

PLANKTONIC FORAMINIFERA FROM THE SAGE BREAKS SHALE, CENTENNIAL VALLEY, WYOMING

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ABSTRACT

Forty species of planktonic foraminifera, many of which have never been reported from the Western Interior, have been identified from the Sage Breaks Shale of southeastern Wyoming. Species diversity is greatest at the base, middle, and top of the formation. The base of the formation is questionably assigned to

the Coniacian, but the top can definitely be assigned to the early Campanian as it contains the concurrent occurrence of *Rugoglobigerina* and *Hastigerinoides*. This same association is restricted to the lower Taylor of Texas which is considered to be early Campanian by both microfossil and megafossil workers.

INTRODUCTION

The purpose of this paper is to describe the planktonic foraminiferal biostratigraphy of the Sage Breaks Shale of southeastern Wyoming. The Sage Breaks Shale crops out throughout southeastern Montana, western South Dakota, eastern Wyoming and northwestern Colorado. Equivalent strata includes the Kevin Shale in Montana, the lower Cody Shale in northwestern Wyoming, the lower Mancos Shale in western Colorado, and the Fort Hays and the lower Smoky Hill Members in eastern Colorado, Kansas and Nebraska.

In Centennial Valley, Wyoming (SE $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 19, T. 15 N., R. 77 W.) there is a continuous exposure of the Sage Breaks Shale. The section is 360 ft thick and was originally collected at a sample interval of 3 ft as part of a paleomagnetic study (Shive and Frerichs, 1974). A 20-ft sample interval was chosen for this study.

Each sample was dried, weighed and washed through a 62-micron screen. After drying, the residues were split with a sample splitter until 200 to 300 plank-

tonic foraminifera remained. These specimens were separated into species and the remainder of the sample examined for additional species.

STRATIGRAPHY

Rubey (1930), first applied the name Sage Breaks Shale to a sequence of shales overlying the Turner Sandstone Member of the Carlile Shale and topped by the chalky beds of the Niobrara Formation. He originally designated the Sage Breaks Shale as the lower member of the Niobrara Formation. Subsequently, Cobban and Reeside (1952b) designated the Sage Breaks Shale to be the top member of the Carlile Shale.

In the Laramie Basin of southeastern Wyoming, Thomas (1936) first applied the term Sage Breaks Shale to the shales overlying the Wall Creek Sandstone and topped by the chalky members of the Niobrara Formation. Thomas suggested that these shales be included in the Niobrara Formation as the lower member (Fig. 1).

DARTON 1908	DOBBIN BOWEN, and HOOTS 1929	THOMAS 1936	SHAW 1953	THIS PAPER
NIOBRARA	NIOBRARA	N I O B R A R A	UPPER CHALK MEM.	N I O B R A R A
			UPPER SHALE MEM.	UPPER SHALE MEM.
			LOWER CHALK MEM.	LOWER CHALK MEM.
BENTON	CARLILE	SAGE BREAKS SHALE MEM.	LOWER SHALE MEM.	SAGE BREAKS SHALE
	FRONTIER	FRONTIER	FRONTIER	FRONTIER

FIGURE 1

Historical summary of stratigraphic usage for units mentioned in this report.

Shaw (1953) suggested that these shales be called the Lower Shale Member of the Niobrara Formation. Shaw felt that the term Sage Breaks Shale was inappropriate as the Sage Breaks at its type locality in northeastern Wyoming is considered to be the top member of the Carlile Shale. Another consideration was the occurrence of the ammonite *Prionocyclus* in the type Sage Breaks and in the Wall Creek Sandstone of Centennial Valley, but not in the Sage Breaks Shale Member of Centennial Valley. For this reason Shaw assumed that the Sage Breaks Shale of Thomas was younger than the type Sage Breaks. This assumption does not seem to be valid, however, because there have been no ammonites found in the Sage Breaks Shale Member of Centennial Valley. Therefore, the lack of *Prionocyclus* would seem to be environmental. And in fact, planktonic foraminiferal evidence suggests a correlation between the type Sage Breaks (Frerichs and others, 1977) and the Sage Breaks Shale Member in Centennial Valley. Both units contain the species *Hastigerinoides subdigitata* (Carman) at the top. This species ranges from the Santonian to the early Campanian in the Western Interior (Frerichs and others, 1977) and is found in the upper 130 ft of the Sage Breaks Shale in Centennial Valley, and at the top of the type Sage Breaks (Evitt, 1976). This establishes a similar age for the type Sage Breaks and the Sage Breaks of Centennial Valley as the underlying Turner Sandstone and Wall Creek Sandstone have been proven to be the same age (Cobban and Reeside, 1952b). As mentioned previously the type Sage Breaks was assigned to the Carlile Shale by Cobban and Reeside (1952b). At that time it was considered to be older than the Fort Hays Member of the Niobrara Formation. In the type area of the Fort Hays Limestone in

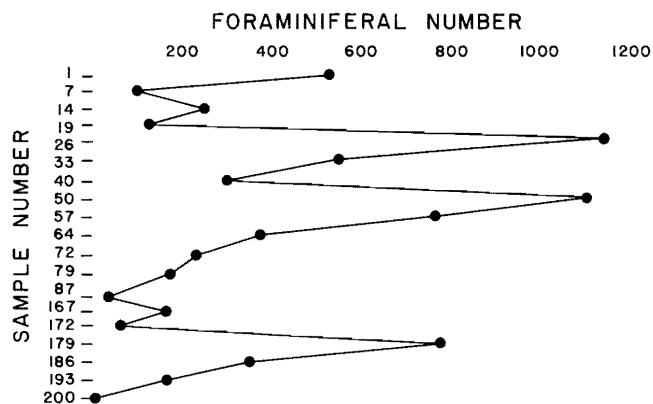


FIGURE 2

Number of planktonic and benthonic foraminifera per one gram of dry sediment. Larger values in the top half of the section may be due to slightly lower rates of sedimentation.

Trego County, Kansas, however, *Hastigerinoides subdigitata* is found in the upper 3 ft of the limestone (Frerichs and others, 1977). This suggests that the two members are roughly equivalent in age. At Pueblo, Colorado the same relationship exists. The upper foot of the Little Fountain Shale (lower shale unit of Scott and Cobban, 1964) contains *Hastigerinoides subdigitata* (Frerichs and others, 1977). This is more than 50 ft above the top of the Fort Hays and correlates the lower two-thirds of the type Sage Breaks with the Fort Hays at Pueblo, Colorado. It also follows that the lower two-thirds of the Sage Breaks Shale in Centennial Valley correlates with the type Fort Hays Limestone.

This resolves the questions of the age of the Sage Breaks Shale, but after examining this unit in some detail another question is raised. The lithology, thickness and areal extent of the Sage Breaks Shale suggests that this unit should be raised to formation rank and this usage is followed in this paper.

PLANKTONIC FORAMINIFERAL ASSEMBLAGES

Archaeoglobigerina and *Heterohelix* are the two most abundant genera in the Sage Breaks Shale. *Hastigerinoides*, *Hedbergella* and *Marginotruncana* are common and *Globotruncana*, *Planoglobulina*, *Rugoglobigerina* and *Whiteinella* are scarce to common.

This assemblage is mainly a temperate one with keeled species, normally associated with tropical areas, only common for a short interval in the middle of the formation. The widespread nature and biostratigraphical significance of this "keeled zone" has been described by Frerichs and Adams (1973).

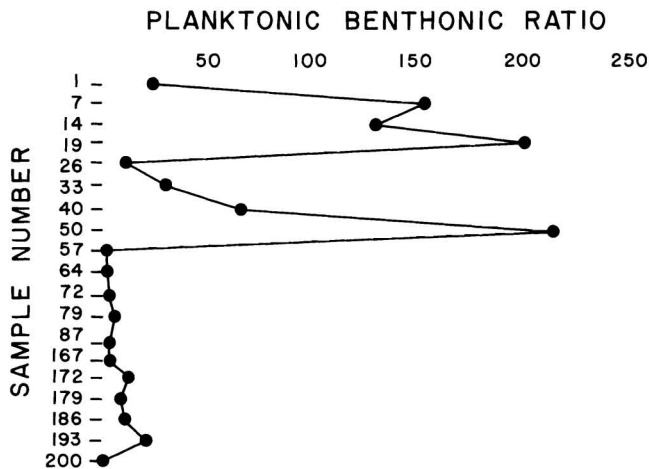


FIGURE 3

The two major peaks in the top half of the section are due, at least in part, to reduction of the benthonic fauna.

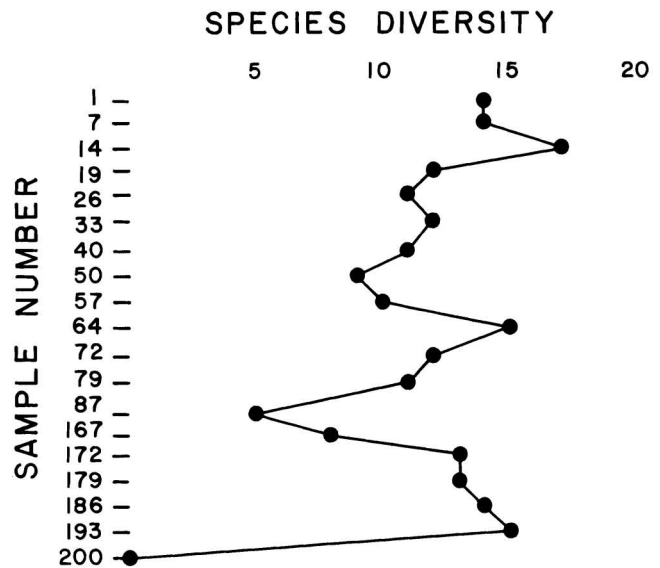


FIGURE 4

The number of planktonic species per sample best reflects the major faunal and environmental changes which occurred during the deposition of the Sage Breaks Shale. The middle peak of diversity reflects the migration of subtropical species into southeastern Wyoming.

Forty species are represented in the formation, many of them reported from the Western Interior for the first time. This assemblage and the species from the overlying chalky members of the Niobrara Formation (Frerichs and others, 1975) represent the most diverse assemblage of planktonic foraminifera reported from the Western Interior.

Foraminiferal Numbers. All samples have relatively low foraminiferal numbers (Fig. 2). The greatest foraminiferal numbers are found in the lower part of the top half of the Sage Breaks Shale. Smaller peaks occur in the lower third and at the top of the formation.

Planktonic-Benthonic Ratios. Planktonic-benthonic ratios show a very interesting trend (Fig. 3). Ratios are highest, with values near 200 in the top half of the shale. Ratios of this size are normally found at bathyal depths in today's oceans. Ratios are smallest near the middle of the shale with values near one. Planktonic-benthonic ratios of this size are generally restricted to shelf environments. This trend suggests that waters were shallowest during deposition of the middle of the formation and deepest at the top of the formation. A close examination of the benthonic fauna shows this picture to be erroneous. The benthonic fauna is predominantly arenaceous in those parts of the shale having high planktonic-benthonic ratios. This suggests that the calcareous benthonic fauna was environmentally excluded from these areas as planktonic foraminifera are abundant and show no signs of solution. The middle part of the Sage Breaks with planktonic-benthonic ratios near one contain numerous calcareous

benthonics. Therefore, those ratios suggesting shelf depths are considered valid.

What factor or factors might be excluding the calcareous benthonic foraminifera from the upper half of the Sage Breaks Shale is a perplexing question. The specimens of arenaceous foraminifera found in this part of the section are very fragile. In the author's experience, arenaceous species such as these are found in the inner shelf environment. In Recent inner shelf environments, however, planktonic species are almost completely excluded (compare Frerichs, 1970; Frerichs, 1971); this is not the case in the Sage Breaks Shale.

Another explanation for the high planktonic-benthonic ratios might involve the oxygen content of the water. Frush and Eicher (1975) have suggested this mechanism to explain high planktonic-benthonic ratios in the Cenomanian of the Western Interior using the recent example of the Arabian Sea. They suggested that an oxygen minimum in the Western Interior could be found at a depth as shallow as 76 m. An oxygen minimum may explain the planktonic-benthonic ratios in the Sage Breaks Shale, but further work with the benthonic assemblages will be required before conclusions can be drawn.

The middle third of the Sage Breaks Shale was deposited at the time of greatest transgression during

deposition of Niobrara age sediments (Frerichs and Adams, 1973) and planktonic-benthonic ratios suggest outer shelf or upper bathyal depths. If the depth for the oxygen minimum suggested by Frush and Eicher (1975) is used, then the middle third of the Sage Breaks Shale, if oceanographic conditions did not change, most probably was deposited in water depths in excess of outer shelf depths. The subtropical-tropical assemblage of planktonic foraminifera characteristic of the middle third of the Sage Breaks Shale, however, is quite distinctive from the temperate assemblage characteristic of the upper third of the shale. This suggests quite strongly that a change in water mass may be responsible for the change in planktonic benthonic ratios.

Species Diversity. There are three peaks of species diversity (Fig. 4) in the Sage Breaks Shale. The lower peak occurs 20 ft above the Wall Creek Sandstone and seems to indicate a rapid increase in water depth at this time. The middle peak coincides with the increase in keeled specimens and is related to a major transgression in the Western Interior. The upper peak is a reflection of the appearance of many new species, usually associated with the Campanian, in the planktonic foraminiferal assemblage.

Age of the Sage Breaks Shale. The planktonic foraminiferal assemblage of the overlying Lower Chalk Member of the Niobrara Formation in Centennial Valley contains *Hastigerinoides watersi* (Cushman), *Rugoglobigerina pilula* Belford (= *R. tradinghousensis* Pessagno) and *R. rugosa* (Plummer), and is considered to be early Campanian in age (Frerichs, and others, 1975). The top of the Sage Breaks Shale also contains an early Campanian assemblage of planktonic foraminifera. Species found in the Sage Breaks and restricted to the Campanian in the Gulf Coast (Pessagno, 1967) are *Heterohelix planata* (Cushman), and *Globigerinelloides multispina* (Lalicker). Species which range into the Campanian include *Heterohelix reussi* (Cushman) *Hastigerinoides watersi* (Cushman), *Globigerinelloides prairiehillensis* Pessagno, *Archaeoglobigerina blowi* Pessagno, *A. cretacea*

(d'Orbigny) *Globotruncana austinensis* Gandolf, and *G. bulloides* (Vogler). The top of the Sage Breaks Shale also contains *Rugoglobigerina bulbosa* Belford which has not previously been reported from North America, but is probably restricted to the Campanian.

The Campanian-Santonian boundary cannot accurately be determined, but is placed at the first common occurrence of the genus *Globigerinelloides*, 45 ft below the top of the formation. The first occurrence of *Rugoglobigerina* also occurs near this horizon. This boundary is similar to the boundary of Pessagno (1967), but is younger than the boundary of Young (1963). The Santonian-Coniacian boundary is tentatively placed at the first occurrence of *Hastigerinoides* 130 ft below the top of the formation. No Turonian index species have been found in the shale and the base of the formation is considered to be Coniacian.

A Coniacian to early Campanian age differs somewhat from previously accepted ages for the Sage Breaks Shale. Cobban and Reeside (1952a, 1952b) suggested a late Turonian to early Coniacian age for this shale in the Laramie Basin. Shaw (1953), by implication, followed the usage of Cobban and Reeside. Most of the difference in ages between the megafossils and microfossils may be attributed to the lack of megafossils in the Centennial Valley section. The author has found no megafossils during his work in the field.

SYSTEMATIC PALEONTOLOGY

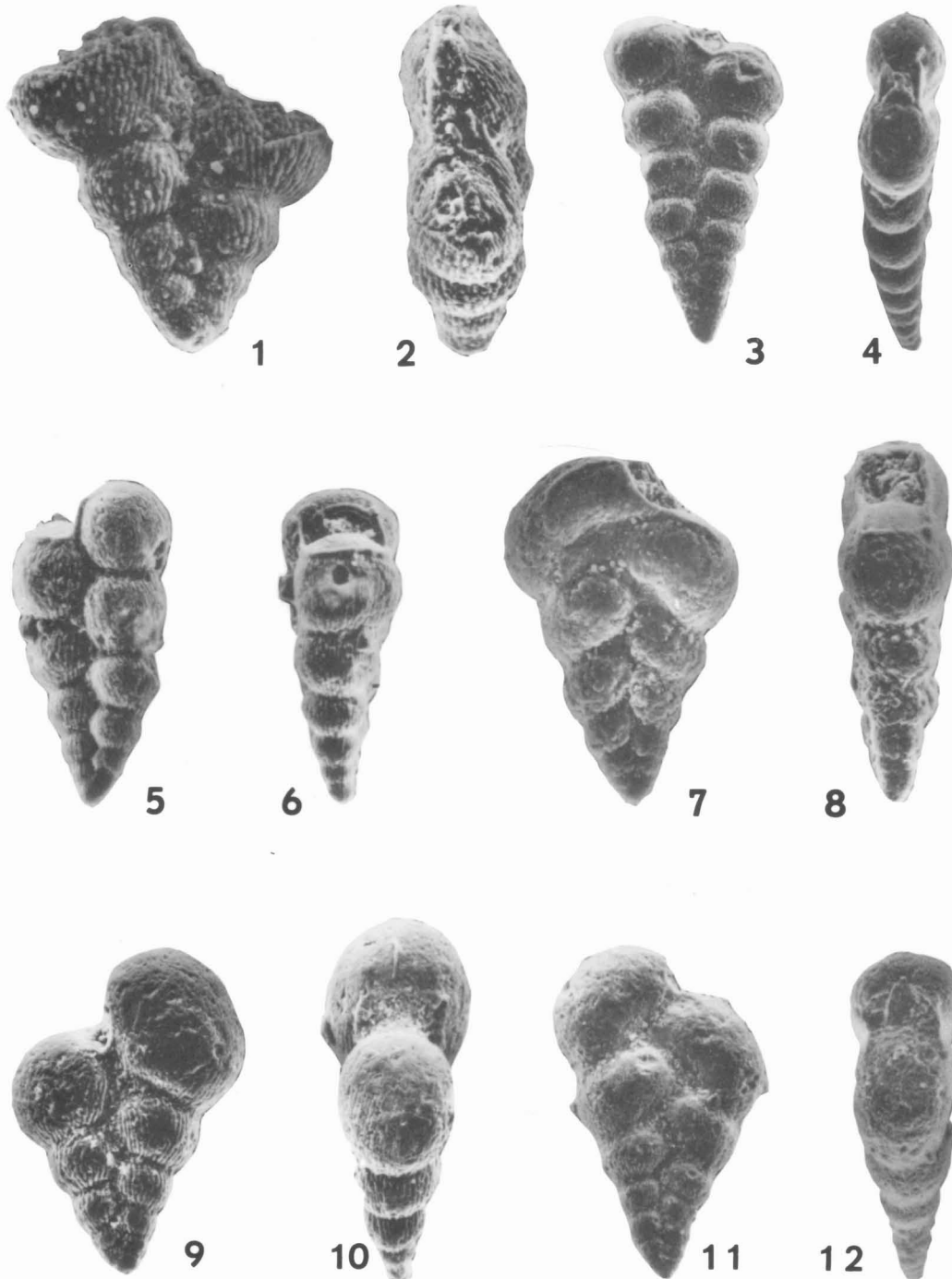
The synonymies and descriptions of Frerichs and others (1975), are followed in this paper. Only those species not previously identified and described from the Western Interior are described in this paper.

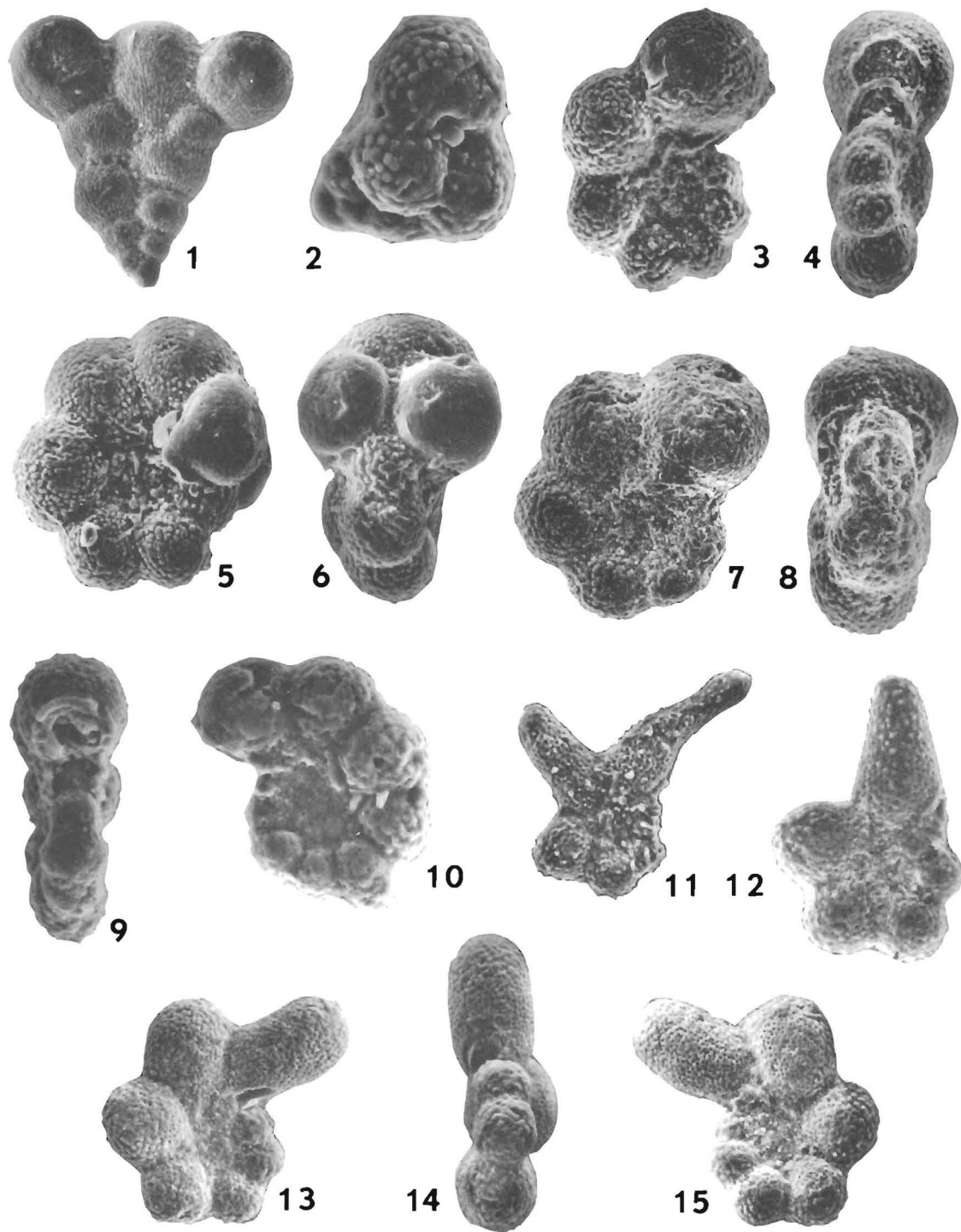
Order FORAMINIFERIDA
Superfamily GLOBIGERINACEA
Family HETEROHELICIDAE
Subfamily GUEMBELITRINAE
Genus **Guembelitria** Cushman, 1933
Guembelitria harrisi Tappan
Pl. 2, Fig. 2

Guembelitria harrisi TAPPAN, 1940, v. 14, p. 115, pl. 19, fig. 2.

PLATE 1

- 1, 2 *Heterohelix americana* Ehrenberg. 1. Side view, $\times 260$. 2. Apertural view same specimen, $\times 260$. (SB14-5).
- 3, 4 *Heterohelix planata*? (Cushman). 3. Side view, $\times 90$. 4. Apertural view same specimen, $\times 90$. (SB1-22).
- 5, 6 *Heterohelix pseudoglobosa* n. sp. 5. Side view, $\times 150$. 6. Apertural view same specimen, $\times 150$. Holotype. (SB193-22). U.S. National Museum 689928.
- 7, 8 *Heterohelix pulchra* (Brotzen). 7. Side view, $\times 150$. 8. Apertural view same specimen, $\times 150$. (SB40-1).
- 9, 10 *Heterohelix reussi* (Cushman). 9. Side view, $\times 160$. 10. Apertural view same specimen, $\times 160$. (SB1-16).
- 11, 12 *Heterohelix* aff. *pulchra* (Brotzen). 11. Side view, $\times 110$. 12. Apertural view same specimen, $\times 110$. (SB50-1).





Occurrence. This species occurs abundantly at the base of the Sage Breaks Shale where it is found in sample 193.

Subfamily HETEROHELICINAE
Genus **Heterohelix** Ehrenberg, 1843
Heterohelix americana (Ehrenberg)
Pl. 1, Figs. 1, 2

Textilaria americana EHRENBURG, 1843, p. 366, 398, 429. EHRENBURG, 1854, pl. 32, pt. 1, fig. 4a (not fig. 7). CUSHMAN, 1927, p. 215, pl. 34, fig. 4a. CUSHMAN, 1938, p. 5, pl. 1, fig. 10 (not fig. 20).

Spiroplecta americana Ehrenberg. EHRENBURG, 1854, pl. 32, figs. 13, 14, not fig. 25. CUSHMAN, 1927, p. 215, pl. 34, figs. 13, 14. *Textilaria missouriensis* Ehrenberg. EHRENBURG, 1854, p. 24, pl. 32, (group 1), fig. 5. CUSHMAN, 1927, p. 215, pl. 34, fig. 5. CUSHMAN, 1938, p. 6, pl. 1, fig. 21.

Not *Heterohelix americana* (Ehrenberg). CUSHMAN, 1927, p. 190. Not *Heterohelix americana* (Ehrenberg). WICKENDEN, 1945, p. 42. *Planoglobulina? glabrata* (Cushman). FRERICHS and others, 1975, v. 5, p. 302, pl. 1, figs. 9, 10.

Heterohelix americana (Ehrenberg). FRERICHS and others, 1978, v. 8, p. 144, pl. 1, figs. 1–11.

Description. Test small to moderately large, coiled in biserial manner, early planispiral portion not observed. Wall calcareous, perforate, ornamented with numerous fine costae, not continuous across chambers. Chambers compressed, increasing gradually in size, final one to three pairs of chambers triangular in shape with apex at outer margin directed upward, final one to two chambers, rarely as many as four, with spine at apex at the triangular chambers. Sutures depressed, medial suture forming a zigzag pattern. Aperture a high narrow arch at the base of last chamber, bordered by a prominent flap.

Remarks. This species is easily distinguished by its flaring, strongly compressed chambers.

Occurrence. *Heterohelix americana* occurs rarely in the upper 140 ft of the formation.

Heterohelix planata (Cushman)
Pl. 1, Figs. 3, 4

Guembelina planata CUSHMAN, 1938, p. 12, figs. 13, 14.

Occurrence. This species is found in the upper 120 ft of the Sage Breaks Shale. It has been reported from strata of late Campanian and early Maastrichtian age of the Gulf Coastal Plain (Pessagno, 1967).

Heterohelix pseudoglobulosa
Frerichs n. sp.
Pl. 1, Figs. 5, 6

Heterohelix reussi (Cushman). PESSAGNO, 1967, p. 263, pl. 85, figs. 1–2 (not figs. 3–9).

Heterohelix globulosa (Ehrenberg). EICHER, 1967, p. 26, pl. 5, figs. 9a, b; 10a, b.

Heterohelix globulosa (Cushman). EICHER and WORSTELL, 1970, p. 296, pl. 8, fig. 3 (not figures 4–6).

Description. Test small to moderately large, biserial with five to eight pairs of chambers. Wall calcareous, perforate, ornamented with discontinuous faint costae. Chambers globular, increasing very slowly in size. Sutures depressed, triangular depressions at the junction with the medial suture in larger specimens. Aperture a high arch at the base of the last chamber bordered by a thin lip.

Remarks. This species is quite similar to *Heterohelix globulosa* but differs in test shape and size of later chambers. It also resembles *H. reussi* Cushman in the triangular depressions between chambers, but differs from this species in general shape and chamber shape.

Occurrence. This species is found sporadically in the lower 380 ft of the Sage Breaks Shale. It has been reported throughout the Western Interior in Cenomanian and Turonian rocks (Eicher and Worstell, 1970).

PLATE 2

- 1 *Planoglobulina austinana* (Cushman). 1. Side view, $\times 115$. (SB179-9).
- 2 *Guembelitria harrisi* Tappan. 2. Apertural view, $\times 300$. (SB193-50).
- 3, 4 *Globigerinelloides prairiehillensis* Pessagno. 3. Side view, $\times 120$. 4. Apertural view same specimen, $\times 120$. (SB1-4).
- 5, 6 *Globigerinelloides multispina* (Lalicker). 5. Side view, $\times 130$. 6. Apertural view same specimen, $\times 130$. Specimen with small biserial portion. (SB14-1).
- 7, 8 *Globigerinelloides multispina* (Lalicker). 7. Side view, $\times 135$. 8. Apertural view same specimen, $\times 135$. (SB1-304).
- 9, 10 *Globigerinelloides* aff. *ehrenbergi* (Barr). 9. Apertural view, $\times 260$. 10. Side view same specimen, $\times 260$. (SB64-15).
- 11, 12 *Hastigerinoides watersi* (Cushman). 11. Side view, $\times 110$. 12. Side view, specimen without bulbous tipped chamber, $\times 110$. (SB14-18).
- 13–15 *Hastigerinoides subdigitata* (Carman). 13. Side view, $\times 110$. 14. Apertural view same specimen, $\times 110$. 15. Side view same specimen, $\times 110$. (SB1-100).

Heterohelix pulchra (Brotzen)

Pl. 1, Figs. 7, 8

Guembelina pulchra BROTZEN, 1936, p. 121, pl. 9, figs. 3a-b.

Occurrence. This species is found throughout the Sage Breaks Shale. It has been reported from the Campanian and lower Maastrichtian of the Gulf Coastal Plain (Pessagno, 1967), but has been reported from rocks as old as the late Cenomanian in the Western Interior (Eicher and Worstell, 1970).

Heterohelix aff. pulchra (Brotzen)

Pl. 1, Figs. 11, 12

Description. Test small, biserial with five to six pairs of chambers, periphery lobate throughout. Wall calcareous, perforate, faintly costate. Chambers subglobular, reniform. Sutures curved, depressed. Aperture interiomarginal, a high arch at the base of the last chamber bordered by a lip.

Remarks. This form is similar to *pulchra* but differs in that *H. pulchra* lacks ornamentation. It differs from *H. planata* (Cushman) in that *H. planata* does not have reniform chambers. Additional reports of this form are needed before it can be named.

Occurrence. This form occurs only rarely in the middle third of the Sage Breaks Shale.

Heterohelix reussi (Cushman)

Pl. 1, Figs. 9, 10

Guembelina reussi CUSHMAN, 1938, p. 11, pl. 2, figs. 6-9.

Remarks. A cline exists within this species and specimens from the base of the member are thinner than specimens from the top of the member.

Occurrence. This species is found throughout the Sage Breaks Shale. It has been reported from the Turonian through middle Campanian of the Gulf Coastal (Pessagno, 1967).

Genus **Planoglobulina** Cushman 1927**Planoglobulina austiniana** (Cushman)

Pl. 2, Fig. 1

Ventilabrella eggeri Cushman. CARMAN, 1929, p. 314, pl. 34, fig. 7.

LOETTERLE, 1937, p. 35, pl. 5, fig. 5.

Ventilabrella austiniana CUSHMAN, 1938, p. 26, pl. 4, fig. 19a, b. CUSHMAN, 1944, p. 92, pl. 14, fig. 7.*Heterohelix globulosa* (Ehrenberg). EICHER and WORSTELL, 1970, p. 296, pl. 8, fig. 4 (not figs. 3, 5, 6).*Ventilabrella* (?) *austiniana* Cushman. MARTIN, 1972, p. 84, pl. 1, figs. 1, 2.

Description. Test small to medium sized, biserial initially, later with three chambers. Wall calcareous,

perforate, ornamented with discontinuous faint costae. Chambers globular, increasing gradually in size. Sutures depressed. Aperture at the base of the last chamber.

Occurrence. This species was found in one sample 40 ft above the base of the Sage Breaks Shale. It has commonly been reported from Santonian and Campanian rocks of the Gulf Coastal Plain (Martin, 1972), with a Turonian report by Cushman (1946). Eicher and Worstell (1970) illustrated a specimen from the Turonian of northeastern Wyoming as *Heterohelix globulosa*.

Family PLANOMALINIDAE Bolli,

Loeblich and Tappan 1957

Genus **Hastigerinoides** Brönnimann, 1952**Hastigerinoides subdigitata** (Carman)

Pl. 2, Figs. 13-15

Globigerina subdigitata CARMAN, 1929, p. 315, pl. 34, figs. 4, 5.

Occurrence. This species is found in the upper 120 ft of the Sage Breaks Shale Member. It is most abundant in the upper 75 ft of the member with the acme at 45 ft below the top of the member.

Hastigerinoides watersi (Cushman)

Pl. 2, Figs. 11, 12

Hastigerinella watersi CUSHMAN, 1931, p. 86, pl. 11, figs. 4, 5.

Occurrence. This species is found in the upper 120 ft of the formation. It is most abundant in the upper 75 ft with its acme at 45 ft. It has been reported from the Niobrara Formation in South Dakota, Nebraska, and Kansas, and from the lower Santonian and lower Campanian of Texas.

Genus **Globigerinelloides** Cushman and

Ten Dam, 1948

Globigerinelloides multispina Lalicker

Pl. 2, Figs. 5, 6; 7, 8

Biglobigerinella multispina LALICKER, 1948, p. 624, pl. 92, figs. 1a-c, 2a-b, 3a-c.*Globigerinella biforaminata* HOFKER, 1956a, p. 53, text-figs. 2, 5.*Biglobigerinella biforaminata* (Hofker). OLSSON, 1960, p. 44, pl. 8, figs. 7-8.*Globigerinelloides messinae* (Brönnimann). OLSSON, 1964, p. 174, pl. 7, figs. 6a-b, 7a-b, 8a-b.*Globigerinelloides multispina* (Lalicker). PESSAGNO, 1967, p. 276, pl. 70, figs. 1-2, pl. 82, figs. 10-11; pl. 91, figs. 1-2. SMITH and PESSAGNO, 1973, p. 38, pl. 13, figs. 1-2, 3-6, 7, 8-9, 10-11.

Description. Test small partially evolute planispiral coil of six to eight chambers; often becoming biserial;

equatorial periphery slightly lobate; axial periphery rounded. Chambers globular. Sutures depressed. Umbilicus wide. Aperture bipartite, at the base of the last chamber, paired chambers often covering the apertures.

Occurrence. This species is rare in the upper 40 ft of the Sage Breaks Shale. It is restricted to the Campanian and younger strata in the Gulf Coastal Plain (Pessagno, 1967). On the east coast it is found in upper Campanian and Maastrichtian strata (Olsson, 1964).

Globigerinelloides prairiehillensis

Pessagno

Pl. 2, Figs. 3, 4

Globigerinelloides prairiehillensis PESSAGNO, 1967, p. 277, pl. 60, figs. 2, 3, pl. 83, fig. 1, pl. 90, figs. 1-2, 4.

Occurrence. This species is found in the upper 160 ft of the Sage Breaks Shale, but is most abundant in the upper 40 ft. In the Gulf Coastal Plain it is found in upper Santonian to upper Maastrichtian strata and is most abundant in the Campanian and upper Maastrichtian (Pessagno, 1967; Smith and Pessagno, 1973).

Globigerinelloides* aff. *ehrenbergi

Barr

Pl. 2, Figs. 9, 10

Planomalina ehrenbergi BARR, 1962, p. 563, pl. 69, figs. 1a-b.

?*Globigerinelloides* sp. A SMITH and PESSAGNO, 1973, p. 42, pl. 16, figs. 8-9.

Description. Test small, an evolute planispiral coil of eight to nine chambers in the last whorl; equatorial periphery slightly lobate; axial periphery rounded. Chambers spherical, increasing slowly in size. Sutures depressed. Umbilicus wide. Aperture equatorial, high, circular, bordered by a well developed lip.

Remarks. This species seems similar to *G. ehrenbergi* Barr, but differs in that it has a high round aperture and *G. ehrenbergi* has a low aperture. It is also similar to a specimen described as *Globigerinelloides* sp. A by Smith and Pessagno (1973), but their specimen was much larger than material from the Sage Breaks Shale.

Occurrence. This species has been found in the upper 200 ft of the Sage Breaks Shale, but is quite rare.

Family ROTALIPORIDAE Sigal 1958

Subfamily HEDBERGELLINAE Loeblich and

Tappan 1961

Genus *Hedbergella* Brönnimann and

Brown 1958

***Hedbergella archaeocretacea* (Pessagno)**

Pl. 3, Figs. 1-3

Whiteinella archaeocretacea PESSAGNO, 1967, p. 298, pl. 51, figs. 2-4, pl. 54, figs. 19-21, 22-24, pl. 100, fig. 8.

Hedbergella archaeocretacea (Pessagno). DOUGLAS, 1969, p. 165, pl. 1, fig. 5, pl. 6, fig. 7.

Description. Test small to medium sized, low trochospiral coil of four to five chambers in the last whorl; equatorial periphery only slightly lobate; axial periphery subrounded. Chambers ovate, more strongly compressed on the spiral side, sausage-shaped. Sutures depressed, straight to slightly curved on the spiral side; depressed, radial on the umbilical side. Umbilicus wide. Aperture interiomarginal, extraumbilical, flanked by an apertural lip.

Remarks. The sausage-shaped chambers of this species are quite distinctive.

Occurrence. This species is rare to common in the lower 180 ft of the Sage Breaks Shale. It has been reported from the Turonian through lower Santonian of the Gulf Coastal Plain (Pessagno, 1967) and from the upper Cenomanian to lower Coniacian of the Great Valley of California (Douglas, 1969).

***Hedbergella* aff. *amabilis* Loeblich and**

Tappan

Pl. 3, Figs. 4-6

Hedbergella amabilis LOEBLICH and TAPPAN, 1961, p. 274, pl. 3, figs. 1-10. EICHER and WORSTELL, 1970. DOUGLAS, 1969, p. 165, pl. 4, figs. 8a-c.

Description. Test small to medium sized, low trochospiral coil of five to six chambers; equatorial periphery lobate; axial periphery rounded. Chambers ovate, the last chamber slightly produced perpendicular to the coil. Sutures depressed, straight to slightly curved on the spiral side; depressed, radial on the umbilical side. Umbilicus small, shallow. Aperture interiomarginal, extraumbilical, covered by a large apertural lip.

Remarks. This species is very similar to *Hedbergella amabilis* Loeblich and Tappan in that they both have large apertural lips, but it differs from *H. amabilis* in that it does not have truly clavate chambers.

Occurrence. This species is common in the lower 160 ft of the Sage Breaks Shale.

***Hedbergella yezoana* Takayanagi and**

Iwamoto

Pl. 3, Figs. 7-9

Description. Test small to medium sized, low to slightly concave trochospiral coil of six to eight chambers; equatorial periphery slightly lobate; axial periphery rounded. Chambers globular. Sutures depressed, straight to slightly curved on the spiral side; de-

pressed, radial on the umbilical side. Umbilicus small. Aperture interiomarginal, extraumbilical.

Remarks. This species is similar to *Whiteinella centennialensis* Frerichs n. sp., but lacks the tangentially produced last chamber of that species.

Occurrence. This species is rare to common in the lower 140 ft of the Sage Breaks Shale.

Genus *Clavihedbergella* Banner and Blow 1959

Clavihedbergella simplex (Morrow)
Pl. 3, Figs. 13–15

Hastigerinella simplex MORROW, 1934, p. 198, pl. 30, fig. 6.

Occurrence. This species was found in only one sample, 63 ft above the base of the Sage Breaks Shale. It has been recorded from the upper Cenomanian to upper Coniacian in the Gulf Coastal Plain (Pessagno, 1967) and from the upper Cenomanian to strata marking the end of the Coniacian in California (Douglas, 1969).

Genus *Praeglobotruncana* Bermúdez 1952
Praeglobotruncana sp. A
Pl. 5, Figs. 1–3

Description. Test small, a low trochospiral, often depressed, coil of six to eight chambers; equatorial periphery slightly lobate; axial periphery angular truncate with a wide double keel. Wall calcareous, perforate, spinose on the early chambers, smooth on younger chambers. Chambers slightly inflated, sub-crescentic to crescentic on the spiral side; slightly inflated, wedge-shaped on the umbilical side. Sutures curved, depressed on the spiral side; straight, depressed on the umbilical side. Umbilicus, small, broken remains of portici obvious on some chambers. Aperture interiomarginal, umbilical extraumbilical.

Remarks. The wide double keel of this species is similar to that of *P. stephani* (Gandolfi), but it is not nearly as high-spired.

Occurrence. This species is found in the lower 40

ft of the Sage Breaks Shale. There are no other reports of this form.

Family MARGINOTRUNCANIDAE

Pessagno 1967

Genus *Whiteinella* Pessagno 1967

Whiteinella aprica (Loeblich and Tappan)
Pl. 4, Figs. 1–3

Ticinella aprica LOEBLICH and TAPPAN, 1961, p. 262, pl. 4, figs. 14–16.

Occurrence. This species is found in the lower 80 ft of the Sage Breaks Shale. It has been reported from the Turonian of Texas (Loeblich and Tappan, 1961) and the Western Interior (Eicher and Worstell, 1970).

Whiteinella centennialensis
Frerichs n. sp.
Pl. 4, Figs. 4–6; 7–9

Hedbergella sp. A. FRERICHS and others, 1975, p. 309, pl. 3, figs. 5–7.

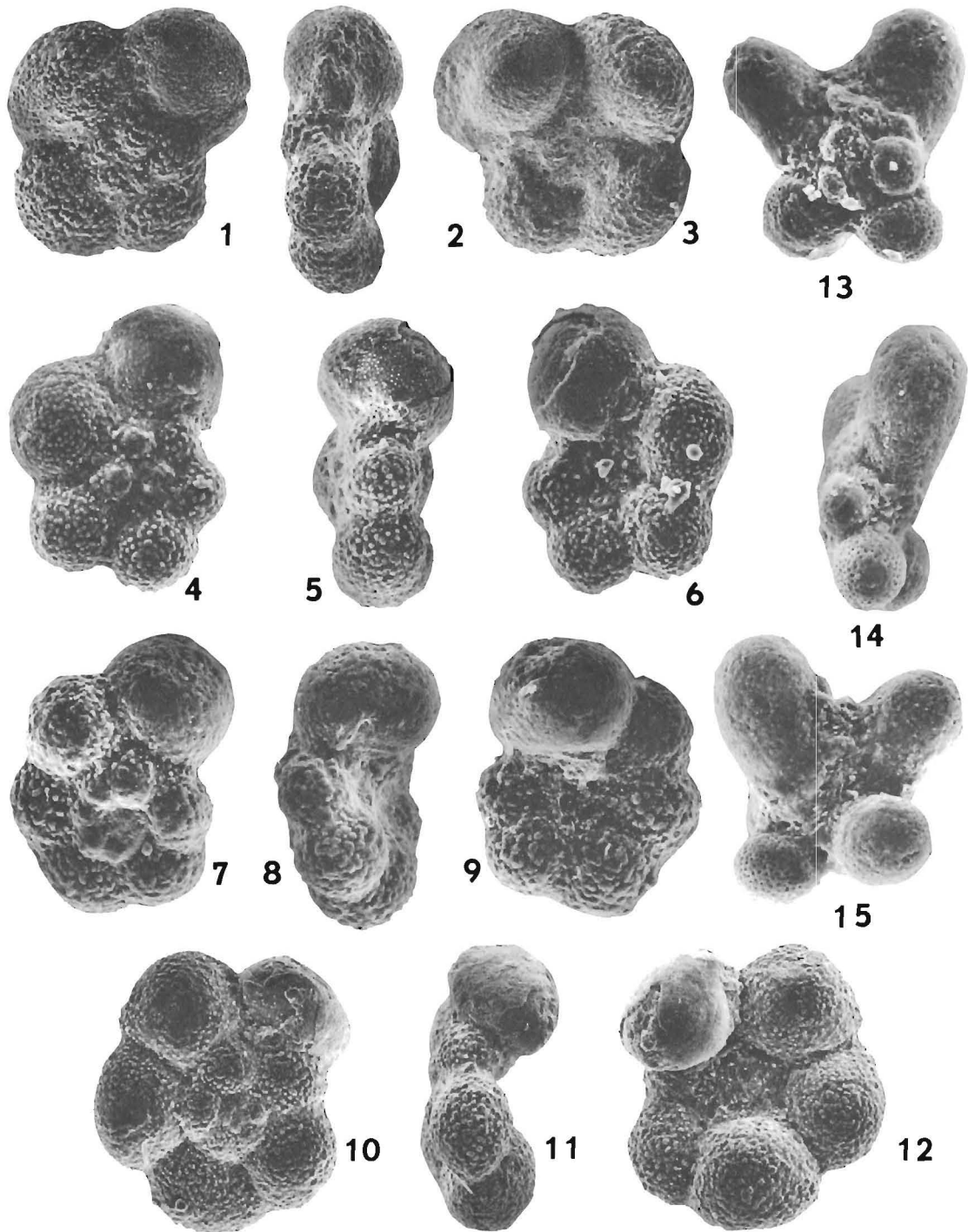
Description. Test small to medium sized, low to slightly concave trochospiral coil of six to nine chambers in the last whorl; equatorial periphery slightly lobate; axial periphery rounded. Chambers globular, ornamented with spines, last chamber slightly produced tangentially to the coil. Suture depressed, straight to slightly curved on the spiral side; depressed, radial on the umbilical side. Umbilicus moderately wide. Aperture interiomarginal, extraumbilical, flanked by a large apertural lip.

Remarks. This species is similar to *Hedbergella planispira* Tappan, but is larger and has more chambers. It is possible that *W. centennialensis* was derived from *H. planispira*. Stratigraphically older specimens have fewer chambers and are quite similar to *H. planispira*. The species is named for Centennial Valley, Wyoming, where the section of the Sage Breaks Shale used in this study is located.

Occurrence. This species is found in all but the lower 40 ft of the Sage Breaks Shale.

PLATE 3

- 1–3 *Hedbergella archaeocretacea* (Pessagno). 1. Dorsal view, $\times 155$. 2. Side view same specimen, $\times 170$. 3. Ventral view same specimen, $\times 155$. (SB179-71).
4–6 *Hedbergella* aff. *amabilis* Loeblich and Tappan. 4. Dorsal view, $\times 230$. 5. Side view same specimen, $\times 230$. 6. Ventral view same specimen, $\times 230$. (SB186-13).
7–9 *Hedbergella yezoana*, Takayanagi and Iwamota. 7. Dorsal view, $\times 200$. 8. Side view same specimen, $\times 215$. 9. Ventral view same specimen, $\times 200$. (SB186-12).
10–12 *Whiteinella hessi* (Pessagno). 10. Dorsal view, $\times 140$. 11. Side view same specimen, $\times 140$. (SB179-1).
13–15 *Clavihedbergella simplex* (Morrow). 13. Dorsal view, $\times 200$. 14. Side view same specimen, $\times 200$. Ventral view same specimen, $\times 200$. (SB172-1).



Type Level. The holotype is from sample SB-186 located 40 ft above the base of the formation.

***Whiteinella hessi* (Pessagno)**

Pl. 3, Figs. 10–12

Praeglobotruncana hessi hessi PESSAGNO, 1967, p. 358, pl. 5, figs. 8–12.

Loeblichella hessi (Pessagno). PESSAGNO, 1967, p. 288, pl. 48, figs. 17–19, pl. 61, figs. 6–8, 9–11, pl. 100, figs. 1–2. SMITH and PESSAGNO, 1973, p. 42, pl. 16, figs. 5–7.

Description. Test medium to large in size, a low trochospiral coil of five to seven chambers in the last whorl; equatorial periphery slightly lobate; axial periphery rounded, ovate. Chambers subglobular, compressed dorsally and ventrally giving the chambers a subtrapezoidal shape in the last whorl. Sutures depressed, radial on both spiral and umbilical sides. Wall calcareous, perforate, spinose. Umbilicus wide, shallow, portici not preserved in Centennial Valley material, but the broken bases are obvious in most specimens. Aperture interiomarginal, umbilical extraumbilical.

Remarks. This species' very low trochospiral coil and chamber shape make it quite distinctive. Specimens at the top of its range normally have fewer chambers than those at the bottom.

Occurrence. This species is found from 60 ft above to 200 ft above the base of the Sage Breaks Shale, but is most common at the base of its range. This is the first report of this species in the Western Interior. In the Gulf Coastal Plain it ranges from the upper Cenomanian to the upper Maastrichtian (Pessagno, 1967; Smith and Pessagno, 1973).

***Whiteinella? loetterlei* (Nauss)**

Pl. 4, Figs. 10–12

Globigerina loetterlei NAUSS, 1947, p. 336, pl. 49, figs. 11a–c.

Description. Test medium to large, a medium to high trochospiral coil (flat in juveniles) of five to six chambers in the final whorl; equatorial periphery lobate;

axial periphery rounded. Wall calcareous, perforate, spinose. Chambers globose. Sutures depressed and radial on both spiral and umbilical sides. Aperture interiomarginal, umbilical, broken portici often present on last few chambers.

Remarks. The taxonomic position of *W. loetterlei* has been much in doubt. Topotypes sent to this author by John Wall suggest that the holotype has been slightly compressed and that the chambers of this species are more spherical than illustrated. Preservation of apertural characteristics is poor in all topotypes and these criteria cannot be used for generic designation. The stratigraphic level of the holotype and topotypes from the Lloydminster Shale correlates with the lower part of the Sage Breaks Shale. This and the general similarity of the Sage Breaks Shale specimens to the topotypes suggests that Nauss' species should be placed in *Whiteinella* and it is the ancestor to *Archaeoglobigerina bosquensis* Pessagno. Comparative material was not available, but it seems possible that *Rugoglobigerina kingi* Trujillo is a junior synonym of *W. loetterlei*.

Occurrence. This species is restricted to the lower 80 ft of the formation.

***Marginotruncana* Hofker 1956**

amended Pessagno 1967

Marginotruncana angusticarinata

(Gandolfi)

Pl. 6, Figs. 1–3

Globotruncana linnei (d'Orbigny) var. *angusticarinata* GANDOLFI, 1942, pp. 126, 150, 153, pl. 4, figs. 17, 30, text-fig. 46 (figs. 3a–c).

Globotruncana renzi Gandolfi. TRUJILLO, 1960, p. 343, pl. 50, figs. 3a–c.

Marginotruncana angusticaremata (Gandolfi). PESSAGNO, 1967, p. 300, pl. 65, figs. 14–19, pl. 98, figs. 5, 9–11.

Praeglobotruncana renzi (Gandolfi). DOUGLAS, 1969, p. 172, pl. 2, figs. 8a–c.

Description. Test medium to large, a low to moderately high trochospiral coil of five to seven chambers in the last whorl; equatorial periphery lobate; axial

→

PLATE 4

1–3 *Whiteinella aprica* (Loeblich and Tappan). 1. Dorsal view, $\times 120$. 2. Side view same specimen, $\times 120$. 3. Ventral view same specimen, $\times 120$. (SB193-7).

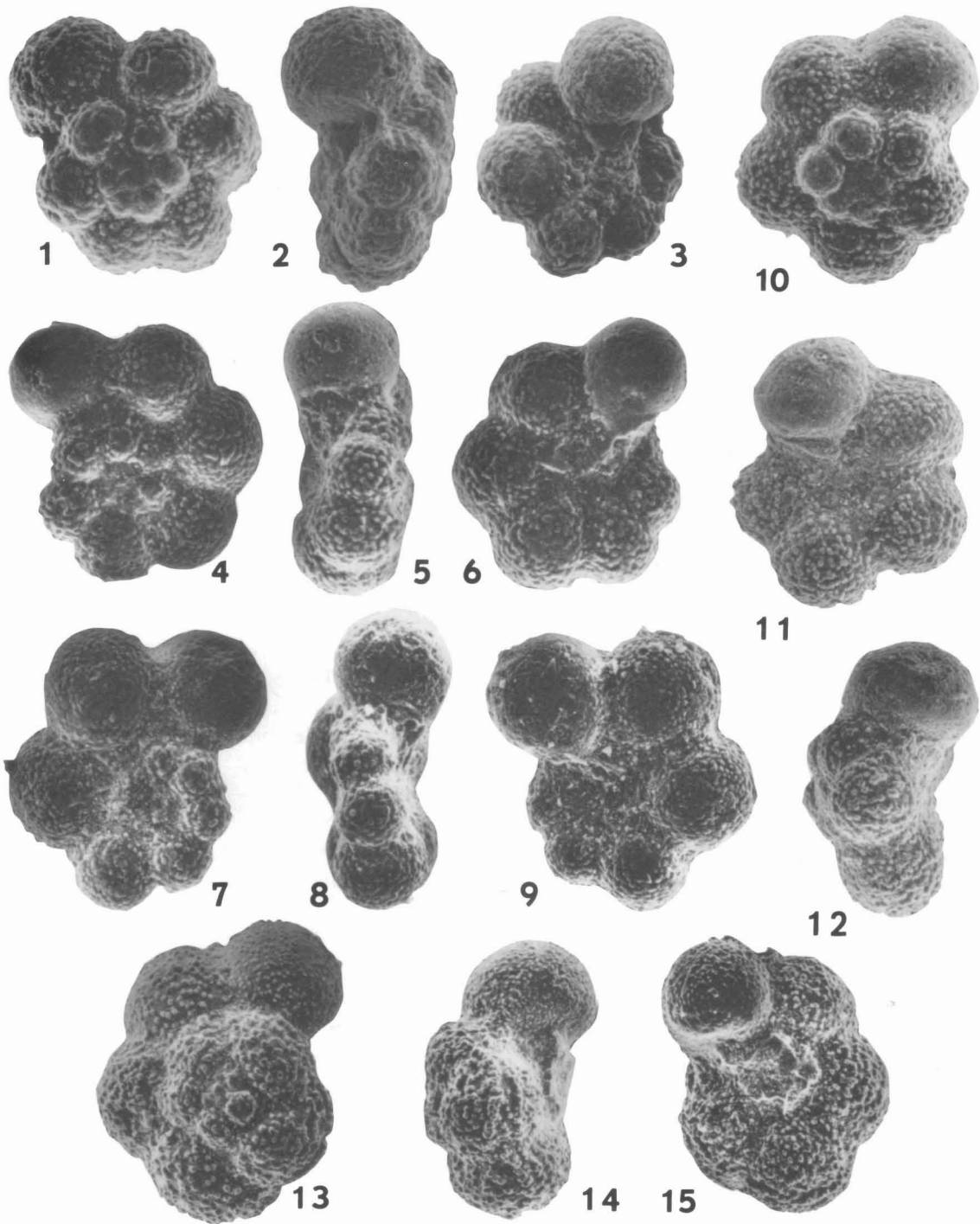
4–6 *Whiteinella centennialensis* n. sp. 4. Dorsal view, $\times 125$. 5. Side view same specimen, $\times 125$. 6. Ventral view same specimen, $\times 125$. Holotype. (SB186-11) U.S. National Museum 689929.

7–9 *Whiteinella centennialensis* n. sp. 7. Dorsal view, $\times 115$.

8. Side view same specimen, $\times 115$. 9. Ventral view same specimen, $\times 115$. (SB1-3).

10–12 *Whiteinella? loetterlei* (Nauss). 10. Dorsal view, $\times 115$. 11. Ventral view same specimen, $\times 115$. 12. Side view same specimen, $\times 115$. (SB193-10).

13–15 *Archaeoglobigerina bosquensis* Pessagno. 13. Dorsal view, $\times 90$. 14. Side view same specimen, $\times 85$. 15. Ventral view same specimen, $\times 85$. (SB1-300).



periphery angular truncate with two narrow to moderately widely spaced keels. Wall calcareous, perforate, smooth. Chambers on the spiral side subcrescentic to crescentic, flattened, latter chambers centrally depressed; flattened and subrectangular on the umbilical side. Sutures raised and curved on the spiral and umbilical sides. Umbilicus large, shallow, although not preserved attachment scars of tegillum obvious. Aperture interiomarginal, umbilical, extraumbilical.

Remarks. Most authors agree that *M. angusticarenata* and *M. renzi* (Gandolfi) differ mainly in the number of chambers per whorl (see Pessagno, 1967 for an excellent discussion). As determined by other authors (Pessagno, 1967; Barr, 1972) this criterion does not seem significant for species distinction. In Wyoming, however, typical five chambered forms of *M. renzi* (Gandolfi) have not been found with forms referable to *M. angusticarenata*. The intergradation of the species therefore cannot be confirmed in this work and the original concept of *M. angusticarenata* is adhered to.

Occurrence. This species is only found in an interval 80 to 200 ft above the base of the Sage Breaks Shale and its range is undoubtedly environmentally truncated. It is never common, but it is very conspicuous in Centennial Valley assemblages. It has been reported from Gulf Coast sediments of late Turonian to early Santonian age (Pessagno, 1967), and has been reported as *Praeglobotruncana renzi* or *Globotruncana renzi* from the Turonian of California (Douglas, 1969; Trujillo, 1960).

***Marginotruncana bandyi* Frerichs n. sp.**

Pl. 7, Figs. 7-9, 10-12

Description. Test medium to large in size, a low trochospiral coil of five to seven chambers in the last whorl; equatorial periphery slightly lobate; axial periphery rounded, truncate. Chambers subglobular, slightly compressed with a wide, but faint double keel. Sutures limbate, depressed on outer whorl on spiral side; limbate, broad horseshoe shape on umbilical side. Umbilicus wide, moderately deep, covered by a tegillum. Aperture interiomarginal, umbilical.

Remarks. This species is quite similar to *Archaeo-*

globigerina cretacea (d'Orbigny), but differs in that its chambers are not ovate and its double keel is wider. It is named in honor of the late Dr. O. L. Bandy.

Occurrence. This species is restricted to the middle third of the Sage Breaks Shale. It becomes abundant for a short interval 180 ft above the base.

Type Level. The holotype is from sample 64 which is located 180 ft below the top of the formation.

***Marginotruncana canaliculata* (Reuss)**

Pl. 5, Figs. 10-12

Rosalina canaliculata REUSS, 1854, p. 70, pl. 26, figs. 4a-b.

Globotruncana canaliculata (Reuss). TRUJILLO, 1960, p. 341, pl. 50, figs. 1a-c.

Marginotruncana canaliculata (Reuss). PESSAGNO, 1967, p. 302, pl. 74, figs. 5-8.

Description. Test moderately large, a low trochospiral coil of five to six chambers in the last whorl; equatorial periphery slightly lobate; axial periphery angular truncate with two moderately wide beaded keels. Wall calcareous, perforate, spinose. Chambers flattened, subcrescentic to petaloid on spiral side; slightly inflated, wedge-shaped to subrectangular on the umbilical side. Sutures curved, beaded on spiral side; radial to slightly sigmoidal on latter chambers, depressed the umbilical side. Umbilicus small, tegillum not preserved on Centennial Valley specimens. Aperture interiomarginal, umbilical extraumbilical.

Remarks. This is the most common species of *Marginotruncana* in the lower Sage Breaks Shale. Its flattened spiral side and radial umbilical sutures make it quite distinctive.

Occurrence. This species is restricted to the lower 20 ft of the Sage Breaks Shale. It has been reported from the Turonian of California (Trujillo, 1960) and from the upper Turonian to lower Santonian of the Gulf Coast, but it is most common in the upper Turonian and Coniacian (Pessagno, 1967). It has not previously been reported from the Western Interior.

***Marginotruncana coronata* (Bolli)**

Pl. 7, Figs. 4-6

Globotruncana lapparenti Brotzen subsp. *coronata* BOLLI, 1945, vol. 37, p. 233, text-fig. 1 (figs. 21, 22), pl. 9, fig. 15.

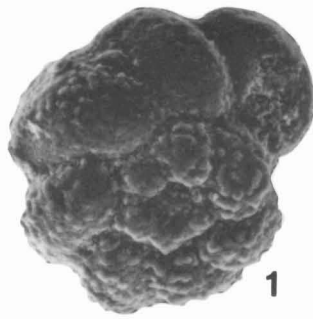
PLATE 5

1-3 *Praeglobotruncana* sp. A. 1. Dorsal view, $\times 155$. 2. Side view same specimen, $\times 155$. 3. Ventral view same specimen, $\times 155$. (SB186-3).

4-6 *Marginotruncana* aff. *roddai* (Marianos and Zingula). 4. Dorsal view, $\times 95$. 5. Side view same specimen, $\times 95$. 6. Ventral view same specimen, $\times 95$. (SB193-31).

7-9 *Marginotruncana* aff. *roddai* (Marianos and Zingula). 7. Dorsal view, $\times 80$. 8. Side view same specimen, $\times 80$. 9. Ventral view same specimen, $\times 80$. (SB-79-5).

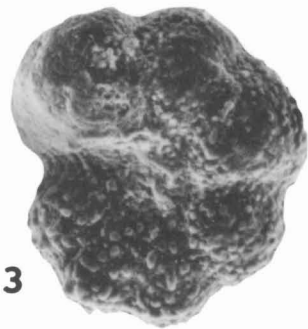
10-12 *Marginotruncana canaliculata* (Reuss). 10. Dorsal view, $\times 115$. 11. Side view same specimen, $\times 115$. 12. Ventral view same specimen, $\times 115$. (SB193-10).



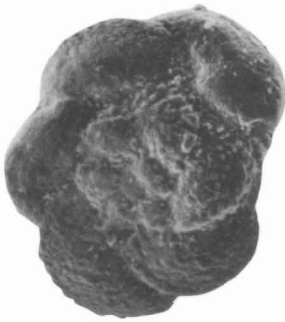
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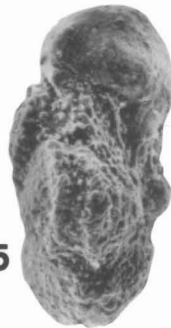
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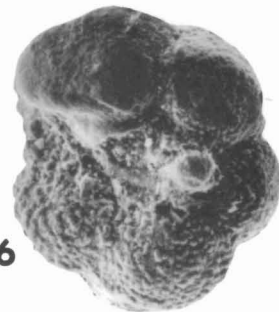
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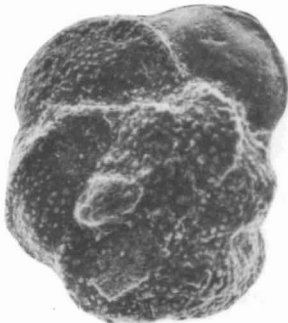
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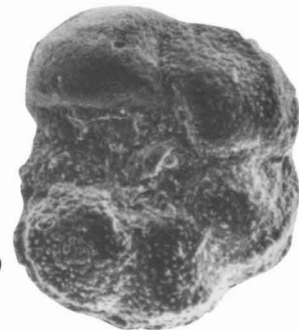
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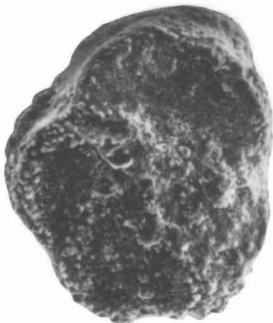
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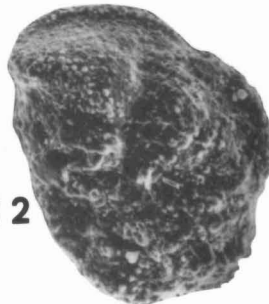
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10



11



12

Globotruncana linneiana (d'Orbigny). TRUJILLO, 1960, p. 342, pl. 49, figs. 8a-c.

Marginotruncana coronata (Bolli). PESSAGNO, 1967, p. 305, pl. 65, figs. 11-13, pl. 100, fig. 6.

Globotruncana coronata Bolli. DOUGLAS, 1969, p. 177, pl. 3, figs. 6-8 (not 5).

Description. Test large, a low trochospiral whorl of six to eight chambers, equatorial periphery lobate; axial periphery angular truncate with two narrow to moderately wide keels. Keels often narrower on younger chambers. Wall calcareous, perforate, often the earlier chambers are spinose. Chambers slightly inflated, petaloid on the spiral side, broadly subrectangular on the umbilical side. Sutures curved and raised on the spiral and umbilical sides, prominent shoulders formed by a continuation of the raised suture on the umbilical side. Umbilicus wide, shallow; broken tegillum present on Centennial Valley specimens. Aperture interiomarginal, umbilical extraumbilical.

Occurrence. This species is rare in Centennial Valley material and occurs sporadically in the lower half of the Sage Breaks Shale. It has been reported from the Turonian to lower Santonian of the Gulf Coast (Pessagno, 1967) where it is most abundant in the upper Turonian and Coniacian. On the west coast it has been reported from the Coniacian to lower Campanian (Douglas, 1969). Its rare occurrence in the Centennial Valley section must be due to environmental restrictions.

***Marginotruncana* aff. *imbricata* (Mornod)**

Pl. 6, Figs. 7-9

Praeglobotruncana aff. *imbricata* (Mornod). BELFORD and SCHEIBNEROVA, 1971, pl. 3, figs. 4-11; not figs. 1-3.

Description. Test medium sized, a mediumly high trochospiral coil of five to six chambers in the last whorl; equatorial periphery slightly lobate; axial periphery angular truncate with two mediumly spaced keels. Wall calcareous, perforate, earlier chambers often spinose. Chambers petaloid on spiral side, wedge-shaped then subrectangular on the umbilical side. Sutures raised and curved on spiral side, straight and depressed on earlier part of last whorl then raised

and curved on umbilical side. Umbilicus small. Aperture interiomarginal, umbilical extraumbilical.

Remarks. In addition to Belford's and Scheibnerova's specimens, Douglas (1969) figured a specimen (Figure 4a-c) which has a small umbilicus and may be similar. A larger population is needed so that the variability of this form can be examined.

Range. This species is found in the lower 40 ft of the formation.

***Marginotruncana paraconcavata*? Porthault**

Pl. 7, Figs. 1-3

Globotruncana renzi GANDOLFI, 1942, pl. 4, fig. 5, text-fig. 45a-c.

Marginotruncana paraconcavata PORTHULT, 1970, p. 77, pl. 10, figs. 21-23.

Description. Test moderately large, a low trochospiral coil of five chambers; equatorial periphery lobate; axial periphery angular truncate with two narrowly spaced keels. Wall calcareous, perforate, early chambers spinose, last chamber smooth. Chambers slightly inflated, early chambers crescentic but grading to petaloid on the spiral side; inflated, subrectangular on the umbilical side. Sutures curved, raised and beaded on the spiral side; straight, depressed due to overlap of younger chambers, but with an umbilical shoulder on the umbilical side.

Remarks. Only one specimen of this species has been found in Centennial Valley material. Consequently species assignment is tentative.

Occurrence. This species has only been found 180 ft below the top of the formation. Porthault named the species from strata of late Coniacian and early Santonian age in southeastern France.

***Marginotruncana pseudolinneiana* Pessagno**

Pl. 6, Figs. 10-12

Marginotruncana pseudolinneiana PESSAGNO, 1967, p. 310, pl. 65, figs. 24-27. *Globotruncana pseudolinneiana* (Pessagno). DOUGLAS, 1969, p. 185, pl. 3, figs. 2-4.

Description. Test large, a low trochospiral coil of five to seven chambers; equatorial periphery lobate; axial periphery angular truncate, sides almost parallel,

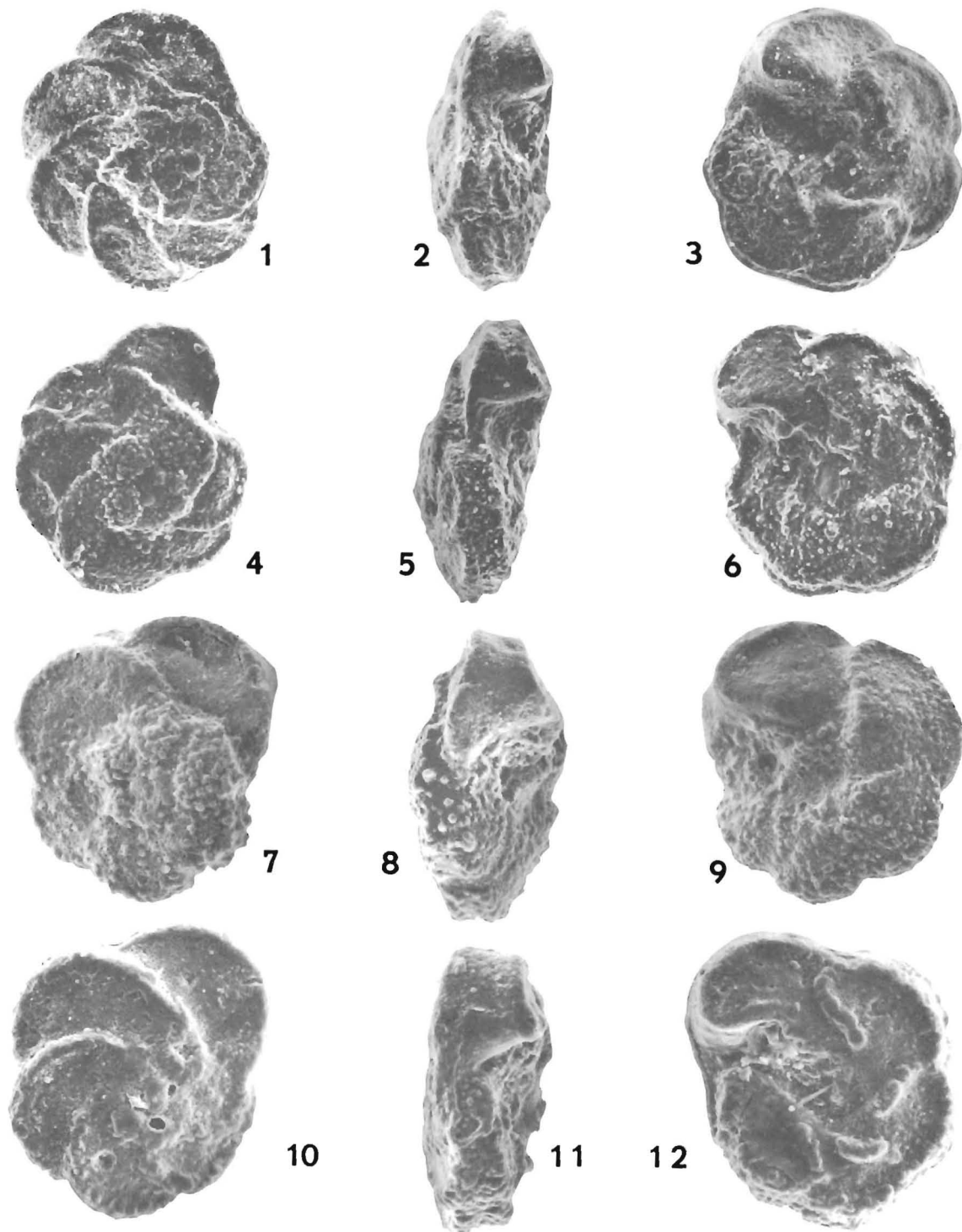
PLATE 6

1-3 *Marginotruncana angusticarenata* (Gandolfi). 1. Dorsal view, $\times 90$. 2. Side view same specimen, $\times 90$. 3. Ventral view same specimen, $\times 90$. (SB64-4).

4-6 *Marginotruncana angusticarenata* (Gandolfi). 4. Dorsal view, $\times 85$. 5. Side view same specimen, $\times 85$. 6. Ventral view same specimen, $\times 85$. (SB64-1).

7-9 *Marginotruncana* aff. *imbricata* (Mornod). 7. Dorsal view, $\times 130$. 8. Side view same specimen, $\times 130$. 9. Ventral view same specimen, $\times 130$. (SB193-29).

10-12 *Marginotruncana pseudolinneiana* Pessagno. 10. Dorsal view, $\times 100$. 11. Side view same specimen, $\times 100$. 12. Ventral view same specimen, $\times 100$. (SB72-1).



with two keels. Wall calcareous, perforate, smooth. Chambers crescentic to subcrescentic on spiral side; subrectangular on the umbilical side. Sutures curved, raised on both spiral and umbilical sides; a strong shoulder is developed on the umbilical side. Umbilicus medium sized, shallow. Aperture interiomarginal, umbilical extraumbilical.

Remarks. This is a very distinctive species in the Centennial Valley material. It differs from *Marginotruncana canaliculata* in the horseshoe-shape of the ventral keel and its continuation onto umbilical side of the chamber.

Occurrence. This species is rare and occurs sporadically in the lower half of the Sage Breaks Shale. In the Gulf Coast area it ranges in age from late Turonian to early Santonian and is most common in the late Turonian to Coniacian interval (Pessagno, 1967). On the west coast it ranges in age from late Turonian to early Campanian (Douglas, 1969) and is most common in the Coniacian. In Centennial Valley its range is environmentally restricted.

***Marginotruncana renzi* (Gandolfi)**

Pl. 8, Figs. 1-3

Globotruncana renzi THALMANN, 1942, p. 51 (*nomen nudum*).

Globotruncana renzi GANDOLFI, 1942, p. 124, pl. 3, fig. 1; pl. 4, figs. 15-16, 28-29; pl. 10, fig. 2; text-fig. 45.

Occurrence. This species is found sporadically in the lower 140 ft of the formation.

***Marginotruncana* aff. *roddai* (Marianos and Zingula)**

Pl. 5, Figs. 4-6, 7-9

Globotruncana roddae MARIANOS and ZINGULA, 1966, p. 340, pl. 39, figs. 5a-c.

Praeglobotruncana roddai (Marianos and Zingula). DOUGLAS, 1969, p. 171, pl. 2, fig. 2a-c.

Praeglobotruncana difformis (Gandolfi). EICHER and WORSTELL, 1970, p. 308, pl. 11, figs. 4a-c, 5, 6a-c.

Description. Test small to moderately large, a low to moderately high trochospiral coil of five to six chambers, equatorial periphery slightly lobate; axial

periphery angular truncate with two narrowly spaced keels. Wall calcareous, perforate, smooth or slightly spinose on the spiral side, spinose on the umbilical side. Chambers slightly inflated, petaloid on the spiral side, imbricate; broadly subrectangular on the umbilical side. Sutures curved, raised on the spiral side; straight, often becoming slightly curved, depressed on the umbilical side. Umbilicus small, tegillum not preserved on Centennial Valley specimens. Aperture interiomarginal, umbilical extraumbilical.

Remarks. As stated by other authors Douglas (1969), *M. roddai* may be synonymous with *M. indica* (Jacob and Sastry).

Occurrence. This species occurs sporadically in the lower 140 ft of the Sage Breaks Shale.

***Marginotruncana* sp. A.**

Marginotruncana indica (Jacob and Sastry). PESSAGNO, 1967, p. 307, pl. 57, figs. 7-9.

Description. Test large, low trochospiral coil of five to five and one-half chambers in the last whorl; equatorial periphery lobate; axial periphery angular truncate with two narrowly spaced keels. Chambers flat, petaloid on the spiral side, wedge-shaped, inflated on the umbilical side. Sutures raised and curved on the spiral side, straight, and depressed on the umbilical side. Umbilicus small, deep. Aperture interiomarginal, umbilical extraumbilical.

Remarks. This may be a new species, but more specimens are needed before it can be named.

Range. This species has been found in the lower 140 ft of the formation.

Family GLOBOTRUNCANIDAE Brotzen, 1942

Genus *Archaeoglobigerina* Pessagno, 1967

***Archaeoglobigerina blowi* Pessagno**

Pl. 9, Figs. 1-3

Archaeoglobigerina blowi PESSAGNO, 1967, p. 316, pl. 59, figs. 1-10, pl. 94, figs. 2-3.

Description. Test small to medium in size, low trochospiral coil of four to five chambers; equatorial

PLATE 7

→

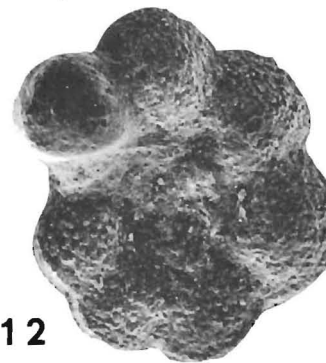
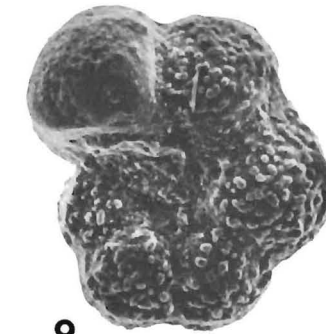
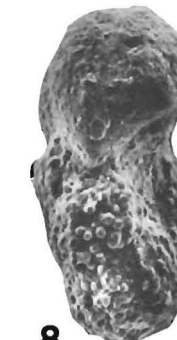
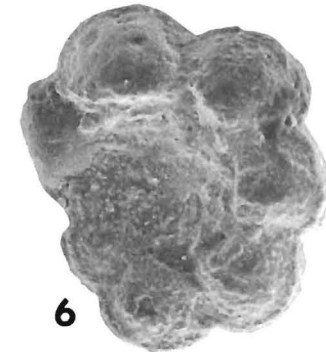
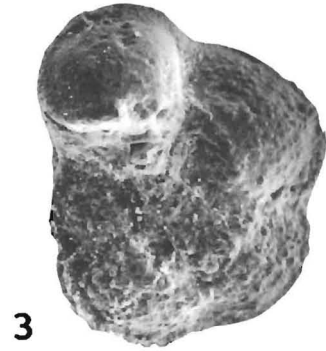
1-3 *Marginotruncana paraconcavata*? (Porthault). 1. Dorsal view, $\times 75$. 2. Side view same specimen, $\times 75$. 3. Ventral view same specimen, $\times 75$. (SB64-98).

4-6 *Marginotruncana coronata* (Gandolfi). 4. Dorsal view, $\times 70$. 5. Side view same specimen, $\times 70$. 6. Ventral view same specimen, $\times 70$. (SB64-33).

7-9 *Marginotruncana bandyi* n. sp. 7. Dorsal view, $\times 110$. 8.

Side view same specimen, $\times 110$. 9. Ventral view same specimen, $\times 110$. Holotype. (SB64-11) U.S. National Museum 689930.

10-12 *Marginotruncana bandyi* n. sp. 10. Dorsal view, $\times 65$. 11. Side view same specimen, $\times 65$. 12. Ventral view same specimen, $\times 65$. Gerontic specimen. (SB64-70).



periphery lobate; axial periphery rounded. Chambers globular, increasing rapidly in size. Sutures depressed, radial on both the spiral and umbilical sides. Wall calcareous, surface smooth to spinose. Aperture umbilical, with tegillum.

Remarks. Stratigraphically younger specimens tend to become spinose as *A. blowi* grades into *Rugoglobigerina bulbosa*.

Occurrence. This species is found throughout the Sage Breaks Shale except for the lowermost 40 ft. It is most abundant in the middle third of the shale and is rare in the upper third. This species has been reported from the middle Coniacian to early Maastrichtian of the Gulf Coastal Plain (Pessagno, 1967).

Archaeoglobigerina bosquensis Pessagno

Pl. 4, Figs. 13–15

Archaeoglobigerina bosquensis PESSAGNO, 1967, p. 316, pl. 60, figs. 7–12. FRERICHS and ADAMS, 1973, p. 192, pl. 2, figs. 8, 9.

Description. Test medium to large, moderately high to high trochospiral coil of five to eight chambers in the last whorl; equatorial periphery lobate; axial periphery rounded. Chambers globular, ornamented with spines. Sutures depressed, straight to slightly curved on spiral side; depressed, radial on umbilical side. Umbilicus moderately wide. Aperture interiomarginal, umbilical in position, covered by a tegillum.

Remarks. Pessagno, in his original description restricted *A. bosquensis* to specimens which are relatively high spired, but in the Sage Breaks Shale smaller, low spired specimens are quite common.

Occurrence. This species is found throughout the Sage Breaks Shale except for the lowermost 40 ft. It has been reported from the middle Coniacian to the middle Santonian in the Gulf Coast region (Pessagno, 1967).

Archaeoglobigerina aff. blowi Pessagno

Pl. 9, Figs. 4–6

Description. Test medium sized, a high trochospiral coil of four to four and one-half chambers in the final whorl; equatorial periphery quadrate and lobate; axial periphery rounded. Wall calcareous, perforate, spi-

nose. Chambers globose. Sutures depressed and radial on both spiral and umbilical sides. Aperture interiomarginal, umbilical; tegillum not preserved.

Remarks. This probably represents a new species which forms an evolutionary link between *A. blowi* Pessagno and *Rugoglobigerina pilula* Belford. I have chosen not to name the species until more is known of its geographic extent.

Occurrence. This species is found in the upper 140 ft of the formation.

Archaeoglobigerina cretacea (d'Orbigny)

Pl. 8, Figs. 4–6

Globigerina cretacea D'ORBIGNY, 1840, p. 34, pl. 3, figs. 12–14. *Globotruncana cretacea* (d'Orbigny). BANNER and BLOW, 1960, p. 8, pl. 7, figs. 1a–c. (Lectotype.)

Occurrence. This species is found in the upper 220 ft of the formation. In the Gulf Coastal Plain it ranges from the middle Coniacian to the early Maastrichtian (Pessagno, 1967).

Genus Globotruncana Cushman 1927

Globotruncana austinensis Gandolfi

Pl. 8, Figs. 7–9

Globotruncana marginata austinensis GANDOLFI, 1955, p. 29, pl. 1, figs. 6a–c.

Globotruncana austinensis Gandolfi. PESSAGNO, 1967, p. 323, p. 82, figs. 12–15, pl. 94, fig. 9.

Description. Test large, a low trochospiral coil of five to six chambers in the last whorl; equatorial periphery circular, lobate; axial periphery angular truncate with two keels. Wall calcareous perforate, initially pustulose, later chambers smooth. Chambers inflated, petaloid on spiral side, wedge-shaped on umbilical side. Sutures curved, depressed on spiral side; straight; depressed on umbilical side. Umbilicus small, shallow, remains of tegillum visible. Aperture interiomarginal, umbilical.

Remarks. Typical specimens in the Sage Breaks Shale have six chambers in the final whorl. In this respect they differ from typical specimens from the Gulf Coast (Pessagno, 1967). They are similar, however, to the holotype which has six chambers in the

PLATE 8

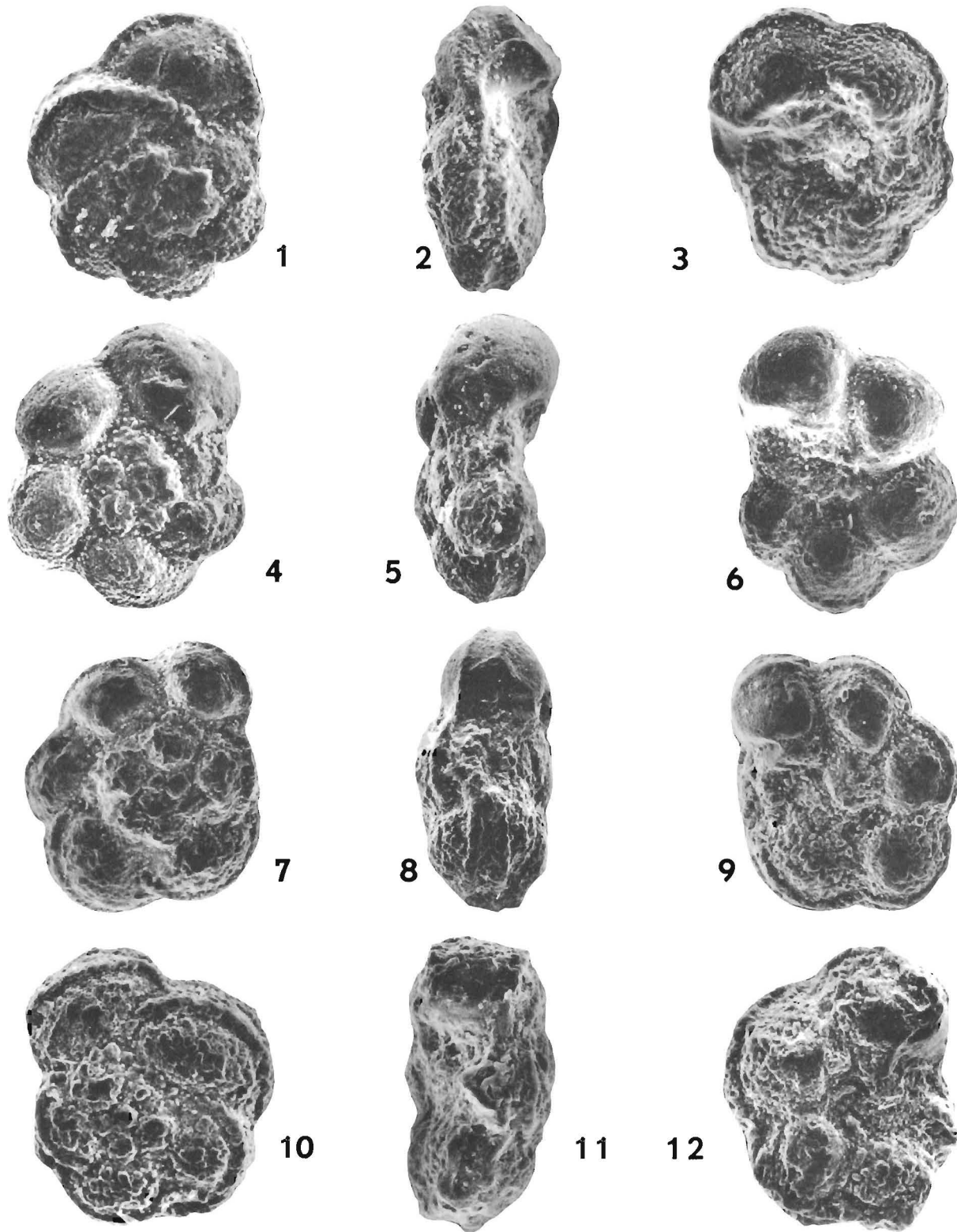
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1–3 *Marginotruncana renzi* (Gandolfi). 1. Dorsal view, ×90. 2. Side view same specimen, ×90. 3. Ventral view same specimen, ×90. (SB193-22).

4–6 *Archaeoglobigerina cretacea* (d'Orbigny). 4. Dorsal view, ×90. 5. Side view same specimen, ×90. 6. Ventral view same specimen, ×90. (SB72-50).

7–9 *Globotruncana austinensis* Gandolfi. 7. Dorsal view, ×75. 8. Side view same specimen, ×75. 9. Ventral view same specimen, ×75. (SB16-2).

10–12 *Globotruncana bulloides* Vogler. 10. Dorsal view, ×95. 11. Side view same specimen, ×95. 12. Ventral view same specimen, ×95. (SB14-6).



final whorl. *Globotruncana austinensis* is one of the few low spired globotruncanids with depressed and straight sutures.

Occurrence. This species is found in the upper 40 ft of the Sage Breaks Shale and is most abundant when it first appears. It has been reported from the lower Santonian to lower Maastrichtian strata in the Gulf Coast area (Pessagno, 1967) where it is most abundant in the late Santonian-early Maastrichtian interval. This is the first report of this species in the Western Interior.

***Globotruncana bulloides* Voegles**

Pl. 8, Figs. 10–12

Globotruncana linnei (d'Orbigny) subsp. *bulloides* VOGLER, 1941, p. 287, pl. 23, figs. 32–39, (lectotype fig. 33, Pessagno, 1967).

Globotruncana marginata (Reuss). CUSHMAN, 1946, p. 150, pl. 62, figs. 2a–c; not (a–c).

Globotruncana bulloides Vogler. PESSAGNO, 1967, p. 324, pl. 67, figs. 1–3; pl. 73, figs. 9, 20; pl. 75, figs. 4–8; pl. 97, figs. 14, 15; not pl. 64, figs. 1–3.

Description. Test moderately large, a low trochospiral coil of four and one-half to five and one-half chambers; equatorial periphery lobate; axial periphery angular truncate with two moderately wide to widely spaced keels. Wall calcareous, perforate, the early chambers and often all the chambers pustulose. Chambers inflated, crescentic on the spiral side; subrectangular on the umbilical side. Sutures raised and thick on the outer side; depressed on inner side of chamber; curved on the spiral side; depressed, straight on the umbilical side; a raised shoulder, a remnant of the extension of the keel onto the umbilical side is left by the overlap of the anterior portion by a new chamber, borders the umbilicus on most chambers. Umbilicus small, remnants of tegillum obvious. Aperture interiomarginal, umbilical.

Remarks. Centennial Valley specimens have wider keels than normal for the species, but seem similar in all other respects.

Occurrence. This species occurs in the upper 40 ft of the Sage Breaks Shale. In the Gulf Coast area it first occurs in the lower Santonian and ranges into the lower Maastrichtian (Pessagno, 1967). Pessagno re-

ports that it is most abundant in the latest Santonian-early Maastrichtian interval. This is the first report of this species in the Western Interior.

***Globotruncana lapparenti* Brotzen**

Globotruncana linnei d'Orbigny. DE LAPPARENT, 1918, Mim. Carte Geol. France, p. 1–17, pl. 1, figs. 1, 7; pl. 9, figs. 2, 3; tf. 1, 3; tf. 2; figs. a, d, m–n.

Globotruncana lapparenti BROTZEN, 1936, p. 175, tf. 2. PESSAGNO, 1967, p. 344, pl. 71, figs. 6–13.

Description. Test medium to large, a low to moderately high trochospiral coil of five and one-half to six and one-half chambers; equatorial periphery lobate; axial periphery angular truncate with two moderately widely spaced keels. Wall calcareous, perforate, spinose. Chambers petaloid on spiral side, subrectangular on umbilical side. Sutures raised and curved on spiral side and umbilical sides. Umbilicus small. Aperture interiomarginal, umbilical extraumbilical.

Remarks. The relatively widely spaced keels and small umbilicus of this species make it referable to *Globotruncana lapparenti* as emended by Pessagno (1967).

Occurrence. *Globotruncana lapparenti* is found from 180 to 200 ft above the base of the formation.

Genus *Rugoglobigerina* Brönnimann 1952

***Rugoglobigerina bulbosa* Belford**

Pl. 9, Figs. 7–9

Rugoglobigerina bulbosa BELFORD, 1960, p. 94, pl. 26, figs. 1–3, 4–5, 6–8, 9, 10; text-fig. 7.

Description. Test small to medium sized, a low trochospiral coil of four to four and one-half chambers in the final whorl; equatorial periphery lobate, roughly quadrate in outline; axial periphery rounded. Wall, calcareous, perforate, ornamented with short discontinuous rugae. Chambers globose. Sutures depressed and radial on both spiral and umbilical sides. Umbilicus small, remnants of tegillum not obvious. Aperture interiomarginal, umbilical.

Remarks. This is the first report of this species from North America. The stratigraphic position of this

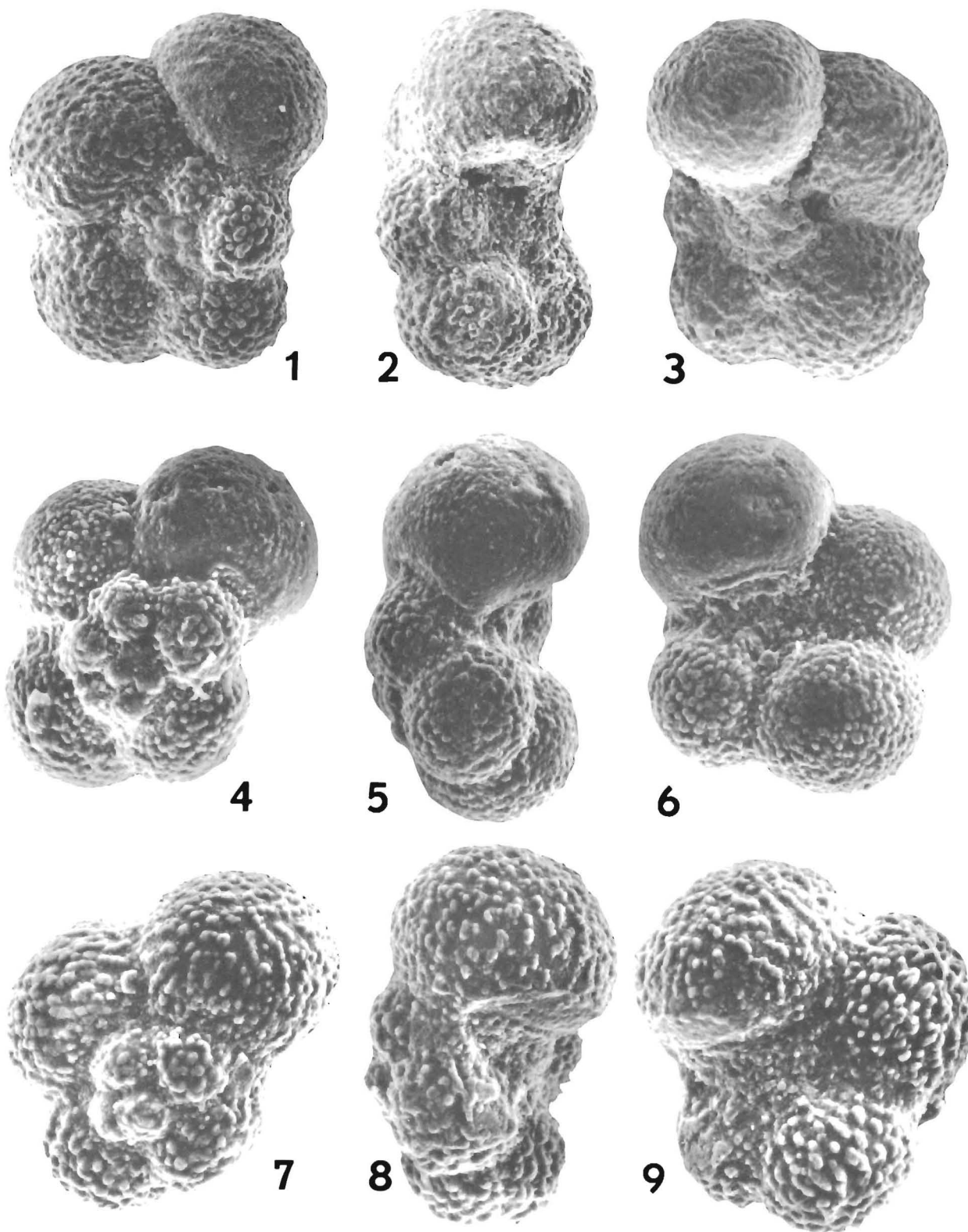
PLATE 9

1–3 *Archaeoglobigerina blowi* Pessagno. 1. Dorsal view, $\times 205$. 2. Side view same specimen, $\times 205$. 3. Ventral view same specimen, $\times 205$. (SB179-50).

4–6 *Archaeoglobigerina* aff. *blowi* Pessagno. 4. Dorsal view,

$\times 200$. 5. Side view same specimen, $\times 200$. 6. Ventral view same specimen, $\times 200$.

7–9 *Rugoglobigerina bulbosa* Belford. 7. Dorsal view, $\times 275$. 8. Side view same specimen, $\times 275$. 9. Ventral view same specimen, $\times 275$.



species and *Rugoglobigerina pilula* Belford (Frerichs and others, 1975) in Centennial Valley is similar to their occurrence in Australia and *R. bulbosa* may have given rise to *R. pilula*.

REFERENCES

- BANNER, F. T. and BLOW, W. H., 1959, The classification and stratigraphic distribution of the Globigerinacea: Paleontology, v. 2, p. 1-27.
- , 1960, Some primary types of species belonging to the superfamily Globigerinacea: Cushman Foundation for Foraminiferal Research Contributions, v. 11, pt. 1, p. 1-41.
- BARR, F. T., 1962, Upper Cretaceous planktonic Foraminifera from the Isle of Wight, England: Paleontology, v. 4, p. 552-586.
- , 1972, Cretaceous biostratigraphy and planktonic foraminifera of Libya: Micropaleontology, v. 18, p. 1-46.
- BELFORD, D. J., 1960, Upper Cretaceous foraminifera from the Toolonga Calcilutite and Gingin Chalk, Western Australia: Australia Bureau of Mineral Resources Geology and Geophysics, Bulletin 57, p. 1-198.
- , and SCHEIBNEROVA, V., 1971, Turonian foraminifera from the Carnavon Basin, Western Australia, and their palaeogeographical significance: Micropaleontology, v. 17, p. 331-344.
- BERMUDEZ, P. J., 1952, Estudio sistematico de los foraminiferos rotaliformes: Venezuela Ministerio de Minas e Hidrocarburos, Boletin de Geologia, v. 2, p. 1-230.
- BOLLI, H. M., 1945, Zur Stratigraphie der Oberen Kreide in den hoheren helvetischen Decken: Eclogae Geologicae Helvetiae, v. 37, p. 217-328.
- , LOEBLICH, A. R., JR., and TAPPAN, H., 1957, Planktonic foraminiferal families Hantkeninidae, Orbulinidae, Globorotaliidae, and Globotruncanidae: United States National Museum Bulletin, no. 215, p. 3-50.
- BRÖNNIMANN, P., 1952, Globigerinidae from the Upper Cretaceous (Cenomanian-Maestrichtian) of Trinidad, B.W.I.: Bulletin of American Paleontology, v. 34, p. 1-70.
- , and BROWN, N. K., JR., 1958, *Hedbergella*, a new name for a Cretaceous planktonic foraminiferal genus: Washington Academy of Sciences Journal, v. 48, no. 1, p. 15-17.
- BROTZEN, F., 1936, Foraminifern aus dem schwedischen untersten Senon von Eriksdal in Schonen: Sveriges Geologiska Undersökning, Årsbok, 30, Ser. C, no. 396, no. 3, p. 1-206.
- , 1942, Die Foraminiferengattung *Gavelinella* nov. gen. und die Systematik der Rotaliiformes: Sveriges Geologiska Undersökning Årsbok, v. 36, no. 8, ser. C, no. 493, p. 1-140.
- CARMAN, K. W., 1929, Some foraminifera from the Niobrara and Benton Formations of Wyoming: Journal of Paleontology, v. 3, no. 3, p. 309-315.
- COBBAN, W. A., and REESIDE, J. B., JR., 1952a, Frontier Formation, Wyoming and adjacent area: American Association of Petroleum Geologists Bulletin, v. 36, p. 1913-61.
- , 1952b, Correlation of the Cretaceous formation of the Western Interior of the United States: Geological Society of America Bulletin, v. 63, p. 1011-1044.
- CUSHMAN, J. A., 1927, Some new genera of the foraminifera: Cushman Laboratory for Foraminiferal Research Contributions, v. 2, p. 77-81.
- , 1931, *Hastigerinella* and other interesting foraminifera from the Upper Cretaceous of Texas: Contributions from the Cushman Laboratory for Foraminiferal Research, v. 7, pt. 4, p. 86.
- , 1933, Some new foraminiferal genera: Cushman Laboratory for Foraminiferal Research Contributions, v. 9, p. 32-38.
- , 1938, Cretaceous species of Guembelina and related genera: Cushman Laboratory for Foraminiferal Research Contributions, v. 14, pt. 1, p. 1-28.
- , 1944, Foraminifera of the lower part of the Mooseville Chalk of the Selma Group of Mississippi: Cushman Laboratory for Foraminiferal Research Contributions, v. 20, p. 83-96.
- , 1946, Upper Cretaceous foraminifera of the Gulf Coast region of the United States and Adjacent areas: United States Geological Survey Professional Paper 206, 241 p.
- , and TEN DAM, A., 1948, *Globigerinelloides*, a new genus of the Globigerinidae: Cushman Laboratory for Foraminiferal Research Contributions, v. 24, p. 42-43.
- DOUGLAS, R. G., 1969, Upper Cretaceous planktonic foraminifera in northern California, Pt. 1—Systematics: Micropaleontology, v. 15, no. 2, p. 151-209.
- EHRENBERG, C. G., 1843, Verbreitung und Einfluss des mikroskopischen Lebens in Süd- und Nord-America: Kryptozoon der kulturellen Preussische Akademie Wissenschaften Berlin, Verhandlungen, Physik, Abhandlungen, Jahrbuch, 1841, Abt., p. 291-446.
- , 1854, Mikrogeologie: Leipzig, L. Voss, p. i-xxviii, p. 1-374.
- EICHER, D. L., 1967, Foraminifera from Belle Fourche Shale and equivalents, Wyoming and Montana: Journal of Paleontology, v. 41, p. 167-188.
- , and WORSTELL, P., 1970, Cenomanian and Turonian foraminifera from the Great Plains, United States: Micropaleontology, v. 16, no. 3, p. 269-324.
- EVITT, M. J., 1976, Microfossil biostratigraphy of the Sage Breaks Shale (Upper Cretaceous) in northeastern Wyoming: Mountain Geologist, v. 13, no. 4, p. 115-134.
- FRERICHS, W. E., 1970, Distribution and ecology of benthonic foraminifera in the sediments of the Andaman Sea: Cushman Foundation for Foraminiferal Research Contributions, v. 21, p. 123-147.
- , 1971, Planktonic foraminifera in sediments of the Andaman Sea: Journal of Foraminiferal Research, v. 1, no. 1, p. 1-14.
- , and ADAMS, P. R., 1973, Correlation of the Hilliard Formation with the Niobrara Formation: Wyoming Geological Association 25th Annual Field Conference, p. 187-192.
- , ATHERTON, C. C., and SHIVE, P. N., 1975, Planktonic foraminifera from the chalky members of the Niobrara Formation, Centennial Valley, Wyoming: Journal of Foraminiferal Research, v. 5, no. 4, p. 294-312.
- , POKRAS, E. M., and EVITT, M. J., 1977, The genus *Hastigerinoides* and its significance in the biostratigraphy of the Western Interior: Journal of Foraminiferal Research, v. 7, p. 149-156.
- , and GASKILL, C. H., 1978, *Textilaria americana* Ehrenberg: type species of Heterohelix: Journal of Foraminiferal Research, v. 8, p. 143-146.
- FRUSH, M. P., and EICHER, D. L., 1975, Cenomanian and Turonian Foraminifera and palaeoenvironments in the Big Bend region of Texas and Mexico, in The Cretaceous Systems in the Western Interior of North America: Geological Association of Canada Special Paper 13, p. 277-302.
- GANDOLFI, R., 1942, Ricerche micropaleontologiche e stratigrafiche sulla Scaglia e sul flysch Cretacico dei Dintorni di Balerna (Canton Ticino): Rivista Italiana di Paleontologia e Stratigrafia, Annal 48, Memoir 4, p. 1-160.

- HOFKER, J., 1956a, Planktonic foraminifera of the Chalk Tuff of Maestricht and environments: *Natuurhistorische Maandblad*, v. 45, p. 51-57.
- , 1956b, Die Globotruncanen von Nordwest-Deutschland und Holland: *Neues Jahrbuch Geologie u Paläontologie*, Abh. 103, p. 312-340.
- LALICKER, C. C., 1948, A new genus of Foraminifera from the Upper Cretaceous: *Journal of Paleontology*, v. 22, p. 624.
- LAPPARENT, J., DE, 1918, Étude lithologique des terrains crétacés de la région d'Hendaye: France, *Carte Géologique Mémoire*, p. 1-153.
- LOEBLICH, A. R., JR. and TAPPAN, H., 1961, Cretaceous planktonic foraminifera: Part I—Cenomanian: *Micropaleontology*, v. 7, p. 257-304.
- LOETTERLE, G. J., 1937, The Micropaleontology of the Niobrara Formation in Kansas, Nebraska, and South Dakota: *Nebraska Geological Survey Bulletin* 12, ser. 2, p. 9-73.
- MARIANOS, A. W., and ZINGULA, R. P., 1966, Cretaceous planktonic foraminifera from Dry Creek, Tehama County, California: *Journal of Paleontology*, v. 40, p. 328-342.
- MARTIN, S. E., 1972, Re-examination of the Upper Cretaceous planktonic foraminiferal genera *Planoglobulina* Cushman and *Ventilabrella* Cushman: *Journal of Foraminiferal Research*, v. 2, p. 72-92.
- MORROW, A. L., 1934, Foraminifera and Ostracoda from the Upper Cretaceous of Kansas: *Journal of Paleontology*, v. 8, no. 2, p. 186-205.
- NAUSS, A. W., 1947, Cretaceous microfossils of Vermilion area, Alberta: *Journal of Paleontology*, v. 21, p. 329-343.
- OLSSON, R. K., 1960, Foraminifera of the latest Cretaceous and earliest Tertiary age in the New Jersey Coastal Plain: *Journal of Paleontology*, v. 34, p. 1-58.
- , 1964, Late Cretaceous planktonic foraminifera from New Jersey and Delaware: *Micropaleontology*, v. 10, no. 2, p. 157-188.
- ORBIGNY, A. D., D', 1840, Mémoire sur les foraminifères de la craie blanche du bassin de Paris: *Mémoires de la Société Géologique de France*, v. 4, pt. 1, p. 1-51.
- PESSAGNO, E. A., JR., 1967, Upper Cretaceous planktonic foraminifera from the western Gulf Coastal Plain: *Palaeontographica Americana*, v. 5, no. 37, p. 242-445.
- PORHAULT, B., 1970, Étude de la Microfaune: Foraminifères: in *Le Senonien Inférieur de Puget-Theniers (Alpes-Maritimes) et sa Microfaune*, *Geobios*, v. 3, p. 50-85.
- REUSS, A. E., 1854, Beiträge zur Charakteristik der Kreideschichten in den Ostalpen, besonders im Gosauthale und am Wolfgangsee: *K. Akad. Wiss. Wien, mathematisch-naturwiss., Cl. Denkschr.*, v. 7, no. 1, p. 261-292.
- RUBEY, W. W., 1930, Lithologic studies of the fine grained Upper Cretaceous rocks of the Black Hills region: *United States Geological Survey Professional Paper* 165-A, p. 1-54.
- SCOTT, G. R., and COBBAN, W. A., 1964, Stratigraphy of the Niobrara Formation at Pueblo, Colorado: *United States Geological Survey Professional Paper*, 454-L, 27 p.
- SHAW, A. B., 1953, Preliminary survey of the foraminifera of the Lower Shale of the Niobrara Formation in the Laramie Basin: *Wyoming Geological Association Guidebook*, 8th Annual Field Conference, p. 47-55.
- SHIVE, P. N. and FRERICH, W. E., 1974, Paleomagnetism of the chalky members of the Niobrara Formation in Colorado and Kansas: *Journal of Geophysical Research*, v. 79, p. 3001-3008.
- SIGAL, J., 1958, La classification actuelle des familles de foraminifères planctoniques du crétacé: *Société Géologique de France, Compte Rendu Sommaire*, p. 262-265.
- SMITH, C. C., and PESSAGNO, E. A., JR., 1973, Planktonic foraminifera and stratigraphy of the Corsicana Formation (Maastriichtian) northcentral Texas: *Cushman Foundation for Foraminiferal Research Special Publication* 12, p. 1-68.
- TAPPAN, H., 1940, Foraminifera from the Grayson formation of northern Texas: *Journal of Paleontology*, v. 14, p. 93-126.
- THALMANN, H. E., 1942, The genus *Globotruncana* and its species: *American Association of Petroleum Geologists 27th Annual Conference Program*, p. 51-52.
- THOMAS, H. D., 1936, The Frontier-Niobrara contact in the Laramie Basin: *American Association Petroleum Geologists Bulletin*, v. 20, no. 9, p. 1189-1197.
- TRUJILLO, E. F., 1960, Upper Cretaceous foraminifera from near Redding, Shasta County, California: *Journal of Paleontology*, v. 34, p. 290-346.
- VOGLER, J., 1941, Beiträge zur geologie von Niederländisch-Indien: Ober-Jura und Kreide von Misol (Niederländisch-Ostindien): *Palaeontographica*, Supplement 4, pt. 4, p. 245-293.
- WICKENDEN, R. T. D., 1945, Mesozoic stratigraphy of the Eastern Plains, Manitoba, and Saskatchewan: *Geological Survey of Canada Memoir* 239, p. 1-87.
- YOUNG, K., 1963, Upper Cretaceous Ammonites from the Gulf Coast of the United States: *University of Texas Publication* 6304, p. 1-373.

Revised Ms accepted February 1979

APPENDIX TABLE 1

Sample number	Number of feet above Wall Creek Sandstone
1	360
7	340
14	320
19	300
27	280
33	260
40	240
50	220
57	200
64	180
72	160
79	140
87	120
167	100
172	80
179	60
186	40
193	20
200	1

APPENDIX TABLE 2

Species	Sample number																		
	200	193	186	179	172	167	87	79	72	64	57	50	40	33	27	19	14	7	1
<i>Archaeoglobigerina blowi</i>			?	X	X	X	X	X	X	X	X	X	X	X	X	?	?	X	X
<i>A. aff. blowi</i>												X		X	X	X	X	X	X
<i>A. bosquensis</i>			?	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
<i>A. cretacea</i>					?				X	X	X		X	X	X	X	X	X	X
<i>Clavibedbergella simplex</i>				X															
<i>Globigerinelloides aff. ehrenbergi</i>									X	X				X			?		
<i>G. multispina</i>																	X	X	X
<i>G. prairiehillensis</i>											X	X	X	X	X	X	X	X	X
<i>Globotruncana austinensis</i>																	X		
<i>G. bulloides</i>																	X		
<i>G. lapparenti</i>										X	X								
<i>Guembelitra harrisi</i>		X																	
<i>Hastigerinoides subdigitata</i>													X	X	X	X	X	X	X
<i>H. watersi</i>													X	X		X	X	X	X
<i>Hedbergella aff. amabilis</i>		X	X		X		?	X	X										
<i>H. archaeocretacea</i>			X	X	X	X		?	X	?									
<i>H. yezoana</i>		X	X		X	?		X											
<i>Heterohelix americana</i>												X	X		X	X	X	X	X
<i>H. planata</i>													X	X		X	X	X	X
<i>H. pseudoglobulosa</i>		X	X	X						X	X	X			X				
<i>H. pulchra</i>		X	X	X	X	X				X		X	X	X	X	X	X	X	X
<i>H. aff. pulchra</i>												X							
<i>H. reussi</i>		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Marginotruncana angusticarenata</i>					X				X	X									
<i>M. bandyi</i>									X	X									
<i>M. canaliculata</i>		X	X																
<i>M. coronata</i>		X	?					X		X	X								
<i>M. aff. imbricata</i>		X	X																
<i>M. paraconcavata</i>									?										
<i>M. pseudolinneana</i>		X				X	X	X	X										
<i>M. renzi</i>		X		X			?												
<i>M. roddai</i>		X					X												
<i>M. sp. A</i>									X										
<i>Planoglobulina austinensis</i>			X	X															
<i>Praeglobotruncana</i> sp. A		X																	
<i>Rugoglobigerina bulbosa</i>																	?	X	X
<i>Whiteinella aprica</i>		X		X	X														
<i>W. centennialensis</i>			X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
<i>W. hessi</i>				X	X	X			X	X	X								
<i>W. loetterlei</i>		X	X	X	X														