fossiliferous deposits of the Vraconian stratotype near La Vraconne, in the Canton de Vaud of the Swiss Jura Mountains and compiled a faunal list that included both ammonites and foraminifera. The *Stoliczkaia dispar* zone (Vraconian) was considered of Albian age. Among the foraminifera recorded in the Vraconian stratotype are three species of *Hedbergella*. Significantly, no keeled trochospiral Globigerinacea were reported. However, overlying lower Cenomanian strata assignable to the *Mantelliceras mantelli* Zone contain keeled trochospiral Globigerinacea, i.e. *Rotalipora*.

A planktonic foraminiferal assemblage mainly of *Hedbergella* and *Ticinella* species was recorded by Moullade (1969, pp. 460–467). Not only did he distinguish the Vraconian from the upper Albian, but he subdivided it into upper and lower (text fig. 4).

After examining the European literature which mentions both the foraminiferal and ammonite assemblages of Cenomanian strata, Pessagno (1969, p. 22) indicated “. . . The base of the *Rotalipora* s.s. Assemblage Zone corresponds more or less to the base of the *Mantelliceras mantelli* Zone, and thus, to the Cenomanian-Albian boundary. In North America, for example, Sellards and others (1932, p. 395) note *Submantelliceras* (*Cottreaquites*) and *Adkinsia* form the Grayson Formation. These ammonites are now regarded as indices for the lower Cenomanian and certainly occur within both the lower part of the *Mantelliceras mantelli* Zone and the *Rotalipora* s.s. Assemblage Zone.”

A detailed ammonite zonation for the Fredericksburg Group was presented by Young (1966, pp. 13–22). He placed the boundary between the upper Albian and the lower Cenomanian at the top of the *Pervinqueria equidistans* Zone (top of the Georgetown Formation of South Central Texas). Later Young (1967) presented correlation charts of the different formations of the Comanchean Series throughout Texas based on ammonite zonation. In the North Central Texas area, he placed the upper Albian-lower Cenomanian boundary at the base of the *Plesioturritites brazoensis* Zone (Young, 1967, table 2, p. 67). This zone includes the Main Street Formation which Young (1967, table 8, p. 70) correlates with the upper portion of the Georgetown Formation of South Central Texas (text fig. 4).

A provisional correlation of Gayle Scott's North Central Texas Albian ammonite zones and similar zones of Spath (1942) in England and of Breistroffer (1947) in France was figured by Lozo (1943, pp. 1069–1075) and shows the *Stoliczkaia dispar* and *Turritites brazoensis* of the Grayson and Main Street Formations to be late Albian in age (text fig. 4). This is, in effect, what the French colloquium on the Lower Cretaceous decided.

It is clear now that the controversy centers around the *Stoliczkaia dispar* Zone. Is it early Cenomanian in age or late Albian in age? Or, in essence, should the Vraconian be placed with the Cenomanian and the Upper Cretaceous or with the Albian and the Lower Cretaceous? The planktonic foraminiferal zonation proposed by the writer (text fig. 4) and integrated with the ammonite zonation presented by Young (1967,

p. 68) and Lozo (1943, p. 1070) for the North Central Texas area indicates that the *Stoliczkaia dispar* Zone should be of Albian age rather than Cenomanian. The first appearance of the keeled trochospiral Globigerinacea, e.g., *Rotalipora*, provides a good datum point that can be taken both as lower limit of the Cenomanian and the Upper Cretaceous. The first evolutionary occurrence of keeled forms was found to be at the lower portion of the Grayson Formation in the area of study (text figs. 3 and 5). This is in agreement with the findings of Pessagno (1969, p. 22) and Renz *et al.* (1965, p. 77). The writer believes that the boundary should be placed at a horizon delimited on the basis of maximum faunal and floral change. The final solution of the Upper Cretaceous-Lower Cretaceous boundary problem in North America, Eurasia and elsewhere can only be reconciled through careful deliberation by an international committee.

SYSTEMATIC PALEONTOLOGY

Order FORAMINIFERIDA

Superfamily GLOBIGERINACEA Carpenter,
Parker and Jones, 1892

Family HETEROHELICIDAE Cushman, 1927

Subfamily GUEMBELITRIINAE Montanaro
Gallitelli, 1957

Genus *Guembelitra* Cushman, 1933

Guembelitra harrisi Tappan
Plate 6, fig. 7

Guembelitra harrisi TAPPAN, 1940, p. 115, pl. 19, figs. 2a–b;
PESSAGNO, 1967, p. 258, pl. 48, figs. 12, 13.

Remarks: This species is distinguished from *G. cretacea* Cushman by the less inflated chambers, the low arched aperture and the relatively more elongate test.

Range: *Rotalipora* s.s. Assemblage Zone (Cenomanian) to *Favusella washitensis* zone (Albian).

Occurrence: *G. harrisi* was noted in the Grayson Formation. It is especially abundant in the middle part of the Grayson. It is rare in Main Street and Kiamichi Formations. Few specimens were recorded in the Walnut and Goodland Formations of North Central Texas.

Genus *Gubkinella* Suleymanov, 1955

Gubkinella graysonensis (Tappan)
Plate 1, figs. 1–3

Globigerina graysonensis TAPPAN, 1940, p. 122, pl. 19, figs. 15–17; 1943, p. 513, pl. 82, figs. 15a–c.

Remarks: This species was originally described from the Grayson Formation of Texas by Tappan (1940, p. 122). She recorded it again (1943, p. 513) from the Duck Creek Formation (Locality HTL60) in Grayson County, Texas.

Occurrence: In the present study, *G. graysonensis* was relatively abundant in the Grayson Formation, rare in the Duck Creek and extremely rare in the Goodland and the Walnut Formations.

Genus *Gumbelitriella* Tappan, 1940

Gumbelitriella graysonensis Tappan

Gumbelitriella graysonensis TAPPAN, 1940, p. 116, pl. 19, figs. 3a-c.

Remarks: This species was originally described by Tappan (1940, p. 116) from the Grayson Formation of north Texas. In the present study, it was found to be rare in the samples from the Grayson Bluff. It was not recorded in units below the Grayson; it is probably restricted to the *R. evoluta* Subzone.

Subfamily HETEROHELICINAE Cushman, 1927

Genus *Heterohelix* Ehrenberg, 1844

Heterohelix moremani (Cushman)

Plate 6, fig. 12

Guembelina moremani CUSHMAN, 1938, p. 10, pl. 2, figs. 1-3. *Heterohelix moremani* (Cushman), PESSAGNO, 1967, p. 260, pl. 48, figs. 10-11, pl. 89, figs. 1, 2.

Remarks: The specimens recorded here are close to the holotype figured by Pessagno (1967, pl. 89, figs. 1, 2), from the Cushman Collection at the U. S. National Museum. Pessagno's figures 10 and 11 of plate 48 from Britton Formation, Eagle Ford Group have more inflated chambers and are less elongate than the holotype.

Range: In this investigation, *Heterohelix moremani* was recorded in the *R. evoluta* Subzone and the *Favosella washitensis* Assemblage Zone.

Occurrence: *H. moremani* has been observed in the Grayson, Main Street Formation and Kiamichi Forma-

tions. In the Denton, Walnut, and Goodland Formations it is extremely rare.

Family PLANOMALINIDAE Bolli, Loeblich, and Tappan, 1957

Genus *Globigerinelloides* Cushman and Ten Dam, 1948

Globigerinelloides bentonensis (Morrow)

Plate 1, figs. 4-6

Anomalina bentonensis MORROW, 1934, p. 201, pl. 30, figs. 4a,b.

Globigerinelloides bentonensis (MORROW), LOEBLICH and TAPPAN, 1961, p. 267, pl. 2, figs. 8-10; PESSAGNO, 1967, p. 275, pl. 76, figs. 10-11.

Range: *Rotalipora* s.s. Assemblage Zone.

Occurrence: This species is common in the Grayson Formation. It was originally described from the Hartland Member of the Greenhorn Limestone of Kansas to which a late Cenomanian age was assigned by Loeblich and Tappan (1961, p. 268).

Globigerinelloides caseyi (Bolli,

Loeblich and Tappan)

Plate 1, figs. 7-9

Planomalina caseyi BOLLI, LOEBLICH and TAPPAN, 1957, p. 24, pl. 1, figs. 4a-5b.

Globigerinelloides caseyi (Bolli, Loeblich and Tappan), 1964, LOW, pp. 122-123; PESSAGNO, 1967, p. 276, pl. 49, figs. 2-5.

Range: *F. washitensis* Assemblage Zone to *Rotalipora* s.s. Assemblage Zone.

Occurrence: *G. caseyi* is rare in the Grayson and Main Street Formations. However, it is common in both the Duck Creek and Kiamichi Formations of North Central Texas.

Loeblich and Tappan (1961, pp. 268, 269) recorded this species as *G. eaglefordensis* (Moreman) from the Gault of England, from the Blake Plateau escarpment in submarine core A167-24, Lamont Geological Observatory, the Eagle Ford of Texas, and the Grayson and Del Rio formations.

PLATE 1

1-3 *Gubkinella graysonensis* (Tappan)

Tex 1. Grayson Formation; Marker = 25 microns.

4-6 *Globigerinelloides bentonensis* (Morrow)

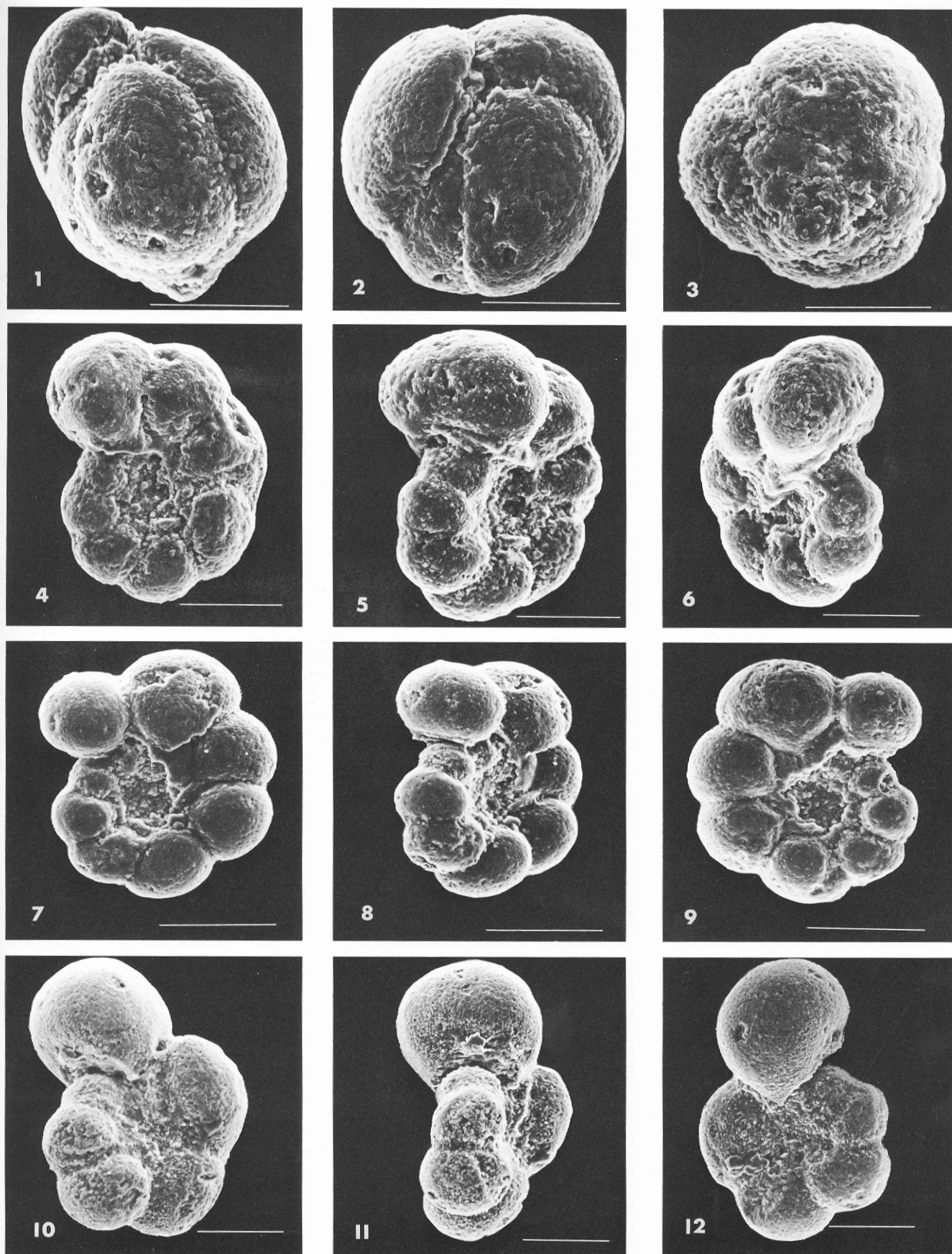
Tex 1. Grayson Formation; Marker = 100 microns.

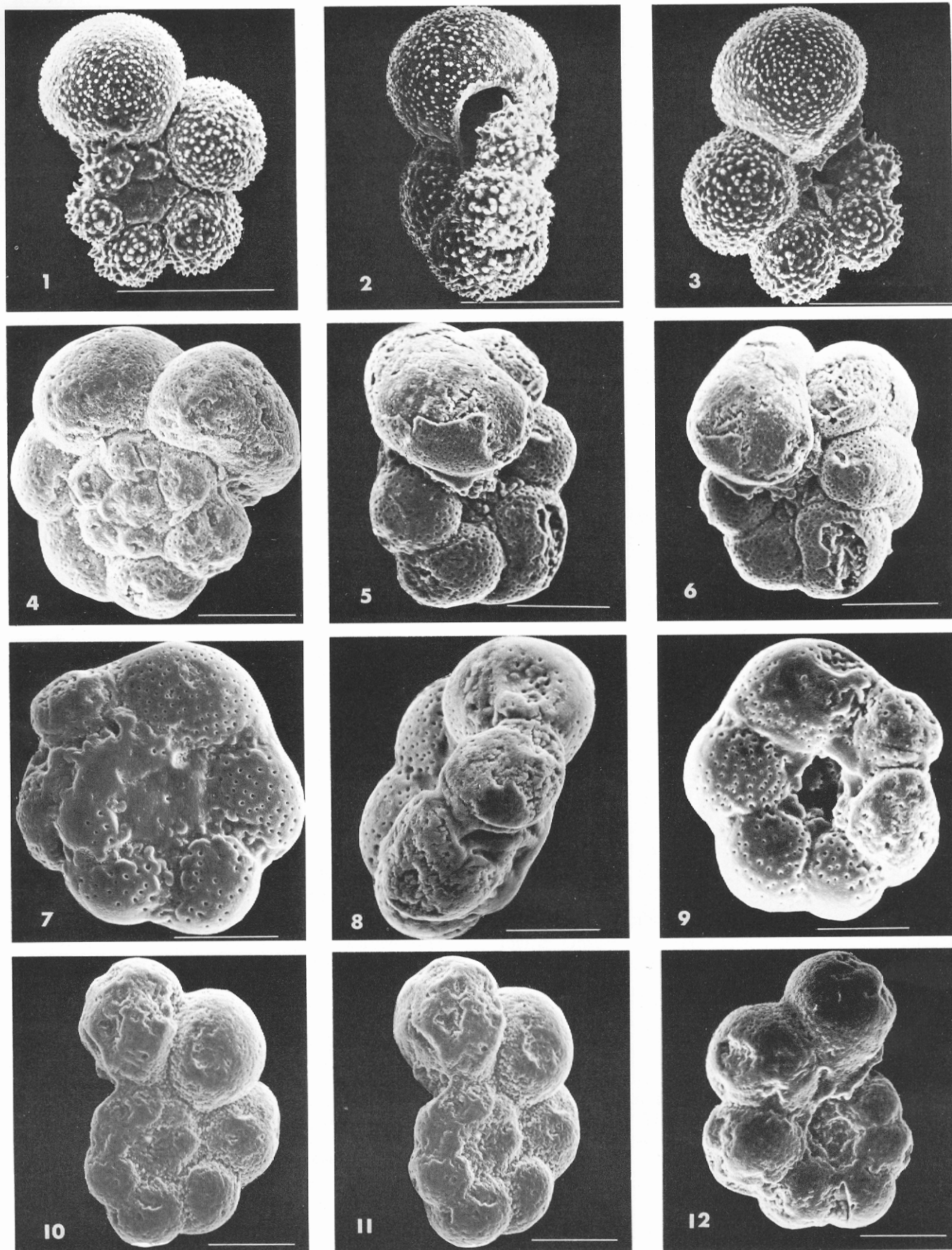
7-9 *Globigerinelloides caseyi* (Bolli, Loeblich and Tappan)

Tex 1. Grayson Formation; Marker = 75 microns.

10-12 *Globigerinelloides tumidus* n. sp.

Tex 13. Duck Creek Formation; Holotype: USNM 172783; Marker = 100 microns. Notice the size of the last chamber relative to the size of the test.





Globigerinelloides texomaensis Michael, new species
Plate 6, figs. 9–11

Description: Test medium sized, planispiral, involute; five subglobular, fairly inflated chambers, increasing gradually in size; last chamber compressed laterally and protrudes to cover part of the narrow umbilicus; peripheral outline lobulate; sutures distinct, straight and radial; primary aperture a broad low interiomarginal, equatorial arch, bordered above by a narrow lip rarely preserved in its entirety.

Remarks: *G. texomaensis*, n. sp., is distinguished by its lobulate compressed shape and the smoothness of its last chamber that usually protrudes on both sides covering part of the narrow umbilicus. This species differs from both *G. bentonensis* (Morrow) and *G. caseyi* (Bolli, Loeblich and Tappan) by having less chambers in the last whorl (usually five) that increase rapidly in size.

G. texomaensis, n. sp., derives its name from Lake Texoma.

Dimensions: Diameter of Holotype 265μ ; thickness 145μ ; other specimens average 260μ in diameter and 140μ in thickness.

Type locality: Tex 13 Grayson County (sample L.T.1); Duck Creek Formation.

Deposition of types: Holotype: USNM 172781; Paratype: USNM 172782; Paratypes: F.M. 1; Pessagno Collection, University of Texas at Dallas.

Range: Upper Albian, *Favusella washitensis* Assemblage Zone, *Hedbergella implicata* Subzone.

Occurrence: *G. texomaensis*, n. sp., is common in the lower horizons of Duck Creek Formation and the upper horizons of Kiamichi Formation.

large and oval; sutures distinct, depressed, straight and radial; primary aperture a low interiomarginal equatorial arch with a narrow broadening lip rarely preserved.

Remarks: This species is characterized by the inflated last chamber that is loosely connected to the rest of the test; the lowly arched aperture, and the small number of chambers in last whorl. The shape of the last chamber and the absence of the circular configuration of the test distinguish this species from both *G. bentonensis* (Morrow) and *G. caseyi* (Bolli, Loeblich and Tappan).

G. tumidus, n. sp., derives its name from *tumidus-a-um* (Latin) = swollen or inflated.

Dimensions: Diameter of Holotype = 325μ , thickness of Holotype = 120μ . Other specimens (15) average 330μ in diameter and 125μ in thickness.

Type locality: Tex 13 Grayson County (sample L.T.Dc.4); Duck Creek Formation.

Deposition of types: Holotype: USNM 172783; Paratypes USNM 172784; paratypes F.M. 2; Pessagno Collection, University of Texas at Dallas.

Range: Upper Albian, *Favusella washitensis* Assemblage Zone, *Hedbergella implicata* Subzone.

Occurrence: *G. tumidus*, n. sp., is common in the Kiamichi and Duck Creek Formations of North Central Texas.

Family SCHACKOINIDAE Pokorny, 1958

Genus *Schackoina* Thalmann, 1932

Schackoina primitiva Tappan

Schackoina primitiva TAPPAN, 1940, p. 123, pl. 18, fig. 14; LOEBLICH and TAPPAN, 1961, p. 272, pl. 1, fig. 1.

Remarks: This is an extremely rare species in the Grayson Formation throughout Central and North Central Texas.

Family ROTALIPORIDAE Sigal, 1958

Type genus: *Rotalipora* Brotzen, 1942.

Remarks: The emended definition given by Pessagno (1967, p. 280) is herein followed.

PLATE 2

1–3 *Hedbergella delrioensis* (Carsey)

Tex 1. Grayson Formation; Marker = 100 microns.

4–6 *Hedbergella implicata* n. sp.

Tex 7. Kiamichi Formation. Holotype: USNM 172785; Marker = 100 microns. Notice the overlapping chambers and the shape and size of the last chamber.

7–9 *Hedbergella intermedia* n. sp.

Tex 7. Kiamichi Formation; Holotype: USNM 172787; Marker = 100 microns. Notice the circular shape of the test and the gradual increase in size of the chambers.

10–12 *Hedbergella planispira* (Tappan)

Tex 13. Duck Creek Formation; Marker = 100 microns.

Subfamily HEDBERGELLINAE Loeblich
and Tappan, 1961

Genus *Hedbergella* Brönnimann and
Brown, 1958

Hedbergella delrioensis (Carsey)
Plate 2, figs 1–3

Globigerina cretacea d'Orbigny var. *delrioensis* CARSEY, 1926,
p. 43, no figures.

Globigerina cretacea d'Orbigny, TAPPAN, 1940, p. 121, pl. 19,
fig. 11; 1943, p. 512, pl. 82, figs. 16, 17.

Hedbergella delrioensis (Carsey), LOEBLICH and TAPPAN, 1961,
p. 275, pl. 2, figs. 11–13; PESSAGNO, 1967, p. 282, pl. 48,
figs. 1, 2, 3–5.

Remarks: This species was first described, without a figure, by Carsey (1926, p. 43) from the Grayson Formation of Travis County, Texas. The diagnosis given by Pessagno (1967, p. 282–283) is followed herein.

Range: *F. washitensis* Assemblage Zone and *R. evoluta* Subzone in the area of the study.

Occurrence: *H. delrioensis* was found in all the formations of the Washita Group and in the Kiamichi Formation of the Fredericksburg Group in the North Central Texas area. It has been reported in the Cenomanian of Trinidad and Cretaceous of Europe.

Hedbergella implicata Michael, new species
Plate 2, figs 4–6

Description: Test small; pores large relative to size of test, widely separated and evenly distributed; very low trochospire of three volutions of ovate chambers that increase gradually in size as added; usually six overlapping chambers in the last whorl; last chamber large, offset toward the umbilicus, sometimes, obscuring it completely; sutures depressed, radial, slightly curved; periphery lobulate, broadly rounded; primary aperture

interiomarginal, extraumbilical; remnants of porticus often preserved.

Remarks: *Hedbergella implicata*, n. sp., is characterized by its lobulate overlapping chambers. The last four chambers are overlapping, and the ultimate one is remarkably large. *H. implicata*, n. sp., is compared to *H. intermedia*, n. sp., under the latter species.

H. implicata, n. sp., derives its name from *implicatus*-*a*-um (Latin) = wrapped together or entangled.

Dimensions: Diameter of Holotype = 248 μ ; thickness = 90 μ . Mean diameter of 15 specimens = 230 μ ; mean thickness of 15 specimens = 85 μ .

Type locality: Tex 7 Fort Worth, Tarrant County (sample K. 18); Kiamichi Formation.

Deposition of types: Holotype: USNM 172785; Paratypes: USNM 172786; Paratypes: F.M. 3; Pessagno Collection, University of Texas at Dallas.

Range: Upper Albian, *Favusella washitensis* Assemblage Zone, *Hedbergella implicata* Subzone.

Occurrence: *H. implicata*, n. sp., is abundant in the uppermost part of the Kiamichi Formation, and is common in the Duck Creek Formation. This species is restricted to these two formations in the North Central Texas area.

Hedbergella intermedia Michael, new species
Plate 2, figs. 7–9

Description: Test small to medium; pores large relative to size of test, widely separated and evenly distributed over test surface; coiling relatively compact; chambers subglobular to subspherical; increasing gradually in size as added and arranged in a low trochospire of about two and one half volutions; usually six chambers in the last whorl; final chamber offset toward umbilicus; sutures distinct, deep radial and straight; umbilicus small; primary aperture interiomarginal, umbilical to extraumbilical portici small, rounded, spatulate, rarely preserved.

PLATE 3

1–3 *Hedbergella punctata* n. sp.

Tex 7. Kiamichi Formation; Holotype: USNM 172791. Marker = 50 microns. Notice wide umbilicus and the remnant apertural lips.

4–8 *Hedbergella pseudotrocoidea* n. sp.

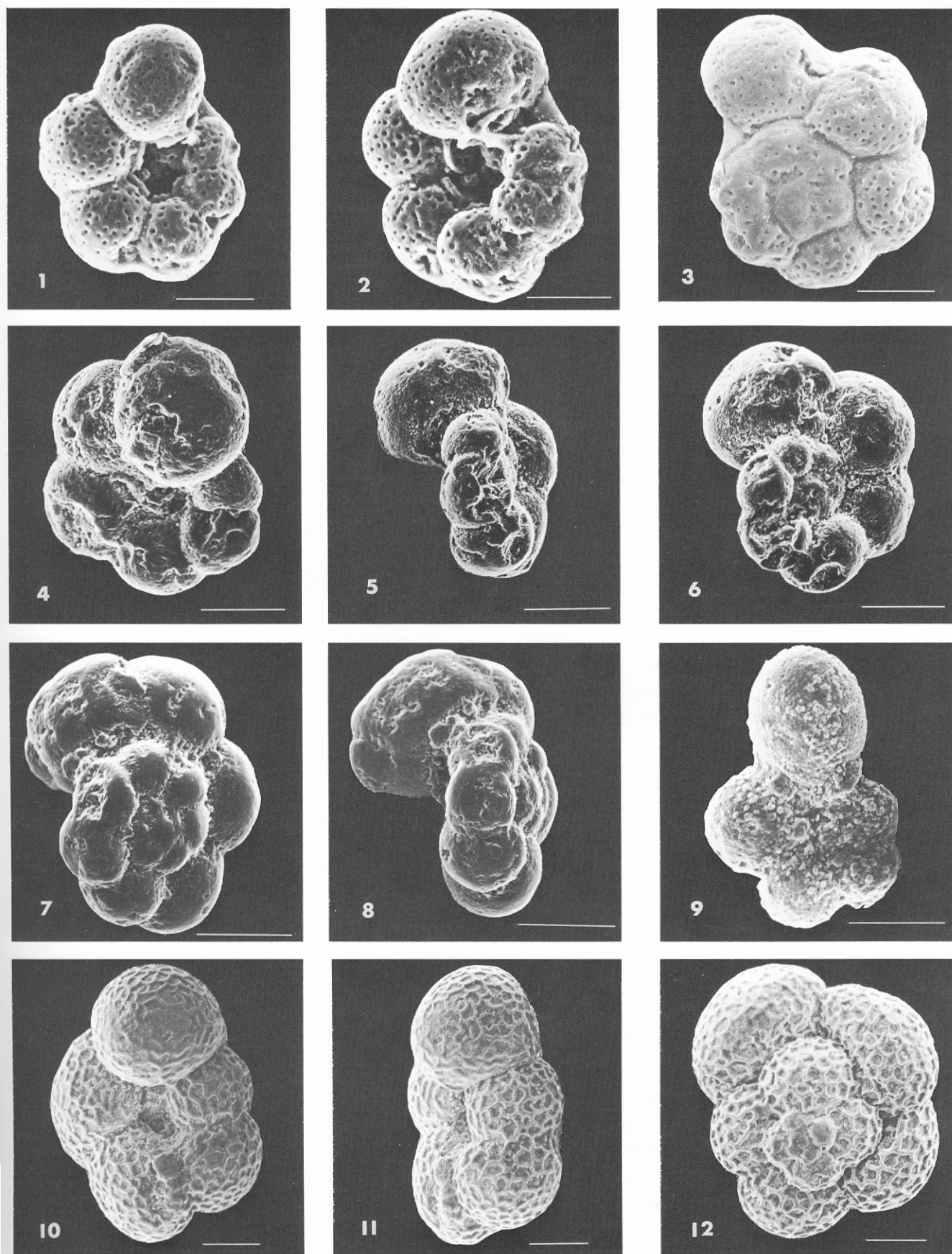
Tex 6. Duck Creek Formation; 4–6 Holotype: USNM 172789; 7 and 8 Paratype: USNM 172790. Marker = 100 microns. Notice size and shape of last chamber in lateral view.

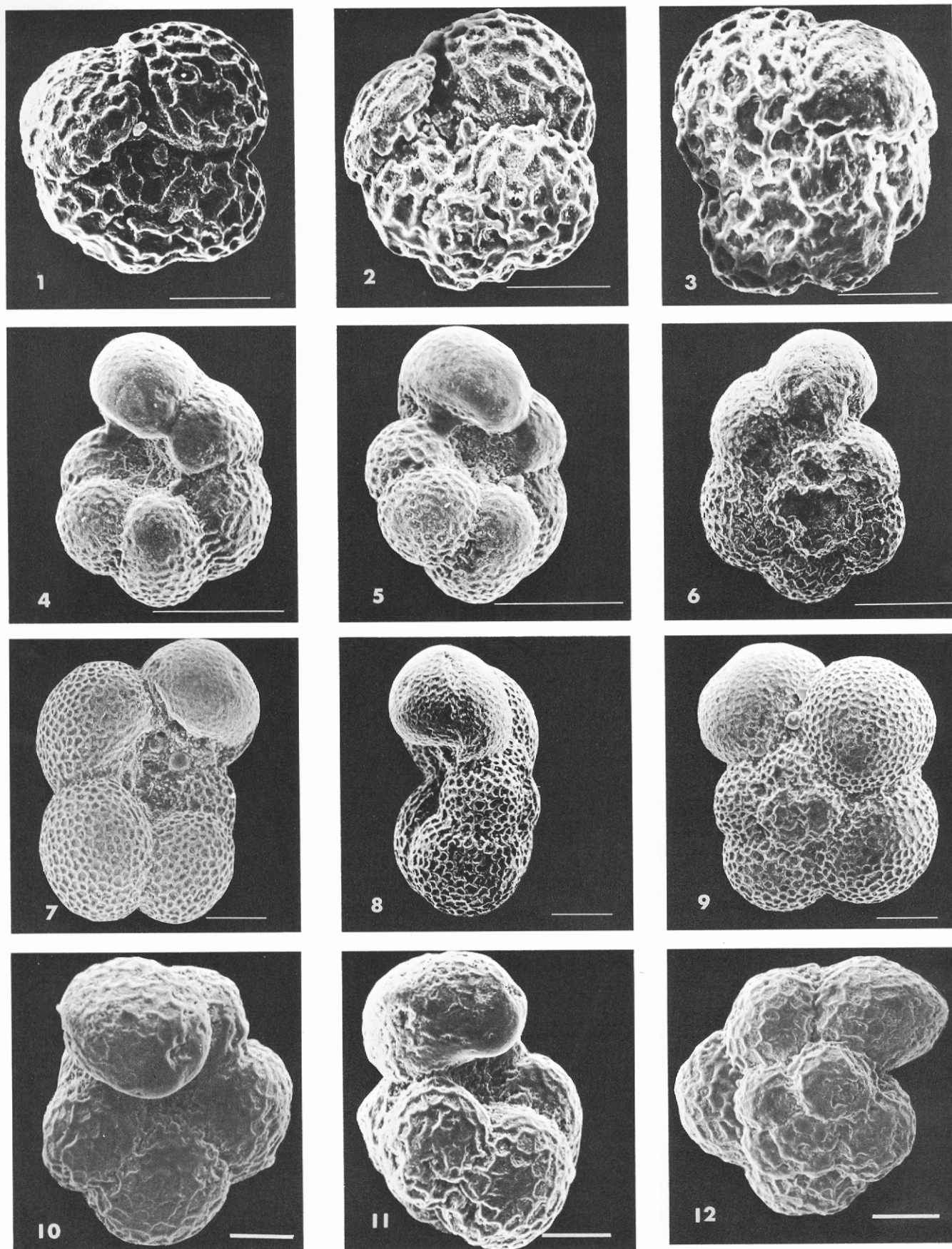
9 *Clavihedbergella subcretacea* (Tappan)

Tex 1. Grayson Formation; Marker = 50 microns.

10–12 *Favusella nitida* n. sp.

Tex 13. Duck Creek Formation; Holotype: USNM 172793. Marker = 100 microns. Notice the pentagonal umbilicus and the completely umbilical aperture.





Remarks: *H. intermedia*, n. sp., is characterized by features that are intermediate between those of *H. implicata* and *H. punctata*. All three species have the same unique pore pattern. The chambers of *H. intermedia* are not as spherical as those of *H. punctata* and are not as ovate, lobe-shaped, and overlapping as those of *H. implicata*. The test is generally circular in outline. This species derives its name from *intermedius-a-um* (Latin) = intermediate or moderate.

Dimensions: Diameter of Holotype = 240μ ; thickness = 115μ . Mean diameter of 20 specimens = 245μ ; mean thickness of 20 specimens = 100μ .

Type locality: Tex 7 Fort Worth, Tarrant County (sample K. 18); Kiamichi Formation.

Deposition of types: Holotype: USNM 172787; Paratypes: USNM 172788; Paratypes: F.M. 4; Pessagno Collection, University of Texas at Dallas.

Range: Upper Albian, *Favusella washitensis* Assemblage Zone, *Hedbergella implicata* Subzone and lower part of *H. punctata* Subzone.

Occurrence: This species is common in the Kiamichi and Duck Creek Formations and rare in the Fort Worth Formation of North Central Texas.

Hedbergella planispira (Tappan)

Plate 2, figs. 10–12

Globigerina planispira, TAPPAN, 1940, p. 122, pl. 19, fig. 12a–c; 1943, p. 513, pl. 83, figs. 3a–c.

Hedbergella planispira (Tappan), LOEBLICH and TAPPAN, 1961, pp. 276–277, pl. 5, figs. 4–11.

Hedbergella trocoidea (Gandolfi), LOEBLICH and TAPPAN, 1961, pp. 277, 278, pl. 5, figs. 1, 2.

Hedbergella planispira (Tappan), PESSAGNO, 1967, pp. 283, 284, pl. 51, fig. 1, pl. 53, figs. 1, 2, 3, 4.

Remarks: This species differs from *H. trocoidea* (Gandolfi) in the rapid increase in the size of its chambers, smaller number of whorls (usually two) and its more lobulate periphery. *H. trocoidea* has more inflated chambers that are lobulate in shape. *H. planispira* can be distinguished from other species of *Hedbergella* by its low trochospiral, nearly planispiral test.

Range: *F. washitensis* Assemblage Zone to *Rotalipora* ?*M. helvetica* Assemblage Zone and *M. renzi* Assemblage Zone.

Occurrence: *H. planispira* was found in all the formations of the Washita Group and in the Kiamichi Formation of the Fredericksburg Group. According to Loeblich and Tappan (1961, pp. 276, 277) this species was recorded from the Eagle Ford Group of Texas, Greenhorn limestone of South Dakota, Wyoming and Kansas; in Cenomanian samples from subsurface cores from the Blake Plateau, in Cenomanian of Germany, and in the Albian and Cenomanian of the U.S.S.R. and Trinidad.

Hedbergella pseudotrocoidea Michael, new species

Plate 3, figs. 4–8

Description: Test small to medium, a low trochospire of about two and a half volutions; last whorl with seven to eight subglobular chambers increasing gradually in size; last chamber exceptionally large and protruding into a relatively wide umbilicus; periphery broadly rounded, lobulate; sutures radial, straight and depressed; primary aperture interiomarginal, extra-umbilical-umbilical; a fragile narrow lip rarely preserved.

Remarks: This species is closely related to *H. trocoidea* (Gandolfi). It differs from the latter species by the gradual increase in the size of chambers in the last whorl, in the extremely large last chamber, which protrudes into the umbilicus, and in the lobulate peripheral outline. *H. trocoidea* as redescribed by Caron and Luterbacher (1969, p. 23, pl. 7, figs. 1–2) from Gandolfi's collection is relatively convex on the spiral side; the chambers are more globular; and the last chamber is not as large and does not protrude into the umbilicus.

PLATE 4

1–3 *Favusella orbiculata* n. sp.

Tex 10. Weno Formation; Holotype: USNM 172795. Marker = 100 microns. Notice the flanges in figures 1 and 2.

4–6 *Favusella pessagno* n. sp.

Tex 4. Fort Worth Formation; Holotype: USNM 172797. Marker = 200 microns. Notice the convex shape of the chambers on the umbilical side.

7–9 *Favusella quadrata* n. sp.

Tex 13. Duck Creek Formation; Holotype: USNM 172799. Marker = 200 microns. Notice wide, shallow umbilicus.

10–12 *Favusella scitula* n. sp.

Tex 6. Duck Creek Formation; Holotype: USNM 172801. Marker = 100 microns. Notice the high trochospire and the protruding last chamber.

Dimensions: Diameter of Holotype = 305μ , thickness of Holotype = 100μ .

Type locality: Tex 6 Fort Worth, Tarrant County (sample DC 7); Duck Creek Formation.

Deposition of type: Holotype: USNM 172789; Paratype USNM 172790; Paratype: F.M. 5, Pessagno Collection, University of Texas at Dallas.

Range: Upper Albian. *H. implicata* Subzone and *H. punctata* Subzone of the *Favusella washitensis* Assemblage Zone.

Occurrence: *H. pseudotrocoidea*, n. sp., is abundant in the Duck Creek Formation and is common throughout the Fort Worth and Denton Formations. This species is rare in the upper parts of the Kiamichi Formation. The absence of this species from formations higher than the Denton Formation indicates an age no younger than Albian. It is probable that both *H. trocoidea* and *H. pseudotrocoidea* are restricted to the Albian Stage, as this was indicated by Caron and Luterbacher (1969) for *H. trocoidea*.

***Hedbergella* (?) *punctata* Michael, new species**

Plate 3, figs. 1–3; Plate 7, figs. 1, 2

Description: Test small; pores large relative to size of test, widely separated and evenly distributed over test surface; a low trochospire of two and one half volutions of spherical chambers which increase in size gradually; usually six chambers in the last whorl; sutures relatively deep, radial; those of earlier whorl almost obscured; those of the last whorl clear and distinct. Primary aperture interiomarginal, extra-umbilical to spiroumbilical with large apertural lip; doubtful sutural supplementary apertures on spiral side, inferred due to small rounded depressions on the sutures; umbilical area very wide.

Remarks: *Hedbergella* (?) *punctata*, n. sp., is characterized by its pore pattern, spherical chambers, very wide umbilicus, massive thick portici; and deep sutures on its spiral side. This species shares characteristics of both *Hedbergella* Bronnimann and Brown and *Loeblichella* Pessagno. The primary aperture is extraumbilical to spiroumbilical; the umbilicus is quite wide and deep; and there are possible sutural supplementary

apertures spirally. Such evidence may suggest that this species belongs to the genus *Loeblichella*. On the other hand the type of coiling, shape of chambers, the large apertural lip suggest a relationship to *Hedbergella*. Its distinctive pore pattern is also characteristic of *H. implicata* and *H. intermedia*, which both possess features characteristic of true *Hedbergella*.

Hedbergella (?) *punctata*, n. sp., derives its name from *punctatus-a-um* (Latin) = punctured or dotted.

Dimensions: Diameter of Holotype = 147μ ; thickness = 55μ . Mean diameter of 15 specimens = 150μ ; mean thickness of 15 specimens = 55μ .

Type locality: Tex 7 Fort Worth, Tarrant County (Sample K.18) Kiamichi Formation.

Deposition of types: Holotype: USNM 172791; Paratype: USNM 172792; Paratype: F.M. 6; Pessagno Collection, University of Texas at Dallas.

Range: Upper Albian. *H. implicata* Subzone and *H. punctata* Subzone of the *Favusella washitensis* Assemblage Zone.

Occurrence: *H. (?) punctata*, n. sp., was found in the Kiamichi, Duck Creek, and Denton Formations of North Central Texas.

Genus *Clavihedbergella* Banner and Blow, 1959

***Clavihedbergella subcretacea* (Tappan)
Plate 3, fig. 9**

Hastigerinella subcretacea TAPPAN, 1943, p. 513, pl. 83, figs. 4a–c.

Clavihedbergella subcretacea (Tappan), LOEBLICH and TAPPAN, 1964, p. C659, fig. 527, 2.

Remarks: This species is rare in the Grayson Formation and was never recorded in any formation below the Grayson in the area of study. Nevertheless, Loeblich and Tappan (1964, p. C659) indicated its presence in Aptian deposits of both hemispheres.

Genus *Favusella* Michael, new genus

Type Species: *Favusella washitensis* (Carsey).

Description: Test calcareous, microgranular hyaline, finely perforate with spherical to ovate chambers

PLATE 5

1–3 *Favusella washitensis* (Carsey)

Type locality, Shoal Creek, Austin; Del Rio Formation. Marker = 50 microns.

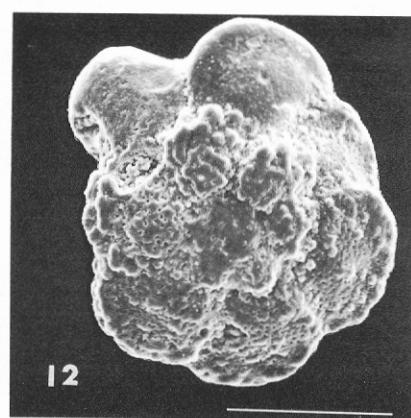
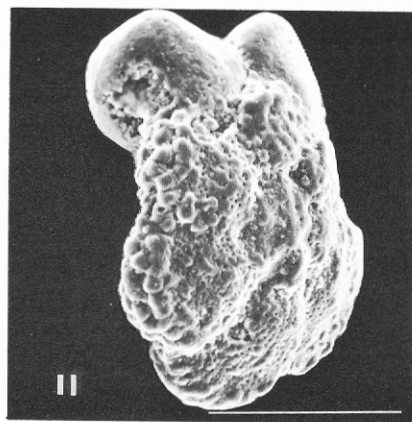
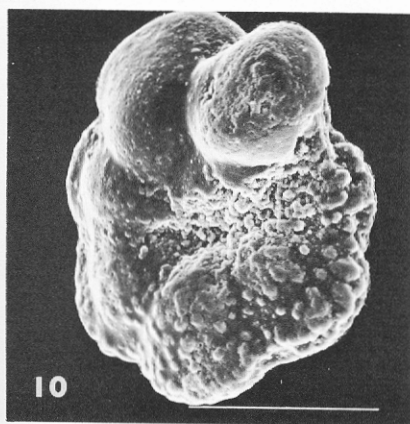
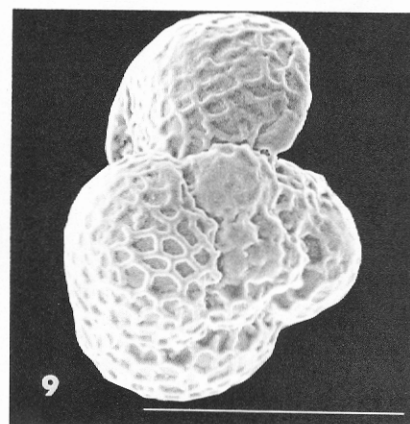
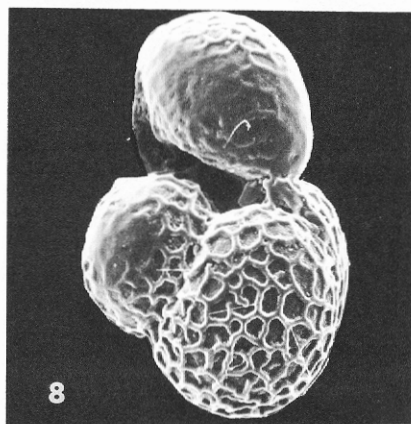
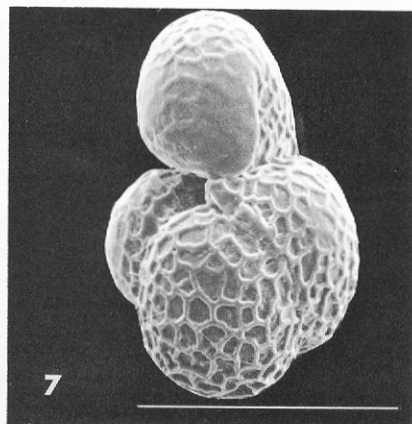
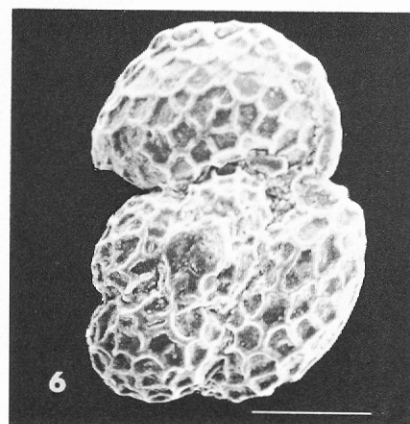
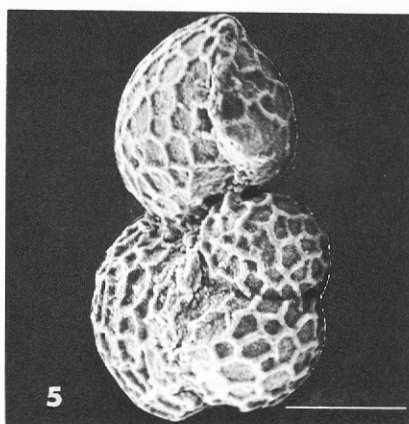
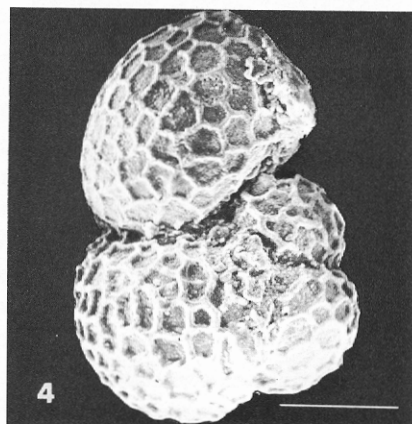
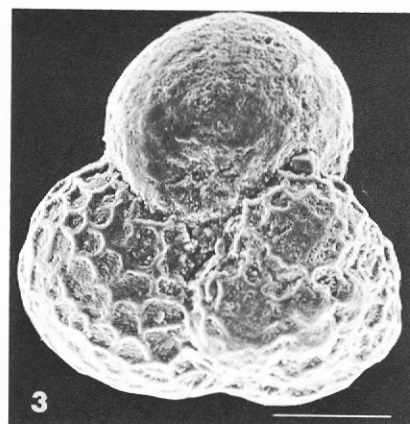
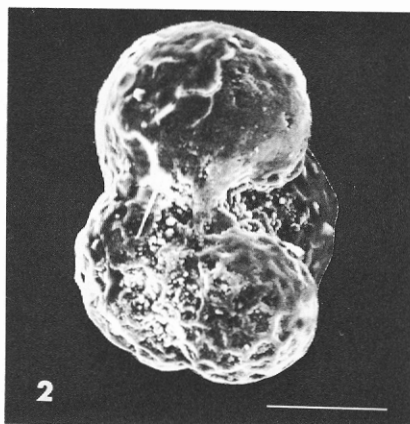
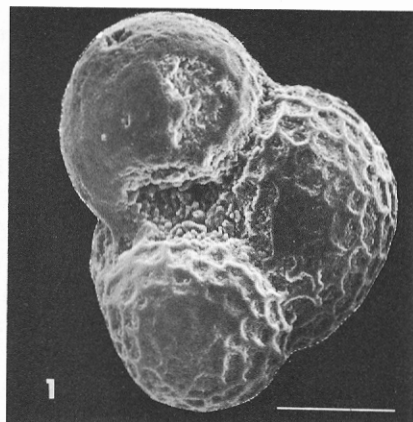
4–9 *Favusella wenoensis* n. sp.

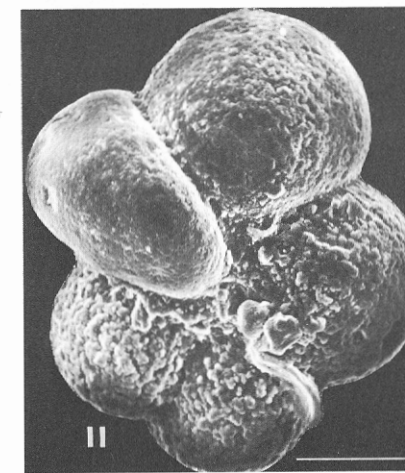
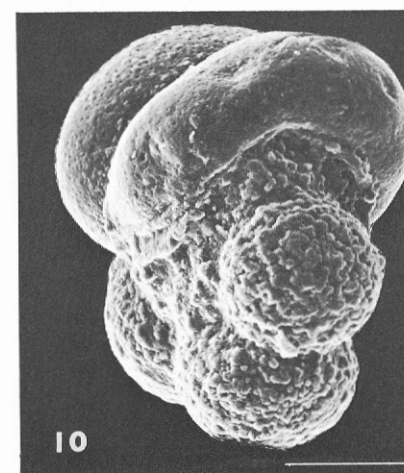
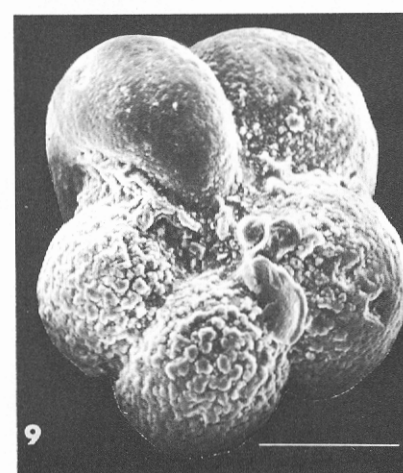
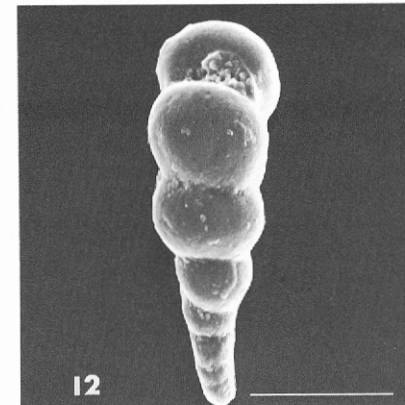
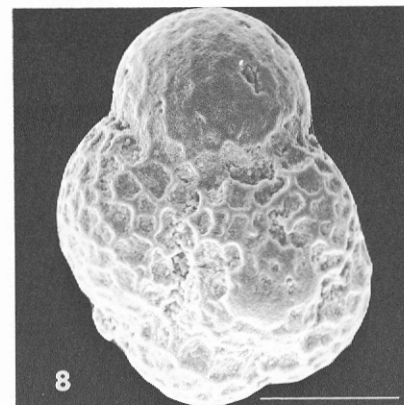
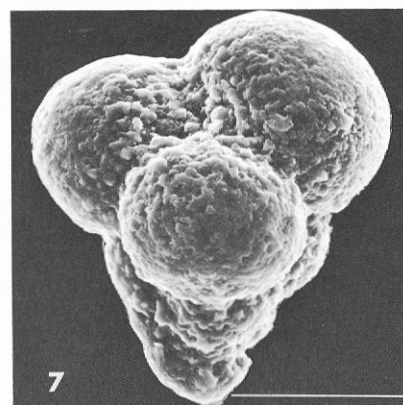
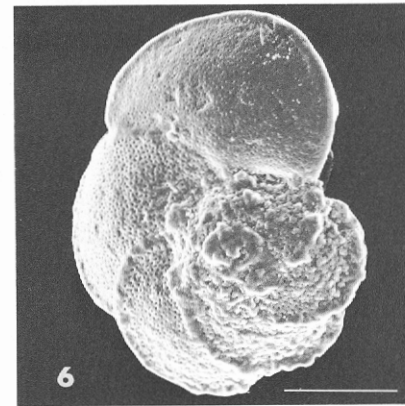
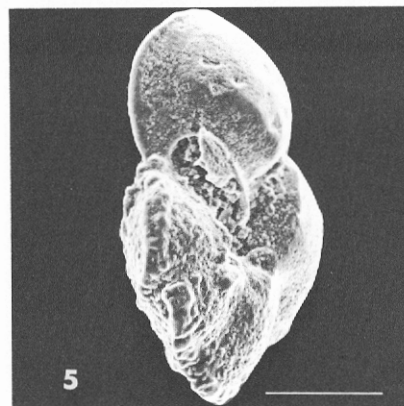
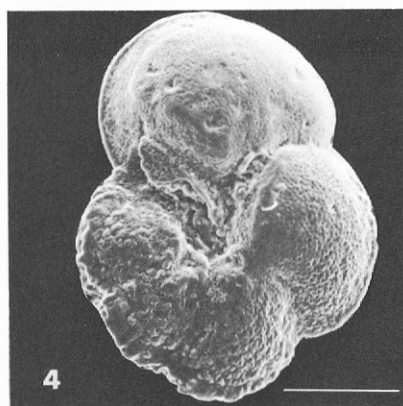
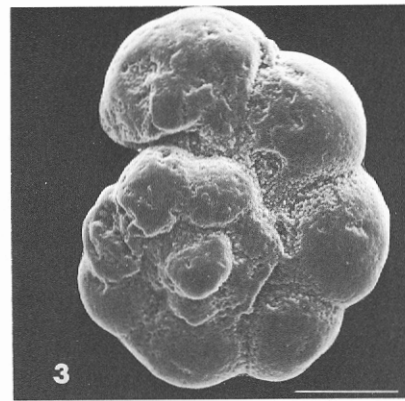
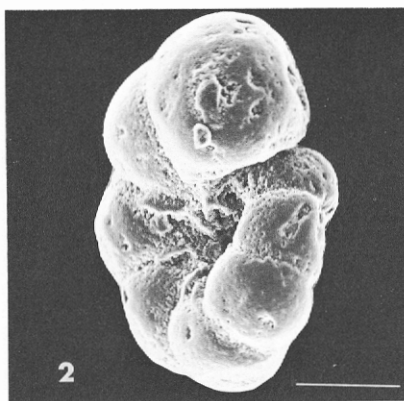
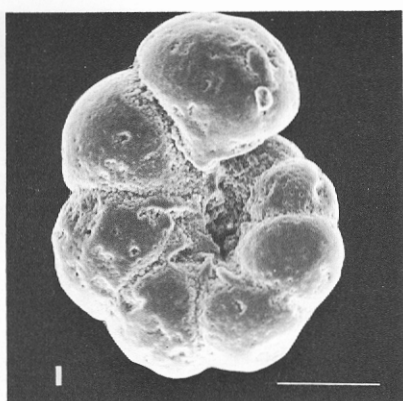
Tex 10. Weno Formation; 4–6 Holotype: USNM 172803. Marker = 100 microns; 7–9 Para-

type: USNM 172804. Marker = 200 microns. Notice the deep suture separating the last, large, flattened, chamber.

10–12 *Praeglobotruncana delrioensis* (Plummer)

Tex 1. Grayson Formation. Marker = 10 microns.





arranged in a low to moderately trochospiral coil; periphery rounded, lacking keel or imperforate peripheral band. Sutures depressed, radial, straight to slightly curved; umbilicus narrow to exceedingly wide. Primary aperture interiomarginal, umbilical to spiroumbilical with all possible intermediate positions; bordered above by a narrow lip in well preserved specimens. Test coarsely reticulated into regular polygonal areas by ridges forming a honey-comb pattern; each polygonal area with twenty or more minute pores.

Remarks: The most diagnostic feature of *Favusella*, n. genus, is its striking pattern of ornamentation composed of coarsely polygonal areas framed by ridges that lend a distinctive honeycomb pattern to the test (Plate 7, figs. 3–4).

Species of *Favusella*, n. genus, such as *F. washitensis* (Carsey) have often been assigned to *Globigerina* by various workers. Admittedly *Favusella* often displays an umbilically placed primary aperture and the cancellate ornamentation characteristic of *Globigerina*. However, *Globigerina* contains a single large pore situated in the center of a polygonal frame, whereas *Favusella* has numerous minute pores distributed throughout the area of the entire polygonal frame. (See Plate 7, fig. 3–4).

Favusella includes species that are often similar to those of *Hedbergella* Bronnimann and Brown, but have cancellate ornamentation and an aperture that varies from umbilical to extraumbilical to spiroumbilical in position and lacks well developed portici. The umbilicus may vary from deep and narrow to moderately deep and wide. The absence of sutural supplementary apertures separates *Favusella* from *Ticinella* Reichel.

Plummer (1931, p. 194) in redescribing the *Globigerina washitensis* Carsey, was the first to notice the great diversity in chamber arrangement in this group of fossils. She stated “. . . Almost any single sample yields tests that present a wide range of variation in arrangement and number of chambers. Most tests show a rather high trochospire, and the larger the number of

chambers in the whorl, the higher the spire. The dominant diagnostic feature of this species that separates it from all other globigerine forms in the Texas section is the striking surface pattern.”

Favusella, n. genus, derives its name from the *Favus* (Latin) = honeycomb.

Range: Albian to earliest Cenomanian.

Occurrence: *Favusella*, n. genus, is usually found in neritic deposits, especially those laid down in the inner neritic depth zone. It has not been recorded in any bathyal or abyssal deposits. Within the Tethys and the Southern Boreal provinces, it has a wide geographic distribution. To date, it has never been reported from the Austral faunal province.

The planktonic nature of this genus is demonstrated by the following facts: 1. The wall structure and globigeriniform character of the test are characteristic of a true planktonic foraminifera. 2. It has always been found associated with other planktonic foraminifera. If the assemblage is completely benthonic forms, no *Favusella* is found. 3. The world-wide distribution of species of this genus as illustrated in the literature where it is always associated with true planktonic forms (See occurrence of *F. washitensis*). Hence, the writer considers *Favusella* to be a planktonic form whose distribution is influenced by a particular environmental parameter such as salinity. Its peculiar ornamentation may be a reflection of such environmental influence.

Favusella hiltermanni (Loeblich and Tappan)

Plate 6, fig. 8

Hedbergella hiltermanni LOEBLICH and TAPPAN, 1961, p. 275, p. 4, figs. 12–13.

Remarks: The specimen described by Loeblich and Tappan (1961, p. 275) has more chambers per whorl; the spire is more elevated; and the increase in chamber size is less rapid than the specimen figured herein. The thick ridges that develop in addition to the honeycomb

←

PLATE 6

1–3 *Ticinella primula* Luterbacher

Tex 6. Duck Creek Formation. Marker = 100 microns. Notice the spiroumbilical primary aperture and the gradual increase in the size of the chambers.

4–6 *Rotalipora evoluta* Sigal

Tex 1. Grayson Formation. Marker = 100 microns.

7 *Guembelitria harrisi* Tappan

Tex 1. Grayson Formation. Marker = 50 microns.

8 *Favusella hiltermanni* Loeblich and Tappan

Tex 1. Grayson Formation. Marker = 100 microns.

9–11 *Globigerinelloides texomaensis* n. sp.

Tex 13. Duck Creek Formation. Holotype: USNM 172781. Marker = 100 microns. Notice shape of last chamber and how it protrudes to cover of the umbilicus.

12 *Heterohelix moremani* (Cushman)

Tex 1. Grayson Formation. Marker = 100 microns.

ornamentation, distinguishes this species from *Favusella washitensis* (Carsey).

Range: Middle Albanian to Lower Cenomanian.

Occurrence: This form was recorded throughout the Washita Group and from the Walnut Marl of the Fredericksburg Group.

***Favusella nitida* Michael, new species**

Plate 3, figs. 10–12

Description: Test large, coiled in moderately low trochospire composed of three volutions of fairly globular chambers that increase gradually in size; usually five chambers in last whorl; umbilicus small, moderately deep, pentagonal in shape; peripheral outline rounded; sutures distinct, radial, deep and straight; primary aperture interiomarginal, umbilical with narrow lip; polygonal ornamentation well developed, usually with equal sized hexagonal frames.

Remarks: *F. nitida*, n. sp., is distinguished from all other *Favusella* species by its completely umbilical aperture, by the globular chambers of its last whorl; by its subtrapezoidal chambers spirally; and by its pentagonally shaped umbilicus.

F. nitida, n. sp., derives its name from *nitidus-a-um* (Latin) = neat or elegant.

Dimensions: Diameter of Holotype = 475 μ ; thickness of Holotype = 180 μ . Twelve specimens average 480 μ in diameter and 190 μ in thickness.

Type locality: Tex 13 Grayson County (sample L.T.Dc. 4); Duck Creek Formation.

Deposition of types: Holotype: USNM 172793; Paratype: USNM 172794; paratypes F.M. 7; Pessagno Collection, University of Texas at Dallas.

Range: Upper Albanian. *F. washitensis* Assemblage Zone: *H. implicata* Subzone to *H. punctata* Subzone.

Occurrence: *F. nitida*, n. sp., is common in the Duck Creek Formation and relatively rare in Fort Worth and Denton Formations of North Central Texas.

***Favusella orbiculata* Michael, new species**

Plate 4, figs. 1–3

Description: Test small, round and circular, a low trochospire having two volutions of five globular cham-

bers per whorl that increase gradually in size; narrow flanges in last three chambers; umbilicus wide and deep; sutures radial, depressed, those of earlier whorl almost obscured by the coarse ornamentation; primary aperture interiomarginal, umbilical-extraumbilical; very coarse polygonal ornamentation composed of relatively thick and high hexagonal ridges.

Remarks. *Favusella orbiculata*, n. sp., is characterized by its rounded circular test, its coarse polygonal ornamentation; its narrow flanges developed by the last 3 or 2 chambers, and its deep umbilicus. This species is distinguished from *Hedbergella hiltermanni* Loeblich and Tappan, by its cameral flanges umbilically, by its regular polygonal ornamentation composed of relatively thick, high, hexagonal ridges; by being lower spired; by having less chambers per whorl; and by being subspherical.

F. orbiculata, n. sp., derives its name from *Orbiculus-a-um* (Latin) = round or circular.

Dimensions: Holotype measures 248 μ in diameter, 132 μ in thickness. Twelve specimens average 225 μ in diameter and 125 μ in thickness.

Type locality: Holotype and paratypes from locality Tex 10 Cook County (sample Wn. 2); Weno Formation.

Deposition of types: Holotype: USNM 172795; Paratype: USNM 172796; Paratype: F.M. 8; Pessagno Collection, University of Texas at Dallas.

Range: Upper Albanian, *Hedbergella implicata* Subzone of the *F. washitensis* Assemblage Zone.

Occurrence: *F. orbiculata* is abundant in the Weno Formation and common in the Pawpaw and Denton Formations of North Central Texas.

***Favusella pessagnoii* Michael, new species**

Plate 4, figs. 4–6

Description: Test large, a low trochospire of about two volutions of subglobular, inflated chambers which increase gradually in size; usually six in the last whorl; last chamber slightly protruding into a relatively wide umbilicus; periphery broadly rounded, peripheral outline lobulate; sutures distinct, radial and straight; primary aperture interiomarginal extraumbilical without apertural lip or porticus; ornamentation composed of

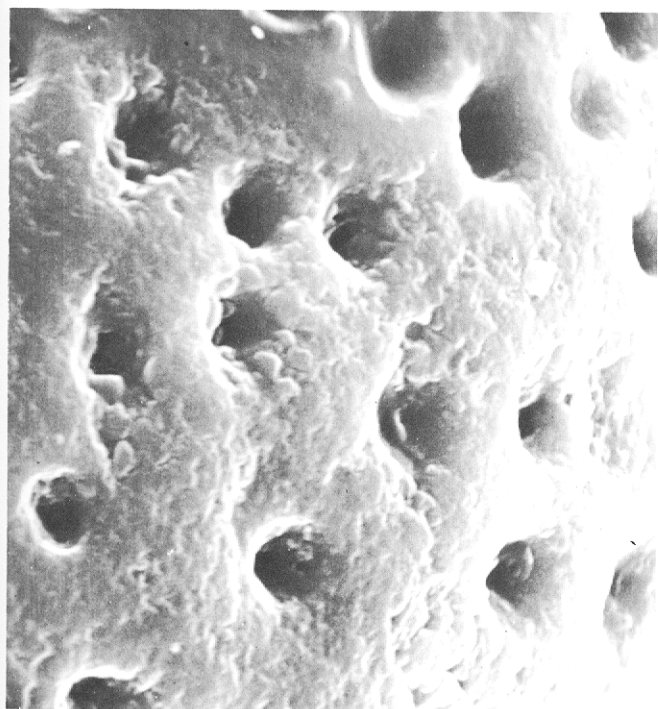
PLATE 7

1–2 *Hedbergella punctata* n. sp.

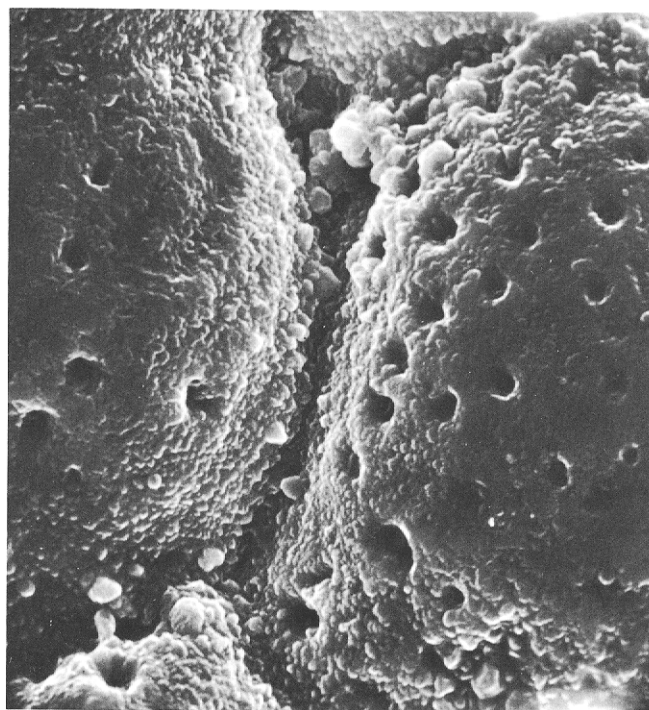
Tex 7. Holotype: USNM 172791. Pore pattern. 1. Marker = 10 microns, 2. Marker = 20 microns.

3–4 *Favusella wenoensis* n. sp.

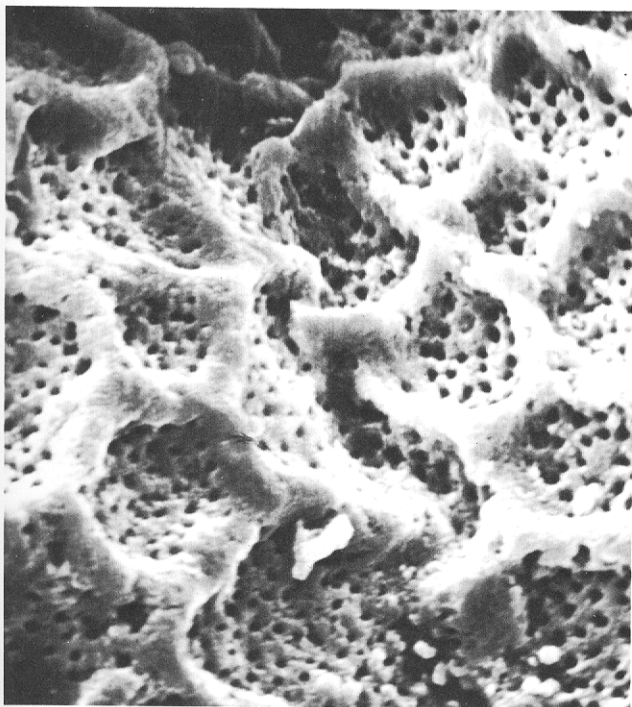
Tex 10. Holotype: USNM 172803. Cancellate ornamentation characteristic of the genus *Favusella*. 3. Marker = 10 microns, 4. Marker = 20 microns.



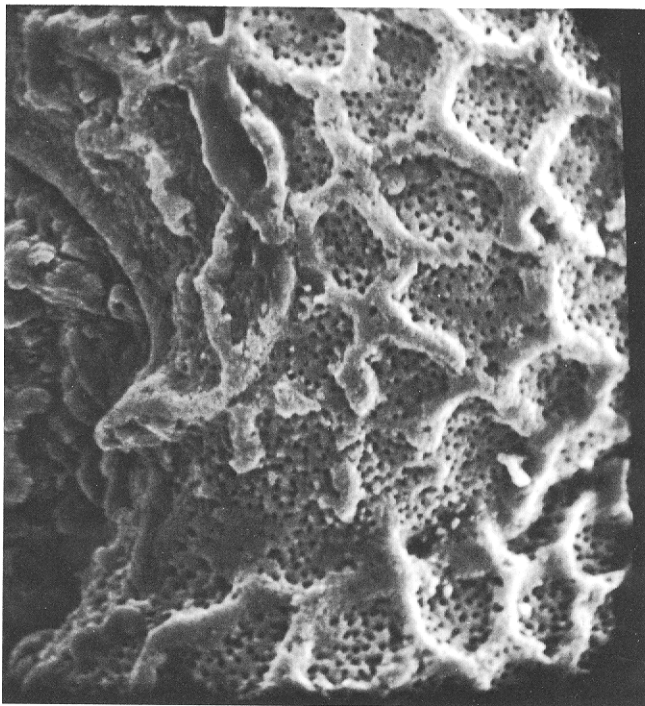
1



2



3



4

ridges forming equal sized polygonal (usually hexagonal) areas.

Remarks: *F. pessagnoii*, n. sp., is similar to *Hedbergella trocoidea* (Gandolfi) in both the shape and arrangement of chambers. It differs, however, by having the cancellate ornamentation characteristic of *Favusella*, n. genus. This species differs from *F. washitensis* (Carsey) by having more chambers in the last whorl (usually six) that increase gradually in size and by having a lobulate periphery.

F. pessagnoii, n. sp., is named in honor of Dr. Emile A. Pessagno, Jr., University of Texas at Dallas, in recognition of his work on Cretaceous Foraminifera.

Dimensions: Diameter of Holotype = 465μ ; thickness = 225μ . Ten specimens average 450μ in diameter and 220μ in thickness.

Type locality: Tex 4 Denton County (Sample F.W. 29); Fort Worth Formation.

Deposition of types: Holotype: USNM 172797; Paratype: USNM 172798; Paratypes: F.M. 9; Pessagno Collection, University of Texas at Dallas.

Range: Upper Albian: *Hedbergella implicata* Subzone to *H. punctata* Subzone of the *F. washitensis* Assemblage Zone.

Occurrence: *F. pessagnoii*, n. sp., is abundant in the Fort Worth Formation and frequent in the Duck Creek and Denton Formations of the North Central Texas area.

***Favusella quadrata* Michael, new species**

Plate 4, figs. 7–9

Description: Test large, a low trochospire of two and a half volutions of fairly spherical chambers that increase gradually in size; usually five chambers in last whorl; umbilicus quite wide, shallow; peripheral outline rounded, overall configuration of test quadrate-shaped; sutures distinct, radial and straight; primary aperture interiomarginal, umbilical to slightly extra-umbilical; cancellate pattern well developed; polygonal areas usually hexagonal, sometimes pentagonal; always equal in size.

Remarks: *F. quadrata*, n. sp., is characterized by its wide umbilicus, spherical chambers and umbilical aperture. It differs from *F. nitida*, n. sp., in having a much wider umbilicus, spherical chambers, a finer cancellate pattern, and a test which is less convex spirally. *F. quadrata*, n. sp., derives its name from *quadratus-a-um* (Latin) = four cornered or square.

Dimensions: Diameter of Holotype = 640μ , thickness of Holotype = 240μ . Ten specimens average 625μ in diameter and 210μ in thickness.

Type locality: Tex 13 Grayson County (Sample L.T.Dc. 4); Duck Creek Formation.

Deposition of types: Holotype: USNM 172799; Paratype: USNM 172800; paratypes F.M. 10; Pessagno Collection, University of Texas at Dallas.

Range: Upper Albian: *Hedbergella implicata* Subzone to *H. punctata* Subzone of the *F. washitensis* Assemblage Zone.

Occurrence: *F. quadrata*, n. sp., is abundant in Duck Creek Formation and relatively rare in Fort Worth and Denton Formations of the North Central Texas area.

***Favusella scitula* Michael, new species**

Plate 4, figs. 10–12

Description: Test relatively large in size; a high trochospire with three volutions; chambers increase gradually in size, usually five globular chambers in the last whorl; last chamber ovate, elongate, protruding, obscures part of umbilicus; umbilicus wide and deep; sutures radial, distinct, depressed; primary aperture interiomarginal, extraumbilical. Polygons of the honeycomb ornamentation usually pentagonal, rarely hexagonal; all equal in size.

Remarks: *Favusella scitula*, n. sp., is characterized by being quite spiroconvex, by having a markedly elevated early whorl, by the elongate shape of its last chamber, and by its uniform cancellate pattern. The name is derived from *scitulus-a-um* (Latin) = pretty or elegant.

Dimensions: Holotype measures 400μ in maximum diameter, 175μ in thickness. Other specimens vary from 350μ to 420μ in maximum diameter and from 150μ to 180μ in thickness.

Type locality: Holotype and paratypes from locality Tex 6 (sample Dc. 9); Duck Creek Formation.

Deposition of types: Holotype: USNM 172801; Paratype: USNM 172802; Paratypes: F.M. 11; Pessagno Collection, University of Texas at Dallas.

Range: Upper Albian: *Hedbergella implicata* Subzone to *H. punctata* Subzone of the *F. washitensis* Assemblage Zone.

Occurrence: *F. scitula*, n. sp., is abundant in the Duck Creek through Denton Formations of the North Central Texas area.

***Favusella washitensis* (Carsey)**

Plate 5, figs. 1–3

Globigerina washitensis CARSEY, 1926, p. 44, pl. 7, fig. 10, pl. 8, fig. 2; Plummer, 1931, p. 193, pl. 13, fig. 12, (Neotype of Plummer); TAPPAN, 1940, p. 122, pl. 19, fig. 13;

1943, p. 413, pl. 83, figs. 1, 2; FRIZZELL, 1954, p. 127, pl. 20, fig. 9; BOLLI, 1959, p. 271, pl. 23, figs. 6, 7.

Hedbergella washitensis (Carsey). LOEBLICH and TAPPAN, 1961, p. 278, pl. 4, figs. 9–11; PESSAGNO, 1967, p. 284, pl. 49, fig. 1.

Description: Test small to medium sized, with low trochospire of two volutions of fairly spherical chambers which increase rather rapidly in size; usually four chambers in the last whorl; umbilical area relatively wide; sutures deep, distinct, radial, those of earlier whorl almost obscured by the coarse ornamentation; primary aperture interiomarginal, extraumbilical-umbilical. Polygons of cancellate pattern usually pentagonal, rarely hexagonal, all equal in size.

Remarks: *Favusella washitensis* (Carsey), was originally described from Del Rio Clay (= Grayson Formation), of Central Texas (Shoal Creek, Austin, Travis County), by Carsey who was the first to recognize its importance "... as a splendid horizon marker of the Washita division of the Comanche series."

Dimensions: This species ranges considerably in size and ranges in diameter from 500 μ to 200 μ . Specimens from the lower formations of the Washita Group are larger and more abundant.

Range: Middle Albian to lowermost Cenomanian. *Favusella washitensis* Assemblage Zone to *Rotalipora evoluta* Subzone.

Occurrence: *F. washitensis* (Carsey), was found throughout the Washita Group and in the Walnut Marl of the Fredericksburg Group. In the Glen Rose Limestone (Trinity Group), a similar form was found in thin-sections but none of the samples were soft enough, to be processed to separate individual specimens. This species has been reported from Albian and Cenomanian strata of Texas and Oklahoma and equivalent strata in Minnesota, in Trinidad and in Algeria, as well as in the submarine Blake Plateau, north of Bahama Islands (Loeblich and Tappan, 1961). Ayala (1962, p. 22) described and figured this species from the Cenomanian of Cuba. Again the same species was recorded by Arkin and Hamaoui (1967) from the Cenomanian of Negev Desert of Israel. Sigal (1965, p. 290) recorded *H. washitensis* in the Albian of Paris Basin, and Barr (1968, p. 140) recorded it from the Lower Cenomanian of Libya. The geographic distribution seems to be world-wide.

Favusella wenoensis Michael, new species

Plate 5, figs. 4–9; Plate 7, figs. 4–5

Description: Test moderately large in size, polygons of the cancellate pattern wide, usually pentagonal, some

hexagonal; a low trochospire of two volutions; chambers ovate to subspherical; increasing rapidly in size, four in last whorl; last chamber flattened, elongate, and large, about half size of the test from which it is separated by a wide deep suture; sutures distinct, more or less radial; umbilicus narrow; primary aperture interiomarginal, extraumbilical-umbilical.

Remarks: *Favusella wenoensis*, n. sp., differs from all other species of *Favusella* by its large flattened last chamber which is often half the size of the test and separated from the rest of the test by a wide, deep suture. Generally, the elongate, flattened shape of the test is highly diagnostic.

F. wenoensis, n. sp., derives its name from the Weno Formation of North Central Texas.

Dimensions: Holotype = 360 μ in the maximum diameter, 180 μ in the minimum diameter, and 125 μ in thickness. Twelve specimens average 335 μ in major diameter, 150 μ in minor diameter, and 100 μ in thickness.

Type locality: Holotype and paratype from locality Tex 10 (Sample Wn. 2); Weno Formation.

Deposition of types: Holotype: USNM 172803; Paratype: USNM 172804; Paratype: F.M. 12; Pessagno Collection, University of Texas at Dallas.

Range: Upper Albian: lower part of the *Hedbergella delrioensis* Subzone.

Occurrence: This species appears to be restricted to the Weno Formation of the North Central Texas area.

Genus *Praeglobotruncana* Bermudez, 1952

Praeglobotruncana delrioensis (Plummer)

Plate 5, figs. 10–12

Globorotalia delrioensis PLUMMER, 1931, p. 199, pl. 13, figs. 2a–c.

Praeglobotruncana delrioensis (Plummer), LOEBLICH and TAPPAN, 1961, pp. 280–284, pl. 6, figs. 9–12; PESSAGNO, 1967, p. 286–287, pl. 52, figs. 3–5, pl. 100, fig. 7.

Remarks: This species is rare and was observed only in the upper parts of the Grayson Formation of North Central Texas. Pessagno (1967, p. 287) indicated that it ranges from "*Hedbergella*" *washitensis* zone to *Rotalipora* s.s. Assemblage Zone, *R. evoluta* subzone. In this study it was never found lower than the *Rotalipora* s.s. Assemblage Zone and is considered to be restricted to it. The first appearance of the *P. delrioensis* as well as *R. evoluta* indicates the advent of the Cenomanian. Loeblich and Tappan (1961, pp. 280–294) recorded this species from Lower Cenomanian and Upper Albian strata in Trinidad and

Switzerland, and in submarine cores from Blake Plateau, north of the Bahamas.

Subfamily ROTALIPORINAE Sigal, 1968

Genus *Ticinella* Reichel, 1950

Ticinella primula Luterbacher

Plate 6, figs. 1–3

Ticinella primula Luterbacher, in Renz, Luterbacher and Schneider, 1963, p. 1085, fig. 4.

Remarks: The low trochospire, the relatively non-compact coiling and the spiroumbilical aperture are the most diagnostic features of this species.

Dimensions: Diameter = 300 μ , thickness = 100 μ .

Range: Middle and Upper Albian. *F. washitensis* Assemblage Zone; *H. implicata* and *H. punctata* subzones.

Occurrence: *Ticinella primula* was found in the Duck Creek, Fort Worth and Denton Formations of the North Central Texas area. This species was originally described from the middle Albian and upper Albian (Vraconian) of the Jura Mountains within the Canton de Neuchâtel (Western Switzerland) and was found to be characteristic of the "pyritized part of the Albian" known as Vraconian.

Genus *Rotaliporia* Brotzen, 1942

Rotalipora evoluta Sigal

Plate 6, figs. 4–6

Rotalipora cushmani var. *evoluta* Sigal, 1948, p. 100, pl. 1, figs. 3; pl. 2, fig. 2.

Globorotalia delrioensis Plummer, Loeblich and Tappan, 1946, p. 257, text-fig. 4B.

R. cf. appenninica (O. Renz.), Bolli, et al., 1957, p. 41, pl. 9, figs. 5a–c.

R. evoluta Sigal, Pessagno, 1967, p. 294, pl. 49, figs. 12–14; pl. 53, figs. 6–8; pl. 98, fig. 12.

This is the oldest Cenomanian species of the *Rotalipora* s.s. Assemblage Zone known to date in the North American section (Pessagno, 1967, p. 295). It is never abundant in the Grayson and Del Rio Formations of Texas, but its appearance in the lower part of the Grayson Formation marks the base of the Cenomanian (See Pessagno, 1967, pp. 7, 8, 21–23).

Range: *Rotalipora* s.s. Assemblage Zone; *R. evoluta* Subzone.

Occurrence: A few specimens of this species were noted in the upper part of Grayson Formation of North Central Texas. It has been recorded from Cenomanian deposits in Trinidad, Switzerland and North Africa (Pessagno, 1967).

LOCALITIES

All the localities included below occur in Texas and are arranged on basis of counties.

DENTON COUNTY

Tex 1: Grayson Bluff; 3.6 miles northeast of Roanoke, dirt road south of F.M. 1171 East, 1.5 miles from its junction with U.S. 377; total thickness 90 feet (29 meters); lower 20 feet (6 meters) hard limestone and marls of the Main Street Formation; this is overlain by 65 feet (20 meters) of mudstones, shales, marls and few limestone intercalations belonging to the Grayson Formation which is in turn overlain by 5 feet (1.5 meters) of Woodbine sands. Locality T-26 of Perkins (1960, p. 44).

Tex 2: Road cut on F.M. 428 (old Texas Rt. 10); 4.5 miles from Denton city limit at northeast side of Denton; immediately southwest of Clear Creek; 25 feet (7.5 meters) of bluish-gray marl to silt with thin-bedded brown-reddish sands assignable to the Pawpaw Formation overlain conformably by 17 feet (5 meters) of alternating marls and hard limestone of the Main Street Formation.

Tex 3: Road cut on F.M. 407, 2 miles east of Justin immediately east of a bridge over Denton Creek; 9 feet (2.7 meters) of alternating hard, gray limestone and marls of the Fort Worth Formation overlain conformably by 7 feet (2 meters) of yellowish marls and clays belonging to lower Denton Formation.

Tex 4: Exposures of Fort Worth and Denton Formations on the banks of a small tributary to Denton Creek; south side of F.M. 407, 2 miles east of Justin and immediately east of a bridge on Denton Creek and opposite locality Tex 3; Fort Worth Formation consisting of 25 feet (7.6 meters) of alternating hard, gray limestone and marls; Denton Formation consisting of 40 feet (12 meters) of yellowish to brownish marls intercalated with thin limestone capped by a 2 foot oyster bed.

TARRANT COUNTY

Tex 5: Small unnamed creek south side of Tappan Boulevard on the southwestern edge of the U.S. Public Health Service Hospital (Federal Narcotic Farm and Hospital), 200 yards southwest of the road; 10 feet (3 meters) of alternating limestone and marl assignable to middle part of the Main Street Formation.

Tex 6: Road cut on Taxco Street at northeast junction of I.S. 20 and U.S. 80, off the Ridgmar exit on the southwest edge of the Westover Hills, Fort Worth; 23 feet (6.6 meters) of alternating limestone and calcareous mudstone with some marly thin intercalations assignable to the lower part of the Duck Creek Formation.

Tex 7: About 200 yards north of locality Tex 6, at the intersection of Calais, Westover Drive and Firth Road at the southwestern edge of Westover Hills, Fort Worth; Kiamichi Formation; 25 feet (7.6 meters) of brownish-black shales, calcareous shales, silts and sands with few limestone beds in lower part.

Tex 8: Road cut on east side of F.M. 2871 south of U.S. 80–U.S. 180, immediately south of bridge on Mary's Creek; Goodland Formation; lower 50 feet (15 meters) consisting of bluish-gray calcareous shales and marls; upper 100 feet (30 meters) consisting of white chalky limestone. Locality T-1 and T-2 of Perkins (1960, p. 43).

Tex 9: Banks of small unnamed creek east of Reservoir I&G dam, southeast of the intersection of Interstate 35W and Berry Street; upper part of the Denton Formation; 15 feet (4.5 meters) of marls and clays capped by a 2 foot (0.6 meter) oyster bed.

COOK COUNTY

Tex 10: Along a small unnamed tributary creek immediately east of U.S. 77 (I.S. 35W), one mile south of the Red River at the northern extremity of Cook County; Weno Formation, consisting of 35 feet (10 meters) of brownish clay to silt intercalated with yellowish marly and hard limestone ledges in lower part.

PARKER COUNTY

Tex 11: Road cut on north side of U.S. 80-U.S. 180, east of Weatherford, 4.5 miles from the Court House; upper 15 feet (4.5 meters) of brownish-red sands assignable to Paluxy Formation, overlain unconformably by 25 feet (7.6 meters) of alternating marls and oyster beds of the Walnut Formation. Locality T-12 of Perkins (1960, p. 44).

Tex 12: Road cut on U.S. 180 directly south of the Road Side Park, 7.5 miles west of Weatherford city limit. Glen Rose Formation; 80 feet (24 meters) of hard, silicified limestone intercalated with occasional thick cross-bedded sand.

GRAYSON COUNTY

Tex 13: Southern shore of Lake Texoma at Loe's Highport Resort at the end of F.M. 120; 50 yards east of mouth of harbour; 20 feet (6 meters) of hard, silicified gray limestone assignable to the upper part of Goodland Formation, overlain unconformably by 12 feet (3.6 meters) of clays and shales with a hard oyster bed assignable to the Kiamichi Formation, overlain conformably by 25 feet (7.6 meters) of alternating calcareous mudstone and marls assignable to the Duck Creek Formation.

JOHNSON COUNTY

Tex 14: Road cut on south side of Godley-Cleburne road, Texas 171, uphill from bridge over Nolan's River; 4.8 miles southeast of Godley; Main Street Formation; 33 feet (10 meters) of alternating marls and yellowish white to gray limestone.

CORYELL COUNTY

Tex 15: Road cut on a dirt road off F.M. 116 at about 0.2 miles east from junction of F.M. 1783, on Efton Carroll Farm; 40 feet (12 meters) of alternating marls and oyster beds assignable to Walnut Formation, overlain conformably by 15 feet (4.5 meters) of bluish-gray calcareous shales and marls assignable to the lower part of Goodland Formation.

Tex 16: Road cut on Tex 36 approximately 6.3 miles south of junction with F.M. 107; Walnut Formation consisting of 10 feet (3 meters) of alternating marls and oyster beds.

Tex 17: Road cut on U.S. 84 west of Gatesville across from the bridge over Leon River; Walnut Formation consisting of 18 feet (5.5 meters) of alternating yellowish marls and oyster beds.

Tex 18: Road cut on junction of F.M. 1829 and F.M. 107 immediately east of Coryell Creek; Goodland Formation (Comanche Peak) consisting of 25 feet (7.6 meters) of bluish-

gray calcareous shales and marls overlain by 40 feet (12 meters) of white chalky and marly limestone.

MCLENNAN COUNTY

Tex 19: Road cut, 0.9 mile east of intersection of Tonkawa Park road and F.M. 185 southeast of Crawford; 4 feet (1.2 meters) of Kiamichi clays, 25 feet of alternating calcareous mud and marls assignable to the Duck Creek Formation.

Tex 20: Exposures of Fort Worth and Denton Formations on the banks of Middle Bosque River immediately east of the bridge on the river on F.M. 185; 25 feet (7.5 meters) of alternating grayish limestone and marls assignable to the Fort Worth Formation, 7 feet (2 meters) of marls and calcareous shales assignable to the Denton Formation.

Tex 21: Exposures on banks of Hog Creek, 1 mile north of F.M. 185; 7 feet (2 meters) of alternating limestones and marls assignable to the Weno Formation; 8 feet (2.2 meters) of clays and shales assignable to the Pawpaw Formation; 12 feet (3.6 meters) of hard limestone assignable to the Main Street Formation.

REFERENCES

- AMERICAN COMMISSION ON STRATIGRAPHIC NOMENCLATURE, 1961, Code of stratigraphic nomenclature: Am. Assoc. Petroleum Geologists, v. 45, no. 5, p. 645-665.
- ARKIN, Y., and HAMAOU, M., 1967, The Judea Group (Upper Cretaceous) in Central and Southern Israel: G.S.I. Bull., v. 42, p. 1-17, pls. 1-2.
- AVALA, CASTANARES A., 1962, Morfologia y estructura de algunos foraminiferos planetonicos del Cenomaniano de Cuba: Soc. Geol. Mexicanas Bol., v. 25, no. 1, p. 1-63, pls. 1-13.
- BARR, F. T., 1968, Upper Cretaceous stratigraphy of Jabal Al Akhdar, northern Cyrenaica, pp. 131-148, pls. 1-3, in *Geology and Archaeology of Northern Cyrenaica, Libya*: Petrol. Explor. Soc. Libya, p. 1-215.
- BOLLI, H. M., 1957, The genera *Praeglobotruncana*, *Rotalipora*, *Globotruncana*, and *Abathomphalus* in the Upper Cretaceous of Trinidad, B.W.I.: U.S. Natl. Mus. Bull. no. 215, p. 51-60, pls. 12-14.
- , 1959, Planktonic foraminifera from the Cretaceous of Trinidad, B.W.I.: Am. Paleontology Bull., v. 39, no. 179, p. 257-277, pls. 20-23.
- BOLLI, H. M., LOEBLICH, A. R., JR., and TAPPAN, H., 1957, Planktonic foraminiferal families Hantkeninidae, Orbulinidae, Globorotaliidae, and Globotruncanidae, p. 3-50, pls. 1-11, text-figs. 1-9 in Loeblich, A. R., Jr., et al., *Studies in foraminifera*: U.S. Natl. Mus. Bull., no. 215, 323 p., 74 pls.
- BREISTROFFER, M., 1947, Sur les zones d'ammonites dans l'Albian de France et d'Angleterre: Travaux Lab. Geol. Univ. Grenoble, v. 26, p. 17-104.
- BRÖNNIMANN, P., and BROWN, N. K., JR., 1958, *Hedbergella*, a new name for a Cretaceous planktonic foraminiferal genus: Washington Acad. Sci. Jour., v. 48, no. 1, p. 15-17, text-fig. 1.
- CARON, M., and LUTERBACHER, H. P., 1969, On some type specimens of Cretaceous planktonic foraminifera: Cushman Found. Foram. Research Contr., v. 20, pt. 1, no. 361, p. 23-29, pls. 7-9.

- CARSEY, D. O., 1926, Foraminifera of the Cretaceous of central Texas: Univ. Texas Bull. 2612, p. 1-56, pls. 1-8.
- COLLIGNON, M., 1963, Conclusions du Colloque de Stratigraphie sur le Crétacé Inférieur en France, Lyon, September, 1963: *Compte Rendu Somm. Sean., Soc. Géol. France*, Fasc. 8, p. 292-296.
- , 1965, Rapport sur L'Etage Albien, pp. 313-318, in *Colloque sur le Crétacé Inférieur* (Lyon, September, 1963): Bureau Res. Geol. Minier. Mem., no. 34, p. 1-840.
- COLLOQUE SUR LE CRÉTACÉ SUPÉRIEUR FRANÇAIS, 1959, *Comptes rendes du Congrès des Sociétés Savantes de Paris et des Travaux historiques et scientifiques, section de sciences, sous-section de géologies, tenu à Dijon, Paris, Gauthier-Villars* (Roger, J., Editor).
- CUSHMAN, J. A., 1938, Some new species of rotaliform foraminifera from the American Cretaceous: *Cushman Lab. Foramin. Research Contr.*, v. 14, pt. 3, p. 66-71, pls. 11-12.
- FRIZZELL, D. L., 1954, Handbook of Cretaceous foraminifera of Texas: Univ. Texas, Bur. Econ. Geol., Rept. Invest. no. 22, p. 1-232, pls. 1-21.
- HENDRICKS, L., 1967, Comanchean stratigraphy of the Cretaceous of North Texas. p. 51-63 in *Hendricks, L., Comanchean (Lower Cretaceous) stratigraphy and paleontology of Texas: Permian Basin Section, Soc. Econ. Paleontologists and Mineralogists Pub.*, 67-8.
- INTERNATIONAL SUBCOMMISSION ON STRATIGRAPHIC TERMINOLOGY, 1961, Statement of principles of stratigraphic classification and terminology (with accompanying glossary of Terms): 21st Internat. Geol. Cong. Rept., pt. 25, 38 pp. Copenhagen.
- LOEBLICH, A. R., JR., and TAPPAN, H., 1946, New Washita foraminifera: *Jour. Paleontology*, v. 20, no. 3, p. 238-258, text-figs. 1-4, pls. 35-37.
- , 1961, Cretaceous planktonic foraminifera: Part 1—Cenomanian: *Micropaleontology*, v. 7, no. 3, p. 257-304, pls. 1-8.
- , 1964, Sarcodina chiefly 'Thecamoebians' and Foraminiferida: *Treatise on Invert. Paleont.*, pt. C. Protista 2, v. 1-2, p. C1-C900, figs. 1-653.
- LOEBLICH, A. R., JR., TAPPAN, H., BECKMAN, J. P., BOLLI, H. M., GALLITELLI, E. M., and TROELSEN, J. C., 1957, Studies in foraminifera: U.S. Natl. Mus. Bull. 215, p. 1-323, pls. 1-74, 30 text figs.
- LOW, D., 1964, Redescription of *Anomalina eaglefordensis* Moreman: *Cushman Found. Foramin. Research*, v. 15, pt. 3, pp. 122-123.
- LOZO, F. E., 1943, Bearing of foraminifera and ostracoda on Lower Cretaceous Fredericksburg-Washita boundary of North Texas: *Am. Assoc. Petrol. Geologists Bull.*, v. 27, no. 8, p. 1060-1080.
- , 1944, Biostratigraphic relations of some north Texas Trinity and Fredericksburg (Comanche) foraminifera: *Am. Midland Naturalist*, v. 31, no. 3, p. 513-582, pls. 1-5.
- , 1949, Stratigraphic relations of Fredericksburg limestones, northcentral Texas: *Guidebook, 17th Ann. Field Trip, Shreveport Geol. Soc.*, p. 85-91.
- , 1959, Stratigraphic relations of the Edwards Limestone and associated formations in north central Texas. p. 1-19 in *Lozo, F. E., Nelson, H. F., Young, K., Shelburne, O. B., and Sandidge, J. R.: Symposium on Edwards Limestone in Central Texas*, Univ. Texas pub. no. 5905, p. 1-235.
- MORROW, A. L., 1934, Foraminifera and ostracods from the Upper Cretaceous of Kansas: *Jour. Paleontology*, v. 8, no. 2, p. 186-205, pls. 29-31.
- MOULLADE, M., 1969, Sur l'importance des phénomènes de convergence morphologique chez les foraminifères planetoniques du Crétacé Inférieur. p. 460-467, pl. 1, in *Bronnmann, P., and Renz, H. H.: Proc. 1st Internat. Conf. Plank. Foraminifera*, Geneva, v. 2, p. 745.
- MURRAY, G. E., 1961, *Geology of the Atlantic and Gulf Coastal Province of North America*: New York, Harper Bros., p. 1-692.
- PERKINS, B. F., 1960, Biostratigraphic studies in the Comanche (Cretaceous) Series of northern Mexico and Texas: *Geol. Soc. America Mem.* 83, p. 1-138.
- PESSAGNO, E. A., JR., 1967, Upper Cretaceous planktonic foraminifera from the Western Gulf Coastal Plain: *Paleontographica Americana*, v. 5, no. 37, p. 245-445, pls. 48-101, figs. 1-63.
- , 1969, Upper Cretaceous stratigraphy of the Western Gulf Coast area of Mexico, Texas and Arkansas: *Geol. Soc. America Mem.* 111, p. 1-139, pls. 1-60 in seven sheets.
- PLUMMER, H. J., 1931, Some Cretaceous foraminifera in Texas: *Univ. Texas Bull.* 3101, p. 109-203, pls. 8-15.
- RENTZ, O., LUTERBACHER, H., and SCHNEIDER, A., 1963, Stratigraphische-paleontologische untersuchungen um Albien und Cenomanian des Nuenburger Jura: *Eclogae Geol. Helv.*, v. 56, no. 2, p. 1073-1116, pls. 1-9.
- RENTZ, O., and LUTERBACHER, H. (with contributions by Richard, M.; Dertti, H. J.; and Stumm, F.), 1965, *Die Mittlere Kreide von La Vraconne bei Ste-Croix (Kt. Waadt)*: *Bull. Ver. Schweiz. Petrol.-Geol. u. Ing.*, v. 31, no. 81, p. 76-101.
- SELLARDS, E. H., ADKINS, W. S., and PLUMMER, F. B., 1932, *The geology of Texas*: Univ. Texas Bull. no. 3232, v. 1, p. 4-1007, geologic map.
- SIGAL, J., 1948, Notes sur les genres foraminifères *Rotalipora* Brotzen, 1942 et *Thalmaninella*: *Inst. Français Petrole Rev.*, v. 3, no. 4, p. 95-103, pls. 1-2.
- , 1963, Conclusions du colloque de Stratigraphie sur la Crétacé inférieur en France Lyon, Septembre 1963: *Compte Rendu Somm. Sean., Soc. Géol. France*, fasc. 8, p. 292-206.
- , 1965a, Presence d'un foraminifère pelagique *Hedbergella washitensis* (Carsey) du domaine Méditerranéen dans L'Albien du Bassin de Paris. p. 289-292 in *Colloque sur le Crétacé inférieur* (Lyon, Septembre 1963): Bureau Resh. Geol. Minier. Mem. 34, p. 1-840.
- , 1965b, Etat des connaissances sur les foraminifères du Crétacé inférieur, p. 489-502 in *Colloque sur les Crétacé inférieur* (Lyon, Septembre 1963): Bureau Resh. Geol. Minier. Mem. 34, pl. 1-840.
- SPATH, L. F., 1942, A monograph of the Ammonoidea of the Gault: pt. 15, *Palaeontogr. Soc. (London)*, v. 96, p. 669-720, figs. 245-248, 4 tables.
- TAPPAN, H., 1940, Foraminifera from the Grayson Formation of northern Texas: *Jour. Paleontology*, v. 14, no. 2, p. 93-126, pls. 14-19.

- , 1943, Foraminifera from the Duck Creek Formation of Oklahoma and Texas: *Jour. Paleontology*, v. 17, no. 5 p. 476–517, pls. 77–83.
- YOUNG, K., 1959, Edwards fossils as depth indicators in Symposium on Edwards Limestone in central Texas: Univ. Texas Pub. 5905, p. 97–104, 3 figs., pls. 31–32.
- , 1966, Texas Mojsisoviciinae (Annonoidea) and the zonation of the Fredericksburg: *Geol. Soc. Amer. Mem.* 100, 225 p., pls. 1–38.
- , 1967, Ammonite zonation, Texas Comanchean (Lower Cretaceous) stratigraphy and paleontology of Texas: *Permian Basin Section, Soc. Econ. Paleontologists and Mineralogists Pub.* 67–8.

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