STATE OF DELAWARE

DELAWARE GEOLOGICAL SURVEY

REPORT OF INVESTIGATIONS NO. 5

PLANKTONIC FORAMINIFERA AND THE CRETACEOUS-TERTIARY BOUNDARY IN CENTRAL DELAWARE

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February, 1962

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PLANKTONIC FORAMINIFERA AND THE CRETACEOUS-TERTIARY BOUNDARY IN CENTRAL DELAWARE

Abstract

The uppermost Cretaceous and lowermost Tertiary planktonic Foraminifera obtained from cores taken in a deep well near Dover, Delaware are studied. The Cretaceous foraminifers are of the *Heterohelix-Globotruncana* assemblage and are probably of late Maestrichtian age. The Danian *Globorotalia compressa - Globigerinoides daubjergensis* zone lies immediately above. The Cretaceous-Tertiary boundary is at a depth of approximately 980 feet and lies within a gray, glauconitic silt.

Introduction

Many studies in recent years have demonstrated the usefulness of the planktonic Foraminifera in the determination of the position of the dividing line between rocks of Tertiary and Cretaceous ages. The location of the Cretaceous-Tertiary boundary provides essentially a time reference plane which is necessary to correlation from well to well and which contributes to the time reference framework to which the depositional history of the sediments may be referred. This is of particular importance in Delaware where data must be obtained from wells due to the scarcity of outcrops and where rock units commonly grade into one another vertically and laterally so that their relationships may be obscured. On the Delaware Coastal Plain almost all of the water used for purposes other than cooling is drawn from wells. The efficient exploitation of the area's natural resources is dependent upon a thorough knowledge of its geology.

The writer wishes to acknowledge, with gratitude, the advice and guidance received from Drs. Steven K. Fox and Richard K. Olsson of Rutgers University. The illustrations were prepared by Mr. Roy F. Jernigan, Jr., University of Delaware.

Foraminifera and the Cretaceous-Tertiary Boundary

A succession of cores taken during the drilling of a deep water test well on the Coastal Plain of Delaware has afforded the opportunity of studying the planktonic Foraminifera at the Cretaceous-Tertiary boundary. The well in which the cores were taken was drilled in 1957 on the Dover Air Force Base three miles southeast of Dover, Delaware (Fig. 1). This well has been designated as Je32-4 in the statewide well numbering system. Cores eighteen inches long were taken at intervals of ten feet throughout the 1422 foot well.

The sediments of Cretaceous, Tertiary and Quaternary age which underlie the Coastal Plain of Delaware form a wedge-shaped mass with the thin edge at the Fall Zone. The individual units dip and generally thicken toward the southeast. The latest Cretaceous unit exposed in Delaware is the Redbank Formation which crops out in the banks of the Chesapeake and Delaware Canal (Groot, Organist and Richards, 1954). There are no outcrops of of sediments of undoubted Paleocene age in Delaware. The few non-Pleistocene exposures presently known south of the Chesapeake and Delaware Canal are weathered and unfossiliferous.

Rasmussen, Groot and Depman (1958) presented the logs and hydrologic properties of the well at the Dover Air Force Base and offered a preliminary interpretation of the stratigraphy. In that report the Cretaceous-Tertiary boundary was placed at 737 feet. The present study shows that the Cretaceous-Tertiary boundary occurs between 978.5 feet (bottom of the deepest core containing Paleocene Foraminifera) and 987 feet (top of the highest core containing Cretaceous Foraminifera).

The so-called "faunal break" of the planktonic Foraminifera at the Cretaceous-Tertiary boundary has been discussed by several authors, especially Loeblich and Tappan (1957a). The Cretaceous *Heterohelix-Globotruncana* assemblage of Loeblich and Tappan is represented here in samples 20667, 20668 and 20669. The completely different Tertiary *Globigerina - Globorotalia* assemblage is found directly above in samples 20663, 20664, 20665 and 20666T and B. The distribution of species in these core samples is shown in Figure 2.

The planktonic Foraminifera from samples 20667, 20668 and 20669 indicate a Maestrichtian age for those sediments. Further, evidence for a late Maestrichtian age is found in the presence of *Planomalina messinae subcarinata* (Bronnimann) and *Rugoglobigerina jerseyensis* Olsson. The stratigraphic range of the former is given by Bolli

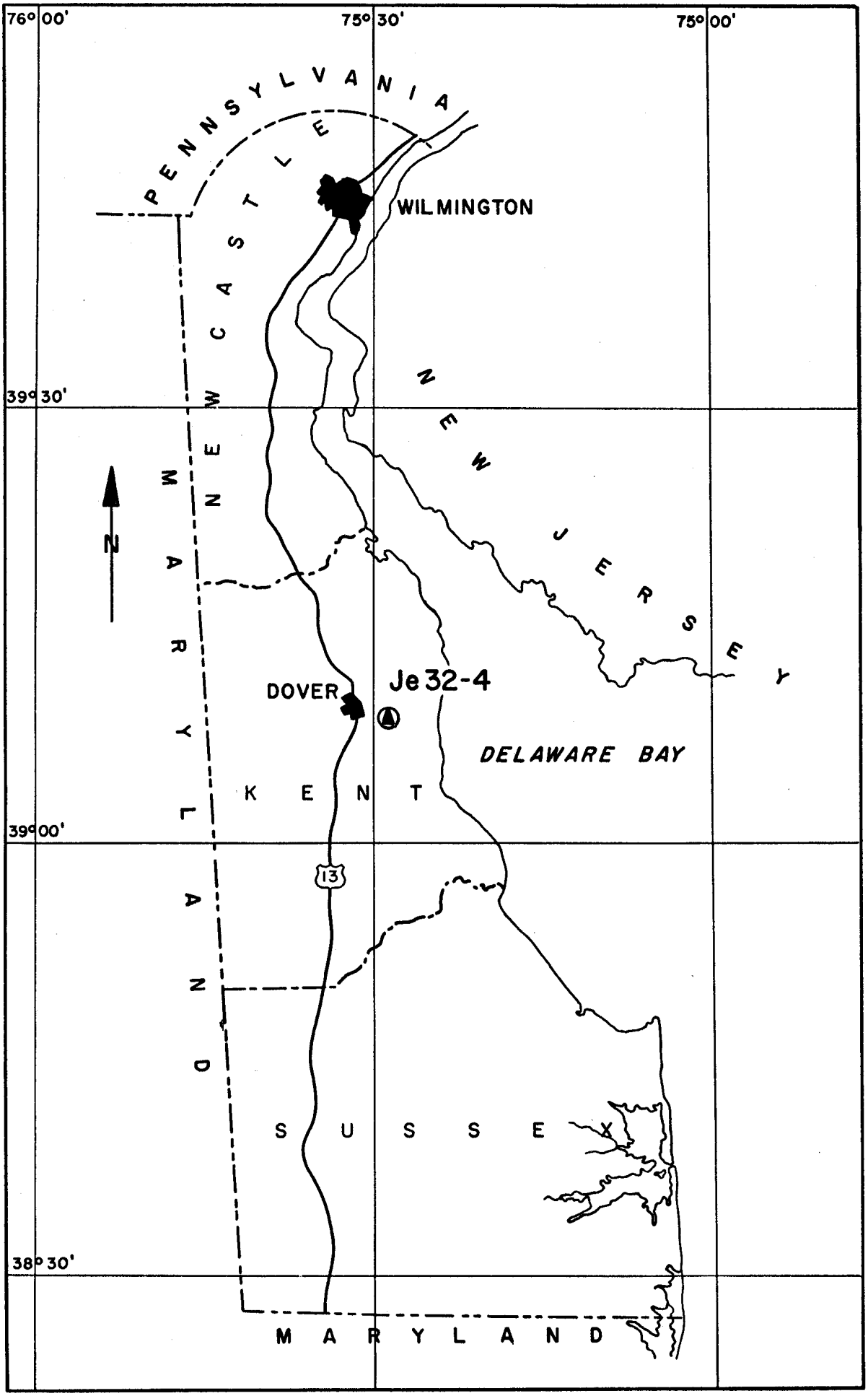

Figure 1. Map showing location of test well at Dover Air Force Base

Sample Number	20663	20664	20665	20666	20667	20668	20669
Depth	947'	957'	967'	977'	987'	997'	1007'
Globotruncana species							X
Planomalina messina subcarinata (Bronnimann)							X
Rugoglobigerina jerseyensis Olsson						X	X
Rugoglobigerina rugosa rugosa (Plummer)						X	X
Pseudoguembelina excolata (Cushman)						X	X
Heterohelix glabrans (Cushman)							X
Heterohelix navarroensis Loeblich					X	X	X
Guembelitria cretacea Cushman					X	X	X
Biglobigerinella multispina Lalicker					X	X	X
Globigerina triloculinoides Plummer	X	X	X	X			
Globigerinoides daubjergensis (Bronnimann)	X	X	X	X			
Globorotalia pseudobulloides (Plummer)		X	X	X			
Globorotalia compressa (Plummer)	X	X	X				
Globorotalia varianta (Subbotina)	X	X	X				
Chiloguembelina morsei (Kline)	X	X	X	X			

Figure 2. - Distribution of species

(1959), for Trinidad, as the *Abathomphalus mayaroensis* zone, the highest Maestrichtian zone in Trinidad. *Rugoglobigerina jerseyensis* was described from the Redbank Formation of New Jersey by Olsson (1960) who stated that the Redbank fauna is (p. 3)"...possibly younger than the *Abathomphalus mayaroensis* zone of Trinidad". Although a few additional feet of Cretaceous sediment appear to be present above it, sample 20667 represents the youngest Cretaceous material yet recorded in the State of Delaware.

None of the Cretaceous species continue upward into sample 20666 or above. Samples 20666-20663 contain the rather restricted assemblage characteristic of the *Globigerina compressa - Globigerinoides daubjergensis* zone of Loeblich and Tappan (1957a, b). This interval is correlated with the type Danian of Europe. The *Globorotalia compressa - Globigerinoides daubjergensis* zone is known from many parts of the world and has been traced in the Gulf and Atlantic Coastal Plains. The zone is present in the Brightseat Formation of Maryland and in the lower part of the Hornerstown Formation of New Jersey. The next core above sample 20663 marks the start of the *Globigerina* - keeled *Globorotalia* assemblage indicating a Late Paleocene age according to Loeblich and Tappan (1957a, b). Thus the upper four cores discussed here represent the entire Danian sequence present in the well.

The Cretaceous-Tertiary boundary indicated by the planktonic Foraminifera falls within a single lithologic unit that is present between depths of 615 and approximately 1070 feet. This thick unit consists of gray silts and clays containing a small but variable amount of glauconite. Detailed petrographic study by Jordan and Adams (1962) of the cores discussed in this paper has failed to show a significant difference between Cretaceous and Tertiary samples in texture or mineralogy. Jordan and Adams reported a bentonite from the upper part of sample 20666 and the presence of authigenic dolomite in the lower portion of that core.

Although the actual contact between the Cretaceous and the Tertiary is not present in this set of cores, the geophysical logs do not indicate any change between samples 20667 and 20666 and it is concluded that an unconformity at the boundary is not demonstrable in this well.

No formational name in current use is thought to be adequate for the unit in which the Cretaceous-Tertiary boundary is found in the well at the Dover Air Force Base. Fossiliferous outcrops of the same ages as the cores discussed here are not known on the Delmarva Peninsula. Outcropping time equivalents found in neighboring states differ in lithology, an expected result of facies changes between up- and downdip locations.

The nomenclature of subsurface and surface units is the subject of a study in preparation by the Delaware Geological Survey.

The usefulness of the planktonic Foraminifera for locating the Cretaceous-Tertiary boundary has been demonstrated many times and it is now clearly applicable in Delaware. Study of the nature and attitude of the boundary will continue as additional subsurface data become available.

SYSTEMATIC DESCRIPTIONS

Family HETEROHELICIDAE Cushman, 1927

Genus HETEROHELIX Ehrenberg, 1843

HETEROHELIX GLABRANS (Cushman)

Pl. 1, Fig. 1

Gümbelina tessera Cushman, 1936, Geol. Soc. Am. Bull., v. 47, p. 418, pl. 1, figs. 9a, b.

Gümbelina glabrans Cushman, 1938, Contr. Cushman Lab. Foram. Res., v. 14, pt. 1, p. 15, pl. 3, figs. 1a,b,2. -- Cushman and Hedberg, 1941, Contr. Cushman Lab. Foram. Res., v. 17, pt. 4, p. 92, pl. 22, figs. 16a,b.--Cushman and Todd, 1943, Contr. Cushman Lab. Foram. Res., v. 19, pt. 3, p. 64, pl. 11, fig. 14.--Cushman, 1946, U.S. Geol. Survey Prof. Paper 206, p. 109, pl. 46, figs. 17, 18.

Heterohelix glabrans Olsson, 1960, Jour. Paleo., v. 34, p. 26, pl. 4, fig. 4.

Occurrence. - *Heterohelix glabrans* was found in small numbers in sample 20669. It is known from the Navarro Formation of the Gulf Coast and from the Redbank and "New Egypt" (Olsson, 1960) Formations of New Jersey.

HETEROHELIX NAVARROENSIS Loeblich

Pl. 1, Fig. 2

Heterohelix navarroensis Loeblich, 1951, Contr. Cushman Found. Foram, Res., v. 2, pt. 3, p. 107, pl. 12, figs. 1-3b, text. fig. 1.-- Montanero Gallitelli, 1957, U. S. Nat. Mus. Bull. 215, p. 137, pl. 31, figs. 5a-11. -- Olsson, 1960, Jour. Paleo., v. 34, p. 27, pl. 4, fig. 5.

Occurrence. - This species is known from the Navarro of Texas and from the Redbank and "New Egypt" Formations of Maestrichtian age of New Jersey. It occurs abundantly in samples 20667, 20668 and 20669.

Genus GUEMBELITRIA Cushman, 1933

GUEMBELITRIA CRETACEA Cushman

Pl. 1, Fig. 4

Gumbelitria cretacea Cushman, 1933, Contr. Cushman Lab. Foram. Res., v. 9, pt. 2, p. 37, pl. 4, figs. 12a, b. --Cushman, 1936, Geol. Soc. Am. Bull., v. 47, p. 418, pl. 1, figs. 12a, b. -- Jennings, 1936, Bulls. Am. Paleo., v. 23, p. 186, pl. 30, figs. 12a, b. -- Cushman, 1938, Contr. Cushman Lab. Foram. Res., v. 14, p. 19, pt. 1, pl. 3, figs. 14a,b. - Cushman and Hedberg, 1941, Contr. Cushman Lab. Foram. Res., v. 17, pt. 4, p. 91, pl. 22, fig. 17.--Cushman and Todd, 1943, Contr. Cushman Lab. Foram. Res., v. 19, pt. 3, p. 65, pl. 11, fig. 16. - Cushman, 1946, U. S. Geol. Survey Prof. Paper 206, p. 103, pl. 44, fig. 14.

Guembelitria cretacea Montanero Gallitelli, 1957, U. S. Nat. Mus. Bull. 215, p. 136, pl. 31, figs. 1a,b. -- Olsson, 1960, Jour. Paleo., v. 34,p. 27, pl. 4, fig. 8.

Occurrence. - This species is widespread in the Upper Cretaceous. It was found in samples 20667, 20668 and 20669 of the present material.

Genus PSEUDOGUEMBELINA Bronnimann and Brown, 1953

PSEUDOGUEMBELINA EXCOLATA (Cushman)

Pl. 1, Fig. 3

Guembelina excolata Cushman, 1926, Contr. Cushman Lab. Foram. Res., v. 2, pt. 1, p. 20, pl. 2, fig. 9.

Gumbelina excolata White, 1929, Jour. Paleo., v. 3, p. 34, pl. 4, figs. 7a,b. -- Cushman, 1938, Contr. Cushman Lab. Foram. Res., v. 14, pt. 1, p. 17, pl. 3, figs. 11a,b.-- Cushman and Hedberg, 1941, Contr. Cushman Lab. Foram. Res., v. 17, pt. 4, p. 92, pl. 22, fig. 14.-- Cushman, 1946, U. S. Geol. Survey Prof. Paper 206, p. 108, pl. 46, fig. 16.-- Hamilton, 1953, Jour. Paleo., v. 27, p. 234, pl. 30, fig. 11.

Occurrence. - This species is known from many localities of Upper Cretaceous age. It is reported from the Maestrichtian Redbank and "New Egypt" Formations of New Jersey by Olsson. In the present study it was found to occur very rarely in samples 20668 and 20669.

Genus CHILOGUEMBELINA Loeblich and Tappan, 1956

CHILOGUEMBELINA MORSEI (Kline)

Pl. 1, Fig. 5

Gumbelina morsei Kline, 1943, Miss. Geol. Survey Bull. 53, p. 44, pl. 7, fig. 12.

Chiloguembelina morsei Loeblich and Tappan, 1957b, U. S. Nat. Mus. Bull. 215, p. 179, pl. 40, figs. 2a,b; pl. 41, fig. 4; pl. 42, figs. 1a,b; pl. 43, figs. 2, 6a,b.

Occurrence. - This species is known from the Danian of Europe and from formations of early Paleocene age on the Atlantic and Gulf Coastal Plains, including the Brightseat Formation of Maryland. It occurs rarely in samples 20663, 20664, 20665 and 20666.

Family HANTKENINIDAE Cushman, 1927

Genus PLANOMALINA Loeblich and Tappan, 1946

PLANOMALINA MESSINAE SUBCARINATA (Bronnimann)

Pl. 1, Figs. 7a, b

Globigerinella messinae subcarinata Bronnimann, 1952a, Bulls. Am. Paleo., v. 34, p. 44, pl. 1, figs. 10, 11, text figs. 21a-m. -- Olsson, 1960, Jour. Paleo., v. 34, p. 43, pl. 8, figs. 9, 10.

Remarks. - It is believed that relict apertures are present on the Delaware specimens but too few individuals are available to be certain. Bolli (1959) placed this species in the genus *Planomalina* because of probable relict, apertures, however *Planomalina messinae subcarinata* was not illustrated.

Occurrence. - According to Bronnimann and to Bolli this species is restricted to the *Abathomphalus mayaroensis* zone of the Maestrichtian of Trinidad. Olsson recorded its presence in the Redbank Formation of New Jersey. It is rare, and only moderately well preserved, in sample 20669.

Genus BIGLOBIGERINELLA Lalicker, 1948

BIGLOBIGERINELLA MULTISPINA Lalicker

Pl. 1, Figs. 8a, b

Biglobigerinella multispina Lalicker, 1948, Jour. Paleo., v. 22, p. 624, pl. 92, figs. 1-3c. --Bolli, Loeblich and Tappan, 1957, U. S. Nat. Mus. Bull. 215, p. 25, pl. 1, figs. 11-12b.

Remarks. - This species was found in various developmental stages ranging from immature forms with a single final chamber and aperture to mature forms with well developed paired final chambers with an aperture in each. The specimen illustrated represents an intermediate stage in which the last formed chambers, although paired, are not distinctly separated. This stage is common in the Delaware material.

Occurrence. - This species was originally described from the Marlbrook Marl of Arkansas. It has subsequently been found in the Navarro. It occurs in the Delaware samples 20667, 20668 and 20669.

Family ORBULINIDAE Schultze, 1854

Genus GLOBIGERINA d'Orbigny, 1826

GLOBIGERINA TRILOCULINOIDES Plummer

Pl. 1, Figs. 9a-c

Globigerina triloculinoides Plummer, 1926, Univ. Texas Bull. 2644, p. 134, pl. 8, figs. 10a -c. -- Galloway and Morrey, 1931, Jour. Paleo., v. 5, p. 348, pl. 39, figs. 11a,b. -- Jennings, 1936, Bulls. Am. Paleo., v. 23, p. 193, pl. 31, fig. 10. -- Cushman, 1940, Contr. Cushman Lab. Foram. Res., v. 16, pt. 3, p. 72, pl. 12, figs. 15a,b. -- Toulmin, 1941, Jour. Paleo., v. 15, p. 607, pl. 82, fig. 3. -- Cushman and Todd, 1942, Contr. Cushman Lab. Foram. Res., p. 43, pl. 8, figs. 1, 2. -- Beck, 1943, Jour. Paleo., v. 17, p. 609, pl. 108, figs. 2, 3. -- Kline, 1943, Miss. Geol. Survey Bull. 53, p. 59, pl. 6, figs. 12, 13. -- Cushman, 1944, Contr. Cushman Lab. Foram. Res., v. 20, pt. 2, p. 48, pl. 8, fig. 4. -- Brotzen, 1948, Sveriges. Geol. Undersökning, Avh., ser. c, no. 493 (Årsbok 42, no. 2), p. 89, pl. 17, fig. 2. -- Cushman, 1951, U. S. Geol. Survey Prof. Paper 232, p. 60, pl. 17, figs. 10, 11. -- Bronnimann, 1952b, Bulls. Am. Paleo., v. 34, p. 172, pl. 13, figs. 13 - 18. -- Graham and Classen, 1955, Contr. Cushman Found. Foram. Res., v. 6, pt. 1, p. 28, pl. 5, figs. 1a, b. -- Weiss, 1955, Micropaleontology, v. 1, p. 308, pl. 1, figs. 18 - 21. -- Haynes, 1956, Contr. Cushman Found. Foram. Res., v. 7, pt. 3, p. 99, pl. 17, figs. 15-15b. -- Bolli, 1957, U. S. Nat. Mus. Bull. 215, p. 70, pl. 15, figs. 18-20. -- Troelsen, 1957, U. S. Nat. Mus. Bull. 215, p. 129, pl. 30, fig. 4a-c. -- Loeblich and Tappan, 1957b, U. S. Nat. Mus. Bull. 215, p. 183, pl. 40, figs. 4a-c; pl. 41, figs. 2a-c; pl. 42, figs. 2a-c; pl. 43, figs. 5a-c; 8a-9c; pl. 45, figs. 3a-c; pl. 46, figs. 1a-c; pl. 47, figs. 2a-c; pl. 52, figs. 3-7; pl. 56, figs. 8a-c; pl. 62, figs. 3a-4c. -- Olsson, 1960, Jour. Paleo., v. 34, p. 43, pl. 7, figs. 22-24.

Occurrence. - This well known species has been reported from Paleocene and early Eocene units in many parts of the world. It is present in samples 20663, 20664, 20665 and 20666.

Genus GLOBIGERINOIDES Cushman, 1927

GLOBIGERINOIDES DAUBJERGENSIS (Bronnimann)

Pl. 1, Figs. 6a-c

Globigerina daubjergensis Bronnimann, 1953, Eclog. Geol. Helvetine, v. 45 (1952), p. 340, fig. 1. -- Bolli, 1957, U. S. Nat. Mus. Bull. 215, p. 70, pl. 16, figs. 13 - 15. -- Troelsen, 1957, U. S. Nat. Mus. Bull. 215, p. 128, pl. 30, figs. 1-2.

Globigerinoides daubjergensis Loeblich and Tappan, 1957b, U. S. Nat. Mus. Bull. 215, p. 184, pl. 40, figs. 1a-c; 8a-c; pl. 41, figs. 9a-c; pl. 42, figs. 6a-7c; pl. 43, figs. 1a-c; pl. 44, figs. 7-8c. -- Olsson, 1960, Jour. Paleo., v. 34, p. 43, pl. 8, figs. 4-6.

Remarks. - In the material studied the supplementary apertures on the spiral side are only rarely visible.

Occurrence. - The species appears to be restricted to the Danian. It has been recorded from the Danian of Europe and, on the Atlantic Coastal Plain, from the Brightseat Formation of Maryland and the Hornerstown Formation of New Jersey. It occurs in the Delaware samples 20663, 20664, 20665 and 20666.

Family GLOBOROTALIIDAE Cushman, 1927

Genus GLOBOROTALIA Cushman, 1927

GLOBOROTALIA COMPRESSA (Plummer)

Pl. 1, Figs. 10a-c

Globigerina compressa Plummer, 1926, Univ. of Texas Bull. 2644, p. 135, pl. 8, figs. 11a-c. -- Jennings, 1936, Bulls. Am. Paleo., v. 23, p. 193, pl. 31, fig. 8. -- Toulmin, 1941, Jour. Paleo., v. 15, p. 607, pl. 82, figs. 1, 2 -- Kline 1943, Miss. Geol. Survey Bull. 53, p. 58, pl. 6, figs. 5, 6. -- Cushman, 1951, U.S. Geol. Survey Prof. Paper 232, p. 60, pl. 17, fig. 9. -- Troelsen, 1957, U.S. Nat. Mus. Bull. 215, p. 129, pl. 30, fig. 5.

Globorotalia compressa Bronnimann, 1952b, Bulls. Am. Paleo., v. 34, p. 173, pl. 12, figs. 19-24. -- Bolli, 1957, U. S. Nat. Mus. Bull. 215, p. 77, pl. 20, figs. 21-23. -- Loeblich and Tappan, 1957b, U. S. Nat. Mus. Bull. 215, p. 188, pl. 40, figs. 5a-c; pl. 41, figs. 5a-c; pl. 42, figs. 5a-c; pl. 44, figs. 9a-10c. -- Olsson, 1960, Jour. Paleo., v. 34, p. 45, pl. 8, figs. 20-22.

Occurrence. - This Danian index species has been found in the Brightseat and Hornerstown Formations in the Atlantic Coastal Plain. It is present in samples 20663, 20664 and 20665.

GLOBOROTALIA PSEUDOBULLOIDES (Plummer)

Pl. 1, Figs. 11a-c

Globigerina pseudobulloides Plummer, 1926, Univ. of Texas Bull. 2644, p. 133, pl. 8, figs. 9a-c. -- Cushman, 1940, Contr. Cushman Lab. Foram. Res., v. 16, pt. 3, p. 72, pl. 12, fig. 16. -- Cushman and Todd, 1942, Contr. Cushman Lab. Foram. Res., v. 18, pt. 2, p. 43, pl. 8, figs. 3, 4. -- Kline, 1943, Miss. Geol. Survey Bull. 53, p. 58, pl. 6, figs. 9-11. -- Cushman, 1951, U. S. Geol. Survey Prof. Paper 232, p. 60, pl. 17, figs. 7, 8. -- Bronnimann, 1952b, Bulls. Am. Paleo., v. 34, p. 169, pl. 13, figs. 7-9. -- Hamilton, 1953, Jour. Paleo., v. 27, p. 223, pl. 31, figs. 10-11. -- Graham and Classen, 1955, Contr. Cushman Found. Foram. Res., v. 6, pt. 1, p. 28, pl. 4, figs. 22a-c, 23a-c. -- Troelsen, 1957, U. S. Nat. Mus. Bull. 215, p. 128, pl. 30, figs. 6-8.

Globorotalia pseudobulloides Bolli, 1957, U. S. Nat. Mus. Bull. 215, p. 73, pl. 17, figs. 19-21. -- Loeblich and Tappan, 1957b, U. S. Nat. Mus. Bull. 215, p. 192, pl. 40, figs. 3a-c, 9a-c; pl. 41, figs. 1a-c; pl. 42, figs. 3a-c; pl. 43, figs. 3a-4c; pl. 44, figs. 4-6c; pl. 45, figs. 1a-2c; pl. 46, figs. 6a-c. -- Olsson, 1960, Jour. Paleo., v. 34, p. 46, pl. 9, figs. 19-21.

Occurrence. - This species has been found in early Tertiary units in many parts of the world. It has been recorded from the Brightseat and Hornerstown Formations in the Atlantic Coastal Plain. It has been found in samples 20666, 20665 and 20664 of the Delaware material.

GLOBOROTALIA VARIANTA (Subbotina)

Pl. 2, Figs. 1a-c

Globigerina varianta Subbotina, 1953, Trudy Vses. Neft. Naukno-Issledov. Geol. - Razved. Inst. n.s., v. 76, p. 63, pl. 3, figs. 5-12; pl. 4, Figs. 1-3; pl. 15, figs. 1-3.

Globorotalia varianta Loeblich and Tappan, 1957b, U. S. Nat. Mus. Bull. 215, p. 196, pl. 44, figs. 1a-2b; pl. 45, figs. 4a-c.

Occurrence. - On the Gulf Coast this species has been found in the Wills Point Formation and the Mathews Landing Formation. It is present in samples 20663, 20664 and 20665.

Family GLOBOTRUNCANIDAE Brotzen, 1942

Genus RUGOGLOBIGERINA Bronnimann, 1952

RUGOGLOBIGERINA JERSEYENSIS Olsson

Pl. 2, Figs. 2a-c

Rugoglobigerina jerseyensis Olsson, 1960, Jour. Paleo., v. 34, p. 49, pl. 10, figs. 19-21.

Occurrence. - This species was described by Olsson from the Maestrichtian Redbank Formation of New Jersey. It occurs very rarely in samples 20668 and 20669.

RUGOGLOBIGERINA RUGOSA RUGOSA (Plummer)

Pl. 2, Figs. 3a-c

Globigerina rugosa Plummer, 1926, Univ. of Texas Bull. 2644, p. 38, pl. 2, figs. 10a-d.

Rugoglobigerina rugosa rugosa Bronnimann, 1952a, Bulls. Am. Paleo., v. 34, p. 28, text figs. 11-13. -- Olsson, 1960, Jour. Paleo., v. 34, p.50, pl. 10, figs. 16-18.

Occurrence. - This species was described from the Navarro of Texas. It is present in the Redbank and lower "New Egypt" Formations of New Jersey. It is relatively abundant in samples 20668 and 20669.

Genus GLOBOTRUNCANA Cushman, 1927

GLOBOTRUNCANA sp.

Pl. 2, Figs. 4a-c

Trochospiral, umbilico-convex, periphery somewhat lobate with two keels which become more distinct in later chambers; wall calcareous, perforate; chambers angular truncate, 5 to 5½ in final whorl, small bead on the early chambers of the final whorl; sutures straight, depressed on umbilical side, raised and curved on spiral side; apertures umbilical, covered by a tegilla.

Diameter of figured specimen .40 mm.; thickness .19 mm.

Remarks. - *Globotruncana* sp. bears some resemblance to *G. gagnebini* Tilev but the keels are less distinct and wider spaced and *G. gagnebini* lacks beads on chamber walls. Attempts to identify the Delaware specimens are hampered by the small number of individuals present.

Occurrence. - These forms are rare in sample 20669.

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PLATE 1

(All figures X 150)

Figure 1. *Heterohelix glabrans* (Cushman).

Figure 2. *Heterohelix navarroensis* Loeblich.

Figure 3. *Pseudoguembelina excolata* (Cushman).

Figure 4. *Guembelitria cretacea* Cushman.

Figure 5. *Chiloguembelina morsei* (Kline).

Figures 6a-c. *Globigerinoides daubjergensis* (Bronnimann). 6a, Edge view. 6b, Umbilical view. 6c, Spiral view.

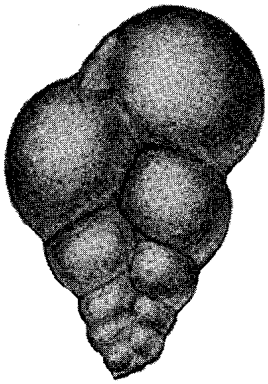
Figures 7a, b. *Planomalina messina subcarinata* (Bronnimann). 7a, Side view. 7b, Edge view.

Figures 8a, b. *Biglobigerinella multispina* Lalicker. 8a, Side view. 8b, Edge view.

Figures 9a-c. *Globigerina triloculinoides* Plummer. 9a, Umbilical view. 9b, Edge view. 9c, Spiral view.

Figures 10a-c. *Globorotalia compressa* (Plummer). 10a, Umbilical view. 10b, Edge view. 10c, Spiral view.

Figures 11a-c. *Globorotalia pseudobulloides* (Plummer). 11a, Umbilical view. 11b, Edge view. 11c, Spiral view.



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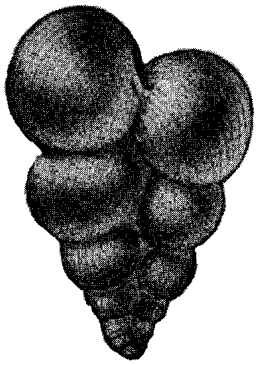

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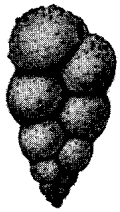

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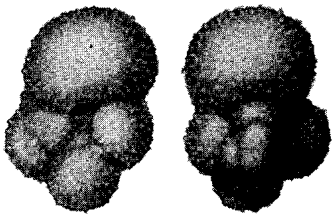

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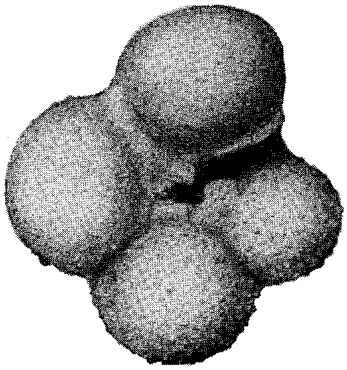

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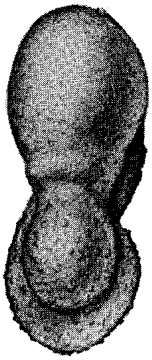

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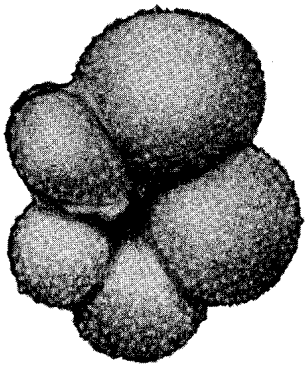

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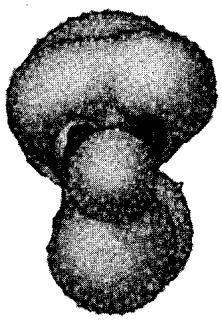

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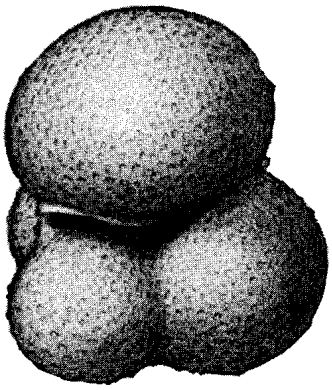

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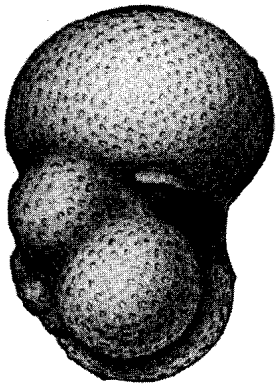

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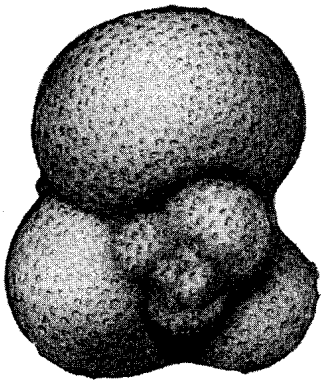

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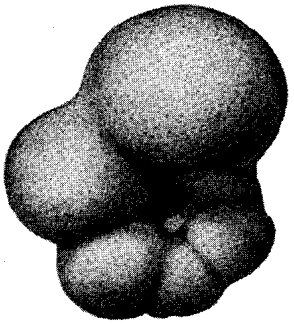

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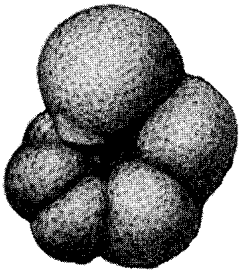

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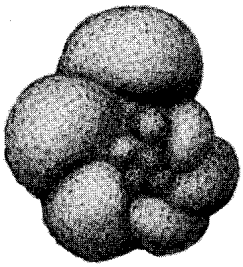

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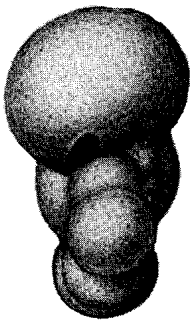

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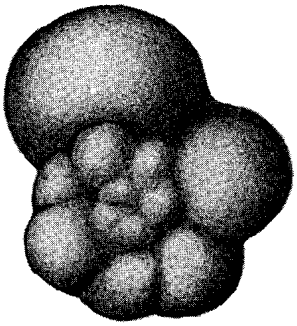


11c.

PLATE 1

11.

PLATE 2

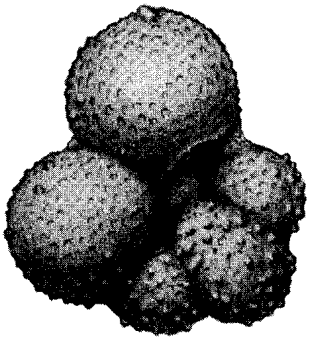
(All figures: a, umbilical view; b, edge view; c, spiral view; all X 150)

Figures 1a - c. *Globorotalia varianta* (Subbotina).

Figures 2a - c. *Rugoglobigerina jerseyensis* Olsson.

Figures 3a - c. *Rugoglobigerina rugosa rugosa* (Plummer)

Figures 4a - c. *Globotruncana* species.



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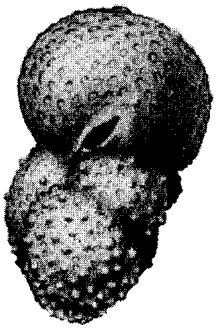

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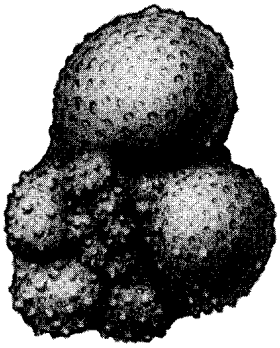

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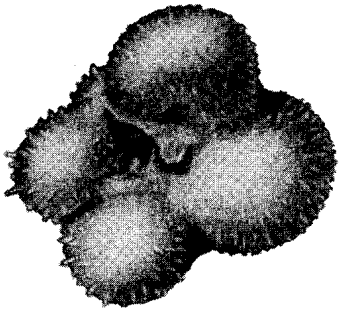

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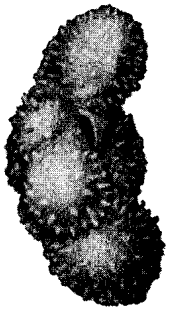

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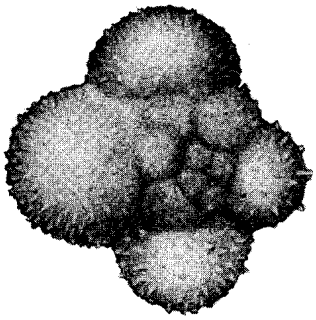

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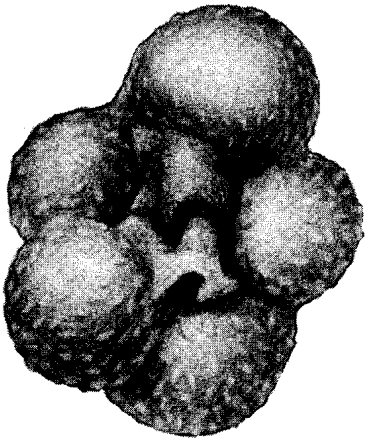

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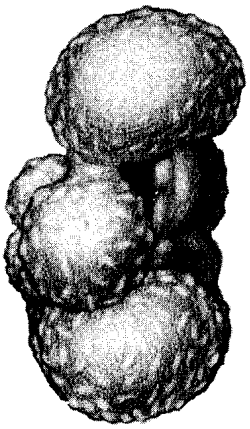

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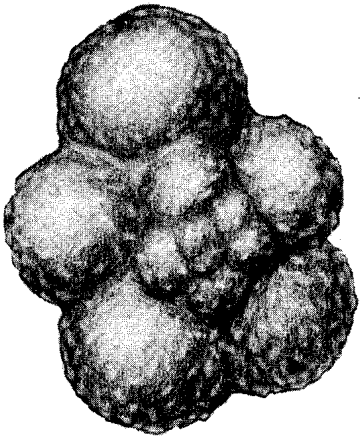

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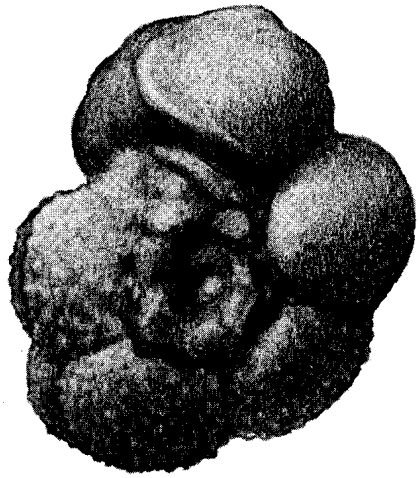

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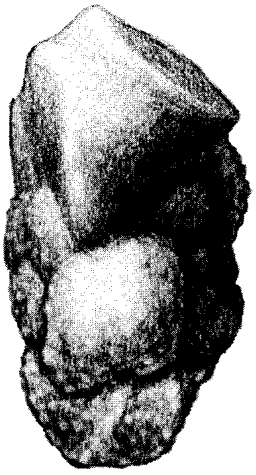

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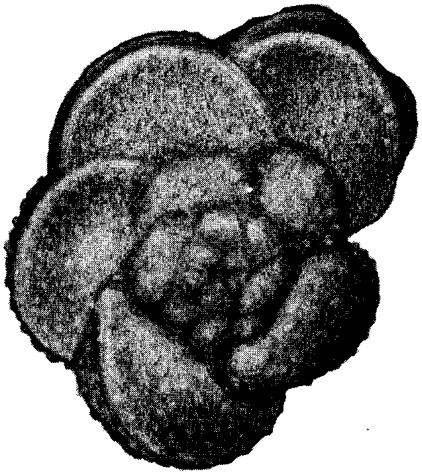

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PLATE 2