Lower Eocene Phosphatized *Globigerina* Ooze from Sylvania Guyot

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BIKINI AND NEARBY ATOLLS, MARSHALL ISLANDS

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LOWER EOCENE PHOSPHATIZED GLOBIGERINA OOZE FROM SYLVANIA GUYOT [1, 2]

By Edwin L. Hamilton [3] and Robert W. Rex [4]

ABSTRACT

Dredge hauls on the top of Sylvania Guyot, the seamount adjacent to Bikini Atoll, Marshall Islands, were made by 1950 Mid-Pacific Expedition of the Scripps Institution of Oceanography and the U. S. Navy Electronics Laboratory. Sylvania has a very flat top at about 705 fathoms and is connected to Bikini Atoll by a saddle at a depth of 790 fathoms; the adjacent sea floor is deeper than 2,500 fathoms.

The dredge haul from Mid-Pacific station 43 A included tuff-breccia with cracks filled with a phosphatized fauna of earliest Eocene age dominated by *Globorotalia velascoensis* and *G. aragonensis;* the nearest faunal affinity of this assemblage, the oldest in the northern Marshall Islands, is with similarly occurring faunas from the Mid-Pacific Mountains about 1,000 miles to the east and with faunas from the Paleocene and Eocene deposits of the Tampico Embayment region of Mexico.

In the dredge hauls from Mid-Pacific stations 43 D and 43 DD, the fossil planktonic fauna was from the Miocene. The material from 43 D is correlated with the *Globigerinatella insueta* zone of the Caribbean; the material is about the same age as that found on Saipan.

The new evidence from Sylvania Guyot fits well into that previously determined and indicates the probability that in Late Cretaceous or earliest Tertiary time Sylvania was eroded to a flat bank; Bikini Atoll at this time was probably a younger and higher feature which had been little eroded. Fast subsidence in the Late Cretaceous or early Tertiary left Sylvania Guyot as a relatively deeply submerged flat bank while Bikini Atoll was at, or above, the surface. Subsequent submergence was relatively slow, so that a great reef grew on Bikini Atoll while planktonic Foraminifera were being deposited on the top of Sylvania Guyot.

INTRODUCTION

From 1946 to 1952 the most concentrated field study of coral atolls ever attempted took place in the northern Marshall Islands. Most of these studies are presented in other chapters of Professional Paper 260. As part of this effort the personnel of the 1950 Mid-Pacific Expedition sponsored by the U. S. Navy Electronics Laboratory and Scripps Institution of Oceanography made dredge hauls on Sylvania Guyot, the flat-topped seamount which lies northwest of Bikini Atoll. Sylvania Guyot and Bikini Atoll form a single twin-peaked massif which is connected by a saddle at a depth of 790 fathoms (fig. 255). Sylvania Guyot has a very flat top

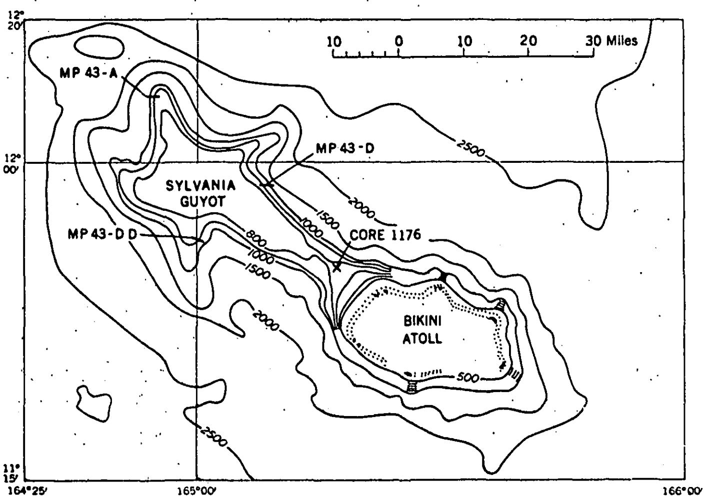

FIGURE 255.—Map of Bikini Atoll and Sylvania Guyot showing the locations at which dredge hauls were made.

with depths of about 705 fathoms; it is about 14 by 30 miles across the top and is larger than Bikini Atoll. The geology of Bikini Atoll and Sylvania Guyot and details on the dredge hauls of this paper have been discussed by Emery, Tracey, and Ladd (1954) and will not be completely repeated here.

One of the 1950 dredge hauls (MP 43 A) was made on a north spur of Sylvania Guyot at depths of from 1,030 to 810 fathoms, near the rounded edge of the flat top of the seamount (fig. 255). The dredged material consisted mostly of yellow and brown tuff-breccia covered by crusts of manganese oxide and containing irregular cracks filled with cemented Foraminifera (pl. 250); 1 rock was 24 inches long and weighed about 200 pounds and was covered by a 1/16–1/4 inch crust of manganese oxide. Macdonald (Emery, Tracey, and Ladd, 1954, p. 120–121) identified this material as a friable tuff-breccia containing rock fragments in a fine matrix. Much of the tuff was altered to clay minerals. Macdonald believed this material was pyroclastic and was probably formed in waters much shallower than that from which the material was dredged. The fossil planktonic Foraminifera from the cracks and pockets of this tuff-breccia are from the earliest Eocene.

A second dredge haul (MP 43 D) was made on the southeast side of Sylvania Guyot, just below the break

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in slope, at depths between 1,150 and 820 fathoms (fig. 255). Part of this material was described by Macdonald as a much altered basaltic lava covered by a shell of manganese oxide.

In this latter material, uncemented Miocene *Globigerina* ooze was found in a small crack under the manganese.

A third dredge haul (MP 43 DD; fig. 255), made on a south spur of Sylvania at 880 fathoms, yielded a small "boulder" of partly indurated *Globigerina* ooze covered with a coat of manganese oxide. The planktonic Foraminifera of this indurated ooze are probably uppermost Miocene, but M. N. Bramlette (personal communication) thinks that the material may be Pliocene, on the basis of the coccoliths in the ooze.

This paper is concerned with the mode of occurrence, mineralogy, and paleontology of these fossil *Globigerina* oozes from the top of Sylvania Guyot and the significance of this material in the geologic history of the area. This material is important in the geologic history of the Pacific Basin because the early Eocene fauna is the oldest in the northern Marshall Islands area and is about the same age as the fossil Foraminifera on the submerged flat tops of the ancient islands of the Mid-Pacific Mountains to the east.

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The mineralogical study was by R. W. Rex and was supported by contract between the University of California, Scripps Institution of Oceanography, and the Office of Naval Research. The foraminiferal studies were by E. L. Hamilton.

OCCURRENCE OF FOSSILIFEROUS MATERIAL

MID-PACIFIC STATION 43 A

Vesicles and cracks in the palagonitized tuff from dredged material often contain buff Foraminifera embedded in a buff matrix. Detailed X-ray analysis and qualitative chemical tests of this buff material indicated that it is nearly pure apatite with only a small amount of calcium carbonate remaining. No chert crack fillings were noted (Macdonald *in* Emery, Tracey, and Ladd, 1954, p. 120). The process of phosphatization of the Foraminifera and other calcium carbonate particles is most complete for the matrix and least complete for foraminiferal tests and coccolith plates. Much of the phosphatized ooze has a dense buff crust, especially in areas where crusts of hydrogenous ferruginous manganese oxide have been deposited. The transition from apatite to crust of ferruginous manganese oxide is visually sharp; however, very small (1–30 microns) apatite particles form the principal nonferruginous manganese oxide part of this size range of the black crusts. The nonferruginous manganese part of the crust is 15 percent by weight of which 2 percent is apatite.

Detailed studies of the crystal structure, morphology, and surface area of the ferruginous manganese crust minerals have been made by Buser and Grütter (1956). The iron, according to these authors, is present as amorphous hydroxide and goethite, and the manganese, as delta-MnO_2 (Buser and Grütter, 1956, p. 51). The chemical composition of the ferruginous manganese crust from MP 43 A has been reported by Goldberg (1954, p. 252).

The paragenetic sequence which is suggested is as follows:

1. Deposition of Foraminifera and coccolith calcium carbonate remains in vesicles and cracks in the palagonitized tuff-breccia (pl. 250).

2a. Phosphatization of the calcium carbonate by orthophosphate ion substitution for carbonate in the solid calcium carbonate, probably according to the mechanism described by Clark and Turner (1955); this is essentially a replacement phenomenon.

2b. Dissolution of surface material in some cracks with reprecipitation of apatite to produce a dense crust over the loosely cemented ooze. This stage may have occurred before stage 2a, so that the solution and redeposition of calcium carbonate produced the hard crust. Evidence determining which step came first was not observed.

3. Sedimentation change from biogenous carbonate to hydrogenous ferruginous manganese crust containing a small quantity of 1- to 30-micron apatite particles. The X-ray powder diffraction pattern of these apatite particles is indistinguishable by spectrometer technique from the apatized Foraminifera. In addition, the presence of these apatite particles suggests that there are at least two mechanisms for production of apatite in equilibrium with sea water. Clark and Turner (1955, p. 665), in their discussion of the kinetically slow orthophosphate ion-solid calcium carbonate reaction, describe the first mechanism which is essentially a replacement of deposited calcium carbonate. If the foraminiferal form is preserved this mechanism is indicated. The second is a direct deposition of apatite particles from sea water. Because no calcium carbonate remains with the apatite of the ferruginous manganese crust and some does remain in the phosphatized ooze, it is concluded that calcium carbonate either was not deposited or was redissolved during deposition of the

ferruginous manganese crust. For this reason it seems improbable that the apatite in the ferruginous manganese crust could form after deposition from phosphatization of biogenous calcium carbonate. However, no evidence is available to indicate the precise mechanism of production of the apatite particles deposited directly from sea water. These particles do not show the small crystallite size characteristic of fishbone fragments or teeth. G. Arrhenius, M. N. Bramlette, and E. Picciotto (1957) have pointed out that the small apatite crystallites of fish debris which settle on ferruginous manganese crusts may dissolve and recrystallize as larger grains thereby decreasing their surface energy. The new apatite would then be in equilibrium with sea water, and the rare earths and thorium originally scavenged by the fish debris is sorbed on the ferruginous manganese phase.

The *d* spacings for the powder diffraction pattern of the apatized Foraminifera are given in the following table with corresponding values for apatized Foraminifera from Horizon Guyot and apatized biogenous calcium carbonate from Cape Johnson Guyot in the Mid-Pacific Mountains (for locations and geology see Hamilton, 1956). The powder-diffraction patterns from these seamounts are remarkably similar and differ only very slightly from a California continental-shelf phosphorite. The X-ray pattern corresponds to those of dehrnite and francolite (McConnell, 1938, p. 5), two different varieties of apatite. Further chemical studies would be necessary to ascertain which of these two varieties is the form present. Fluorapatite does not fit the marine apatite pattern as well as does francolite or dehrnite. Dietz, Emery, and Shepard (1942, p. 818) suggested that the California continental-shelf phosphorite be called francolite, basing their conclusion on the powder diffraction pattern and a fluorine content of about 3 percent. Dehrnite is a hydroxyapatite rich in sodium carbonate, and it may be that marine apatite precipitates as hydroxyapatite, the common aqueous precipitate (Clark, 1955, p. 1696), and then undergoes slow fluorine for hydroxyl substitution to gradually change to francolite.

X-ray diffraction analyses of apatite from seamounts and banks of the North Pacific compared with dehrnite, francolite, and fluor-apatite

All *d* values in Å. Measurements made with Norelco Diffractometer, CuKα, Ni filter, scanning ¼° 2θ per minute, 1° slits, 4 second time constant, and employing a rotating sample holder]

	Sylvania Guyot, MP-43A		Cape Johnson Guyot, MP-37C		Horizon Guyot, MP-25 F-2		Phosphorite, F. P. S. 183-5, Coronado Bank, San Diego, Calif.		Dehrnite (McConnell, 1938)[1]		Francolite (McConnell, 1938)[1]		Fluor-apatite (McConnell, 1938)[1]	
h, k, l	*d*	*I*	*d*	*I*	*d*	*I*	*d*	*I*	*d*	*I*	*d*	*I*	*d*	*I*
(002)	3.45	4	3.45	4	3.45	6	3.44	6	3.43	1	3.43	2	3.43	2
(102)	3.17	3	3.17	2	3.17	2	3.17	2	3.16	0.5	3.16	0.5		
(120, 210)	3.05	2	3.05	2	3.05	3	3.05	2	3.04	3	3.04	2	3.06	3
(300 β)	2.95	1			2.95	1			2.96	.5	2.96	.5	2.98	.5
(121, 211)	2.79	10	2.79	10	2.79	10	2.79	10	} 2.77	10	2.77	>10	{ 2.80	>10
(112)	2.77	8	2.77	6	2.77	7	2.77	7					2.77	4
(300)	2.69	5	2.69	6	2.69	8	2.69	6	2.69	6	2.68	7	2.70	6
(202)	2.62	3	2.62	3	2.62	4	2.62	3	2.61	3	2.62	4	2.62	3
(301)	2.51	1	2.50	1	2.51	1			2.51	.5	2.51	.5	2.52	.5
(122, 212)	2.28	1			2.29	1	2.28	1	2.28	.5	2.28	1	2.29	.5
(130, 310)	2.24	2	2.24	3	2.24	3	2.24	3	2.23	4	2.24	3	2.25	2
(131, 311)	2.13	1	2.13	1	2.13	1	2.13	1	2.12	2	2.13	2	2.14	1
(113)	2.06	1	2.06	1	2.06	1	2.06	1	2.05	.5	2.06	1	2.06	1
(203)			2.00	1	2.00	1	1.99	1			2.00	1	2.00	.5
(222)	1.93	2	1.93	3	1.93	3	1.93	3	1.93	6	1.93	3	1.94	3
(132, 312)	1.88	1	1.88	2	1.88	2	1.88	2	1.88	2	1.88	1	1.88	1
(123, 213)	1.84	3	1.84	3	1.84	4	1.83	3	1.83	6	1.84	3	1.84	6
(231, 321)	1.79	1	1.79	2	1.79	2	1.79	1	1.79	2	1.79	2	1.80	3
(140, 410)	1.76	1	1.76	2	1.76	2	1.76	1	1.76	2	1.76	2	1.77	3
(402)	1.74	1	1.74	2	1.74	2	1.74	1	1.74	2	1.74	2	1.75	3
(004)	1.72	2	1.72	2	1.73	2	1.72	2	1.72	2	1.72	2	1.72	3
(232, 322)	1.63	1	1.63	1	1.63	1			1.63	1	1.63	.5	1.64	1

[1] McConnell's *d* spacings given here rounded off at second decimal place.

It should be noted that the paragenetic sequence and mineralogy of this material from Sylvania Guyot is identical with that for the phosphatized ooze from Horizon Guyot some 1,500 miles to the east. For the phosphatization of an expanse of ooze to take place, it is necessary that there be a cessation or marked diminution of the rate of accumulation; this is especially true if there has been a manganese crust deposited over the indurated material which is the case on Hess Guyot and Guyot 19171 in the Mid-Pacific Mountains.

MID-PACIFIC STATION 43 D

The *Globigerina* ooze in the cracks of the altered basalt of MP 43 D has been altered to phosphatic minerals in the same manner as the material from MP 43 A. This indicates that phosphatization was going on in the Miocene in the same manner as in the early Eocene.

MID-PACIFIC STATION 43 DD

This partly indurated, uppermost Miocene calcium carbonate ooze was in the form of a small boulder about

8 inches in diameter and was protected by a shell of manganese oxide about 6–10 millimeters thick. This material has not been phosphatized.

DESCRIPTION OF THE PLANKTONIC FORAMINIFERA

MID-PACIFIC STATION 43 A

The cracks and pockets inside the tuff-breccia from material dredged in haul MP 43 A contained the following fossil planktonic Foraminifera:

Globigerina apertura Cushman
aff. *G. collactea* (Finlay)
eocaena Gümbel
mckannai White
orbiformis Cole
pseudobulloides Plummer
rotundata d'Orbigny var. *jacksonensis* Bandy
topilensis Cushman
triloculinoides Plummer
Globorotalia aragonensis Nuttall
centralis Cushman and Bermudez
crassata (Cushman)
crassata densa (Cushman)
membranacea (Ehrenberg)
velascoensis (Cushman)
whitei Weiss
wilcoxensis Cushman and Ponton

One crack contained an unusually well-preserved party phosphatized planktonic fauna. The crack was about half filled with the fossiliferous material. The top surface of the filling had an excellently preserved fauna which was lightly cemented together in the top part and was incorporated into the more indurated material on the bottom (pl. 251). The species of the material were easily identified. A distinctive feature of this fauna was that numerous specimens of *Globorotalia velascoensis* (Cushman) and *G. aragonensis* Nuttall appeared together, this allowed excellent age dating, as described below. The fauna of this and the other cracks was a *Globorotalia-Globigerina* planktonic fauna with very few benthonic species. The strongly keeled *Globorotalia* dominated the fauna.

The systematic descriptions of this, and the other fossil faunas will be found at the end of the paper together with plates which illustrate the main index species.

MID-PACIFIC STATION 43 D

The pocket, or crack, in the altered basalt and under the manganese crust, from material dredged in haul MP 43 D contained the following fossil planktonic Foraminifera:

Globigerina apertura Cushman
bulloides d'Orbigny
ciperoensis Bolli
dissimilis Cushman and Bermudez
ouchitaensis Howe and Wallace var. *senilis* Bandy
Globigerina rotundata d'Orbigny var. *jacksonensis* Bandy
venezuelana Hedberg
Globigerinoides bispherica Todd
rubra (d'Orbigny)
sacculifera (Brady)
subquadrata Bronniman
triloba (Reuss)

As can be seen from the above list this was a *Globigerina-Globigerinoides* fauna; a distinctive feature is that no species of *Globorotalia* were identified, which is in sharp contrast with the fauna previously described from the Eocene. Stainforth (1949, p. 419) stated that the appearance of large-apertured species of *Globigerinoides* may be taken as evidence of postmiddle Oligocene; this mass aspect is certainly true of the Sylvania Guyot (MP 43 D) material.

MID-PACIFIC STATION 43 DD

The unindurated calcium carbonate ooze from dredge haul MP 43 DD contained the following fossil Foraminifera in addition to most of the planktonic species which occur in the Recent material from the area.

Globigerina altispira Cushman and Jarvis
Globorotalia menardii (d'Orbigny) var. *fijiensis* Cushman
menardii (d'Orbigny) var. *multicamerata* Cushman and Jarvis
Sphaeroidinella multiloba LeRoy
rutschi Cushman and Renz
seminulina (Schwager)

With the exception of the above species, this fauna looks like the modern tropical planktonic fauna expectable in the area.

DISCUSSION AND CONCLUSIONS

AGE AND AFFINITIES OF THE FOSSIL FAUNAS

When the prolific, fossil, planktonic foraminiferal faunas of the Mid-Pacific Mountains were discovered, it was realized that these forms, so familiar in land deposits, were actually present all over the Pacific Basin and should be looked for and expected in ancient sea-floor deposits (Hamilton, 1953). The present study confirms this expectation and again presents the utility of the planktonic smaller Foraminifera in long-range time correlations.

MID-PACIFIC STATION 43 A

Studies of the mass aspects of fossil planktonic faunas by Henson (1938), Glaessner (1945), Tromp (1949), Reiss (1955), and others indicate that the *Globotruncana-Gümbelina* faunas of the Upper Cretaceous are replaced by the *Globigerina-Gümbelina* faunas of the Danian. In the Paleocene (Midway) and lower Eocene (Wilcox), the keeled Globorotalias are strongly represented, and the fauna is, in general, dominantly made up of *Globorotalia-Globigerina* species, which is the faunal type of the Sylvania samples from MP 43 A.

Several worldwide index species are represented in the MP 43 A fauna. The two most important, and the ones whose overlapping total ranges allow a rather precise age determination, are *Globorotalia velascoensis* (Cushman) and *Globorotalia aragonensis* Nuttall. *G. velascoensis* was described by Cushman from the Velasco shale of the Tampico Embayment region of Mexico. *G. aragonensis* was described by Nuttall from the Aragon formation of Mexico. Since their first description, both species have been noted in the Middle East, Mediterranean, Gulf of Mexico and Caribbean areas, and from seamounts in the Mid-Pacific. The range of *G. velascoensis* is possibly uppermost Cretaceous, definitely Paleocene, and probably lower Eocene. *G. aragonensis* is a restricted lower Eocene to middle Eocene form. The fact that these two forms are found together in an apparently uncontaminated fauna (in one crack filling) places the age of the fauna at about the boundary between the Paleocene (Midway) and the Eocene (Wilcox). The remainder of the planktonic species, from cracks and pockets, tend to favor an age dating just into the earliest Eocene, although it is uncertain whether all the listed species lived at the same time.

The nearest affinity of this Sylvania Eocene fauna is with the fossil planktonic species of the Mid-Pacific Mountains to the east (Hamilton, 1953). In the Mid-Pacific Mountains, planktonic Foraminifera of Paleocene and Eocene age occur on the tops of four flat-topped seamounts. On Horizon Guyot almost the identical fauna (as noted above for Sylvania) occurs in the cracks of manganese-coated volcanic rocks. Other than the Mid-Pacific faunas, the nearest faunal affinity of the Eocene Sylvania species is with those of the Paleocene and Eocene deposits of the Tampico Embayment region of Mexico.

MID-PACIFIC STATION 43 D

The fossil planktonic fauna from the pocket within the altered basalt of MP 43 D is correlated with the *Globigerinatella insueta* zone of the Carribbean area on the basis of the ranges of the contained species. The *G. insueta* zone was originally placed in the lower part of the upper Oligocene of the Caribbean area (for example, Stainforth, 1948a, and 1948b), but recent work both in Europe and in the Caribbean area (Kugler, 1954; Akers, 1955; Drooger, 1956; Akers and Drooger, 1957; Blow, 1957; and Bolli, 1957) indicate that this zone is in the lower to middle Miocene of the Caribbean.

The appearance in the Sylvania Guyot fauna of *Globigerinoides bispherica* Todd and *G. subquadrata* Bronnimann is of particular interest. These two species were recently named by Todd and Bronnimann (*in* Todd and others, 1954); they occur in the Miocene of the Caribbean region and in deposits on Saipan, and *G. bispherica* has been noted in the Mediterranean area (Drooger, 1956). The chances of finding these species in a single rock from a haul of dredged material on the top of a seamount are such that their discovery in this areally intermediate location is almost more than hoped for (Todd and others 1954, p. 679). The discovery of these two index species on Saipan extended the usefulness of the *Globigerinatella insueta* zone of the Caribbean area into the central Pacific; their discovery on Sylvania Guyot and in the Mediterranean (Drooger, 1956) emphasizes the importance of the species of this zone in worldwide correlations.

MID-PACIFIC STATION 43 DD

The fossil planktonic fauna from the manganese-coated calcium carbonate material obtained in dredge haul MP 43 DD is correlated with the late Miocene on the basis of the overlapping ranges of *Globigerina altispira*, *Sphaeroidinella multiloba*, *S. rutschi*, *S. seminulina*, *S. dehiscens*, and *Pulleniatina obliquiloculata* (for example see Grimsdale, 1951). M. N. Bramlette (oral communication) after an examination of the coccoliths prefers an early Pliocene dating, but adds, correctly, that the exact ranges of the coccoliths, as well as the Foraminifera, are not well enough known to state the exact age more precisely. Most species of the modern planktonic fauna had appeared by the early Miocene; therefore planktonic foraminiferal faunas younger than that must be dated on relatively few species. It appears from this study and examination of the literature (for example Phleger, Parker, and Peirson, 1953, p. 85, and Grimsdale, 1951) that the best chance to date the upper Miocene in planktonic assemblages is with the species named above and their overlap in ranges with more modern elements of the fauna such as *S. dehiscens*, and *P. obliquiloculata*.

SIGNIFICANCE OF THE FOSSIL FAUNAS

In the central North Pacific Basin, there are now several age datings of seamounts and events. From the borings at Eniwetok Atoll (Ladd, and others, 1953; Cole, 1958), it is known that Eocene (Tertiary *b*) shallow-water calcareous deposits lie just above the olivine basalt.

At Bikini Atoll, the deep bore hole to 2,556 feet bottomed in the Oligocene (?); but in footnotes (Emery, Tracey, and Ladd, 1954, p. 83) and in the papers by Cole (1954) and Todd and Post (1954), it is noted that there is a distinct possibility that the top of the Eocene was reached. A revision of the Bikini Atoll evidence by Cole (1958), however, indicates Tertiary *e* (Aquitanian).

Cushman, Todd, and Post (1954) note the presence of Tertiary Foraminifera in a core (No. 1176) taken in the saddle between Bikini Atoll and Sylvania Guyot (fig. 255). It was supposed that these species may have been redeposited from the slopes of Bikini Atoll above, but now that older material has been found on Sylvania Guyot and Tertiary fossil material has been found at the surface in the Mid-Pacific Mountains, there is a distinct possibility that this material was in place and not redeposited.

Macdonald (*in* Emery, Tracey, and Ladd, 1954, p. 123) notes that the presence of fresh glass in the volcanic rocks on Sylvania Guyot indicates that the rocks are not older than the late Paleozoic and that they, being pyroclastic rocks, were erupted in waters much shallower than the water from which they were dredged.

The early Eocene fauna from a crack in the tuff-breccia boulder (MP 43 A) near the break in slope on top of Sylvania Guyot places the age of the flat top of the volcanic peak at not younger than earliest Eocene.

In the Mid-Pacific Mountains, about 1,000–1,500 miles to the east of the Marshall Islands, Eocene ooze was found in surficial material on the top of Horizon Guyot, and Paleocene ooze was found on the top of Hess Guyot, at or near the surface of the sediment (Hamilton, 1953, 1956). The dating of an ooze on the top of a seamount merely indicates that the surface was there at a certain time and available to receive sediment; it is definitely a "not-younger-than" type of dating and may be far from the actual time when the seamount was formed, or, in the case of the flat-topped seamounts, when the seamount was at the surface of the sea. For example: Hess Guyot in the Mid-Pacific Mountains was at the surface of the sea in the Cretaceous (Aptian to Cenomanian), but the oldest ooze collected from the surface of the flat top was laid down about 40 million years later during the late Paleocene.

At Eniwetok Atoll the sample from 2,780–2,790 feet contained the first Eocene species according to Cole, so that there is about 1,900 feet of Eocene material above the basalt basement of the atoll (at about 4,600 feet). This is comparable to the Bikini Atoll bore hole, where at 2,556 feet the hole bottomed in Tertiary *e* (Aquitanian). At this point the hole was about 2,400 feet above the volcanic basement as determined by seismic techniques; if these assumptions are true then it seems likely that there is about 2,400 feet of Oligocene and Eocene (and perhaps older rock) above the basement which is about the same situation as at Eniwetok Atoll.

The finding of early Tertiary Foraminifera in the tuff-breccia on Sylvania Guyot is another block of evidence in the structure forming the geologic history of the Pacific Basin and especially the northern Marshall Islands. This new evidence fits very well into all of the other information previously reported.

The best postulated history for the Bikini Atoll–Sylvania Guyot feature is still about the same as that formulated by Emery, Tracey, and Ladd (1954, p. 126–131). The new evidence can be assimilated easily into the history, so that the events might have been somewhat as follows:

The Bikini Atoll–Sylvania Guyot feature was a twin-peaked volcanic mass (Raitt, 1954) in Late Cretaceous or earliest Tertiary time. Sylvania Guyot, the older peak, had been eroded to a bank, and possibly corals had begun to grow and form banks among the erosional debris, much of which was pyroclastic. The marginal ridges around parts of Sylvania Guyot could thus be explained; a similar marginal ridge was noted on Hess Guyot (Hamilton, 1956, p. 15) but only 1 dredge haul out of 6 on Hess Guyot contained reef coral. Bikini Atoll at this time was younger and higher and had been relatively little eroded. Subsidence in Late Cretaceous or early Tertiary time was too fast to permit coral to continue to stay at the surface (which is the favored hypothesis for the sunken, coral-bearing guyots of the Mid-Pacific Mountains). This would have left Bikini Atoll at or above the surface while Sylvania Guyot was a relatively deeply submerged bank—too deep for coral growth and below the depth of profuse bottom life. Subsequent submergence must have been relatively slow because a great reef probably began to grow on the foundation of Bikini Atoll in early Tertiary time while, at the same time, planktonic Foraminifera were being deposited in the cracks of the pyroclastic rocks on Sylvania Guyot. Nonaccumulation of sediment around the rims of Sylvania Guyot and in the saddle between Sylvania Guyot and Bikini Atoll left old rocks and sediment deposits at the seamount surface, some of which became phosphatized. This is, in general, the same situation as in the Mid-Pacific Mountains.

After the start of deposition on Sylvania Guyot in the early Tertiary one might expect to find later deposits clear through the Tertiary to Recent time. The Miocene faunas are not, therefore, unexpected.

It may be very significant in the geologic history of the north-central Pacific Basin that roughly the same events were transpiring at about the same time in the Bikini Atoll–Sylvania Guyot area, in the Mid-Pacific Mountains to the east, and at Eniwetok Atoll to the west.

SYSTEMATIC DESCRIPTIONS

The bulk of the material will be deposited in the U. S. National Museum, Washington, D. C.

Family GLOBIGERINIDAE

Genus GLOBIGERINA d'Orbigny, 1826

Globigerina altispira Cushman and Jarvis, 1936[5]

Plate 254, figures 1–3

Globigerina altispira Cushman and Jarvis, 1936, Cushman Lab Foram. Res., Contr., v. 12, p. 5, pl. 1, figs. 13, 14.

This species has been reported from the Miocene of Jamaica and Haiti, and from the upper Oligocene and Miocene of the Dominican Republic. Grimsdale (1951) reports the species from the Middle East, and it was reported as rare in a mixed-fauna core from the Mid-Pacific Mountains. Phleger, Parker, and Peirson report this species in Miocene ooze from the Atlantic. This distinctive species appears to be a worldwide index fossil of some importance; it is common in the Miocene material from MP 43 DD.

Globigerina apertura Cushman, 1918

Plate 252, figure 7

Globigerina apertura Cushman, 1918, U. S. Geol. Survey Bull. 676, p. 57, pl. 12, fig. 8.

This species has been reported from the Eocene to the Pleistocene of North America and from the Eocene faunas of the Mid-Pacific Mountains. It is rare in the MP 43 A material.

Globigerina bulloides d'Orbigny, 1826[6]

Plate 253, figure 14

Globigerina bulloides d'Orbigny, 1826, Annals Sci. Naturelles, v. 7, p. 277, no. 1; Modèles no. 76 and young, no. 17.
Phleger and Parker, 1951, Geol. Soc. America Mem. 46, p. 34, pl. 19, figs. 6, 7.

A few forms referred to this species (as diagnosed from comparison with modern forms such as those of the second citation) occur in the material from MP 43 D.

Globigerina ciperoensis Bolli, 1954

Plate 253, figures 23, 24

Globigerina ciperoensis Bolli, 1954, Cushman Found. Foram. Res. Contr., v. 5, p. 1, figs. 3, 4, 5, and 6.
Globigerina cf. *G. concinna* Reuss. Cushman and Stainforth, 1945, Cushman Lab. Foram. Res. Spec. Pub. 14, p. 67, pl. 13, fig. 1.

Bolli considers that the lower Oligocene form sometimes referred to as *G. concinna* Reuss is sufficiently distinctive to merit a new species name. This form is common in the material from MP 43 D.

Globigerina aff. G. collactea (Finlay), 1939

Globorotalia collactea Finlay, 1909, New Zealand Royal Soc. Trans. v. 69, pt. 3, p. 327, pl. 29, figs. 164, 165.

A few forms which appear to be close to *G. collactea* (Finlay) occur in the MP 43 A fauna.

[5] Genus should be *Globoquadrina*.
[6] Reidentified as *Globorotalia obesa* Bolli, 1957.

Globigerina dissimilis Cushman and Bermudez, 1937

Plate 253, figures 9, 10

Globigerina dissimilis Cushman and Bermudez, 1937, Cushman Lab. Foram. Res. Contr., v. 13, p. 25, pl. 3, figs. 4–6.

A few forms referrable to this species occurred in the material from MP 43 D.

Globigerina eocaena Gümbel, 1868

Plate 252, figure 4

Globigerina eocaena Gümbel, 1868, K. Bayer. Akad. Wiss. Munchen, Math.-Physik. Cl., Abh., Munchen, Deutschland, Band 10 (1870). Abt. 2, p. 662, pl. 2, fig. 109a–b.

This species is rare in the Eocene (MP 43 A) fauna.

Globigerina mckannai White, 1928

Plate 252, figures 10, 11

Globigerina mckannai White, 1928, Jour. Paleontology, v. 2, p. 194, pl. 27, fig. 16.

This species is rare in the Sylvania Guyot fauna (MP 43 A). It was common in the Eocene fauna from Horizon Guyot.

Globigerina orbiformis Cole, 1927

Plate 252, figure 6

Globigerina orbiformis Cole, 1927, Am. Paleontology Bull., v. 14, no. 51, p. 33, pl. 5, fig. 7.

This species is rare in the Sylvania fauna from MP 43 A as it was, also, in the Eocene material from Horizon Guyot.

Globigerina ouachitaensis Howe and Wallace var. senilis Bandy, 1949

Plate 253, figure 4

Globigerina ouachitaensis senilis Bandy, 1949, Am. Paleontology Bull., v. 32, p. 121, pl. 22, fig. 5.

This variety occurs in the Eocene and middle Oligocene of the gulf coastal area and was found in the Eocene material from Horizon Guyot. It is rare in the material of MP 43 D.

Globigerina pseudobulloides Plummer, 1926

Plate 252, figure 3

Globigerina pseudobulloides Plummer, 1926, Texas Univ. Bull. 2644, p. 133, pl. 8, figs. 9a–c.

This species is common in Paleocene deposits around the world and is recorded by Nuttall from the Eocene of Mexico. It is rare in the MP 43 A material. In the Paleocene ooze from Hess Guyot this form was common.

Globigerina rotundata d'Orbigny var. jacksonensis Bandy, 1949

Plate 252, figure 1

Globigerina rotundata jacksonensis Bandy, 1949, Am. Paleontology Bull., v. 32, no. 131, p. 121, pl. 23, figs. 6a–c.

This form is rare in the Sylvania Guyot faunas.

Globigerina topilensis Cushman, 1925

Plate 252, figures 17, 21

Globigerina topilensis Cushman, 1925, Cushman Lab. Foram. Res., Contr., v. 1, p. 7, pl. 1, fig. 9.

Sylvania forms which appear to fall into this species are common in the crack fillings of the tuff-breccia of MP 43 A.

Globigerina triloculinoides Plummer, 1926

Plate 252, figure 2

Globigerina triloculinoides Plummer, 1926, Texas Univ. Bull. 2644, p. 134, pl. 8, figs. 10a–c.

This Danian to lower Eocene species is rare in the fossil fauna from Sylvania guyot (MP 43 A). It was common in the Mid-Pacific Mountains faunas.

Globigerina venezuelana Hedberg, 1937

Plate 253, figures 15, 16

Globigerina venezuelana Hedberg, 1937, Jour. Paleontology, v. 11, p. 681, pl. 92, fig. 7.

This species is recorded from the upper Eocene to the middle Miocene. It is common in the material from MP 43 D.

Genus GLOBIGERINOIDES Cushman, 1927

Globigerinoides bispherica Todd

Plate 253, figures 11–13

Globigerinoides bishperica Todd, 1954, Am. Jour. Sci., v. 252, p. 681, pl. 1, 4.

This species, described from the "upper Oligocene" of Saipan is also a common form in the Mediterranean area and in the *Globigerinatella insueta* zone of the Caribbean. This form, and that of *G. subquadrata* Bronnimann, may well prove to be extremely important index fossils for the lower Miocene now that worldwide distribution is shown.

Globigerinoides rubra (d'Orbigny), 1839

Plate 253, figure 5

Globigerina rubra d'Orbigny, 1839, *in* de la Sagra, Histoire Phys. Pol. Nat. Cuba, p. 82, pl. 4, figs. 12–14.

This abundant Recent form is sparsely represented in the material from MP 43 D; it is common in the late Miocene ooze (MP 43 DD).

Globigerinoides sacculifera (Brady), 1877

Plate 253, figures 3, 20–22

Globigerina sacculifera Brady, 1877, Geol. Mag., v. 4, p. 535. Brady, 1884, Dept. Sci. Results Voyage H. M. S. *Challenger*, Zool., v. 9, p. 604, pl. 80, fig. 4.

This species is common in the material from MP 43 D and in the upper Miocene fauna from MP 43 DD.

Globigerinoides sacculifera var. fistulosa (Schubert), 1910

Plate 254, figure 14

Globigerina fistulosa Schubert, 1910, K. k. geol. Reichsanstalt Verh., no. 14, p. 324 (7), fig. 2 (in text).
Schubert, 1911, K. k. geol. Reichsanstalt Abh., Band 20, pt. 4, p. 100, figs. 132–c (in text).

This form, described from the Tertiary of New Guinea, is common in the upper Miocene material from MP 43 DD.

Globigerinoides subquadrata Bronnimann, 1954

Plate 253, figures 6–8

Globigerinoides subquadrata Bronnimann, 1954, Am. Jour. Sci., v. 525, p. 680, pl. 1, figs. 5, 8.

This species is abundant in the "upper Oligocene" of Saipan (Todd and others 1954) and is known from the Miocene of Trinidad and Venezuela. The form is common in the material from MP 43 D.

Globigerinoides triloba (Reuss), 1850

Plate 253, figures 17–19

Globigerina triloba Reuss, 1850, K. Akad. Wiss. Wien, Math.-Nat. Cl. 1., Denkschr., Wien, Osterreich, Band 1, p. 374, pl. 47, fig. 11.

This form is common in the material from MP 43 D.

Genus ORBULINA d'Orbigny, 1839

Orbulina bilobata (d'Orbigny), 1846

Plate 254, figure 11

Globigerina bilobata d'Orbigny, 1846, Foraminifères fossiles du bassin tertiare de Vienne, Gide et Comp., Paris, France, p. 164, pl. 9, figs. 11–14.

This form is rare in the upper Miocene material from MP 43 DD.

Genus SPHAEROIDINELLA Cushman, 1927

Sphaeroidinella multiloba LeRoy, 1944

Plate 254, figure 7

Sphaeroidinella multiloba LeRoy, 1944, Colorado School Mines Quart., v. 39, p. 91, pl. 4, figs. 7–9.

A form which is tentatively assigned to this species is common in the Miocene material from MP 43 DD. As noted by the writer (Hamilton, 1953, p. 228) and Miss Frances L. Parker (*in* Phleger, Parker, and Peirson, 1953, p. 18) this species, *S. rutschi*, and *S. seminulina* may well be variations of a single species (especially true of *S. seminulina* and *S. rutschi*). In 1952 Hamilton examined topotype material of specimens of *S. rutschi* and *S. seminulina* sent to Miss Parker by the U. S. National Museum. In Miss Parker's opinion and in that of Hamilton, the two species (in the material at hand) were the same, with the possible exception that the wall of *S. seminulina* appeared to be thinner and more translucent and had a round pore structure which appeared as white dots, whereas *S. rutschi* had the typical hexagonal pore structure of the Globigerinidae and a thicker, whiter wall. All these forms are important worldwide index species of the Upper Tertiary and fortunately have about the same reported range: *S. multiloba* from the lower to upper Miocene, *S. seminulina* from the upper Oligocene to the lower Pliocene, and *S. rutschi* from the middle Oligocene to the middle Miocene.

Sphaeroidinella rutschi Cushman and Renz, 1941

Plate 254, figure 6

Sphaeroidinella rutschi Cushman and Renz, 1941, Cushman Lab. Foram. Res., Contr., v. 17, p. 25, pl. 4, figs. 5a-c.

A few forms assigned to this species were noted in the Miocene material from MP 43 DD. See also the remarks under *S. multiloba* LeRoy.

Sphaeroidinella seminulina (Schwager), 1866

Plate 254, figures 4, 5

Globigerina seminulina Schwager, 1866, Novara. Exped., Geol. Theil, v. 2, p. 256, pl. 7, fig. 112.

This form occurs commonly in the Miocene material from MP 43 DD. For further remarks see the note under *S. multiloba*.

Family GLOBOROTALIIDAE

Genus GLOBOROTALIA Cushman, 1927

Globorotalia aragonensis Nuttall, 1930

Plate 252, figures 14–16

Globorotalia aragonensis Nuttall, 1930, Jour. Paleontology, v. 4, p. 288, pl. 24, figs. 6–8, 10, 11.

This species is a worldwide index fossil for the early and middle Eocene; it has been reported from the Middle East, the gulf coast area, the Caribbean area, and the Mid-Pacific flat-topped seamounts. It is common in the Sylvania guyot fauna and occurs in the same indurated crack filling (pl. 251) as *G. velascoensis* (Cushman). The overlapping range of this species with that of *G. velascoensis* places the age of the fauna as at about the boundary between the Paleocene and the Eocene.

Globorotalia centralis Cushman and Bermudez, 1937

Globorotalia centralis Cushman and Bermudez, 1937, Cushman Lab. Foram. Res., Contr., v. 13, p. 26, pl. 2, figs. 62–65.

Three specimens of this form were found in the MP 43 A material.

Globorotalia crassata (Cushman)

Plate 252, figure 5

Pulvinulina crassata Cushman, 1925, Am. Assoc. Petroleum Geologists Bull., v. 9, p. 300, pl. 7, fig. 4.

Globorotalia crassata (Cushman). Cole, 1927, Am. Paleontology Bull., v. 14, no. 51, p. 34, pl. 1, figs. 7–8.

Cushman, 1939, Cushman Lab. Foram, Res., Contr., v. 15, p. 74, pl. 12, fig. 19.

In connection with the Mid-Pacific material, plesiotype material of the last named citation was obtained from the U. S. National Museum and compared to the Mid-Pacific material. The species, as so diagnosed, is common in the Paleocene and Eocene faunas of the Mid-Pacific Mountains and is common in the Sylvania guyot material. The original figure by Cushman is entirely inadequate to identify this species.

Globorotalia crassata densa (Cushman)

Plate 252, figures 8,9

Pulvinulina crassata densa (Cushman), 1925, Am., Assoc. Petroleum Geologists Bull., v. 9, p. 301, no fig.

Globorotalia crassata densa (Cushman), 1939, Cushman Lab. Foram. Res., Contr., v. 15, p. 74, pl. 12, fig. 20.

Plesiotype material from the last-named citation was obtained from the U. S. National Museum for comparison with the Mid-Pacific material. The variety is common in the Mid-Pacific guyot faunas and is common in the Sylvania guyot material from MP 43 A.

Globorotalia membranacea (Ehrenberg), 1854

Plate 252, figure 13

Planulina membranacea Ehrenberg, 1854, Mikrogeologie, pl. 25, 1A, fig. 41, pl. 26, fig. 43.

One specimen of this Paleocene species was found in the Sylvania guyot material from MP 43 A.

Globorotalia menardii (d'Orbigny) var. fijiensis Cushman, 1934

Plate 254, figure 13

Globorotalia menardii fijiensis Cushman, 1934, B. P. Bishop Mus. Bull. 119, p. 136, pl. 17, fig. 5.

This form, named from the Tertiary of Suva, is rare in the Miocene material from MP 43DD.

Globorotalia menardii (d'Orbigny) var. multicamerata Cushman and Jarvis, 1930

Plate 254, figure 12

Globorotalia menardii multicamerata Cushman and Jarvis, 1930, Jour. Paleontology, v. 4, p. 367, pl. 34, fig. 8.

This form, named from the Miocene of Jamaica, is rare in the Miocene material from MP 43DD. It was reported by Phleger, Parker, and Peirson (1953, p. 20) from the Miocene of deep-sea cores in the Atlantic. Its geographic range is now extended to the Pacific. As noted by Phleger, Parker, and Peirson, only one report has been made from the Recent. If this occurrence in deep water off Cuba is the result of transported material, then the form might be useful in dating the upper Tertiary.

Globorotalia tumida (Brady) cf. G. tumida var. flexuosa (Koch), 1923

Plate 254, figures 8–10

Pulvinulina flexuosa Koch, 1923, Eclogae Geol. Helv., Lausanne, Suisse, v. 18, p. 357, p. 351, tfs., 9a–b, 10a–b.

The form illustrated may be compared to the variety, but further study is needed to differentiate the *menardii*-

tumida complex. It is probable that close study of this group will yield species and varieties of stratigraphic importance, especially from the upper Miocene to the Recent where such markers are sorely needed.

Globorotalia velascoensis (Cushman), 1925

Plate 252, figures 18–20

Pulvinulina velascoensis Cushman, 1925, Cushman Lab. Foram. Res., Contr. v. 1, p. 19, pl. 3, figs. 5a–c.
Globorotalia velascoensis (Cushman), 1927, Jour. Paleontology, v. 1, pl. 27, figs. 7–9.

This species is the best worldwide index fossil for the lower Tertiary. It has been noted in material from the Middle East, the gulf coast area, Caribbean area, and the Mid-Pacific Mountains. Its geologic range is possibly uppermost Cretaceous, definitely Paleocene, and probably lower Eocene. The form noted in the Sylvania guyot material is very close to the type; it has the distinctive beaded and raised sutures on the dorsal side, as well as the open umbilicus.

Globorotalia whitei Weiss, 1955

Plate 253, figures 1, 2

Globigerina crassaformis Galloway and Wissler. White, 1928, Jour. Paleontology, v. 2, p. 193, pl. 27, fig. 14.
Globorotalia crassaformis (Galloway and Wissler). Nuttall, 1935, Jour. Paleontology, v. 9, p. 130, pl. 15, figs. 21, 29.
Globorotalia whitei Weiss, 1955, Jour. Paleontology, v. 29, p. 18, pl. 6, figs. 1–3.

This new species, as diagnosed by Weiss, is known from the Paleocene and lower Eocene of Peru, the Upper Cretaceous and Paleocene of Mexico, and the Eocene of Venezuela. This species is rare in the lowermost Eocene fauna from Sylvania guyot, but this new locality indicates a widespread distribution. Specimens from the Sylvania guyot fauna were sent to Weiss, who affirmed that they were identical with his type material.

Globorotalia wilcoxensis Cushman, 1932

Plate 252, figure 12

Globorotalia wilcoxensis Cushman and Ponton, 1932, Cushman Lab. Foram. Res., Contr. v. 8, p. 71, pl. 9, fig. 10.

This form is rare in the Sylvania material.

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INDEX

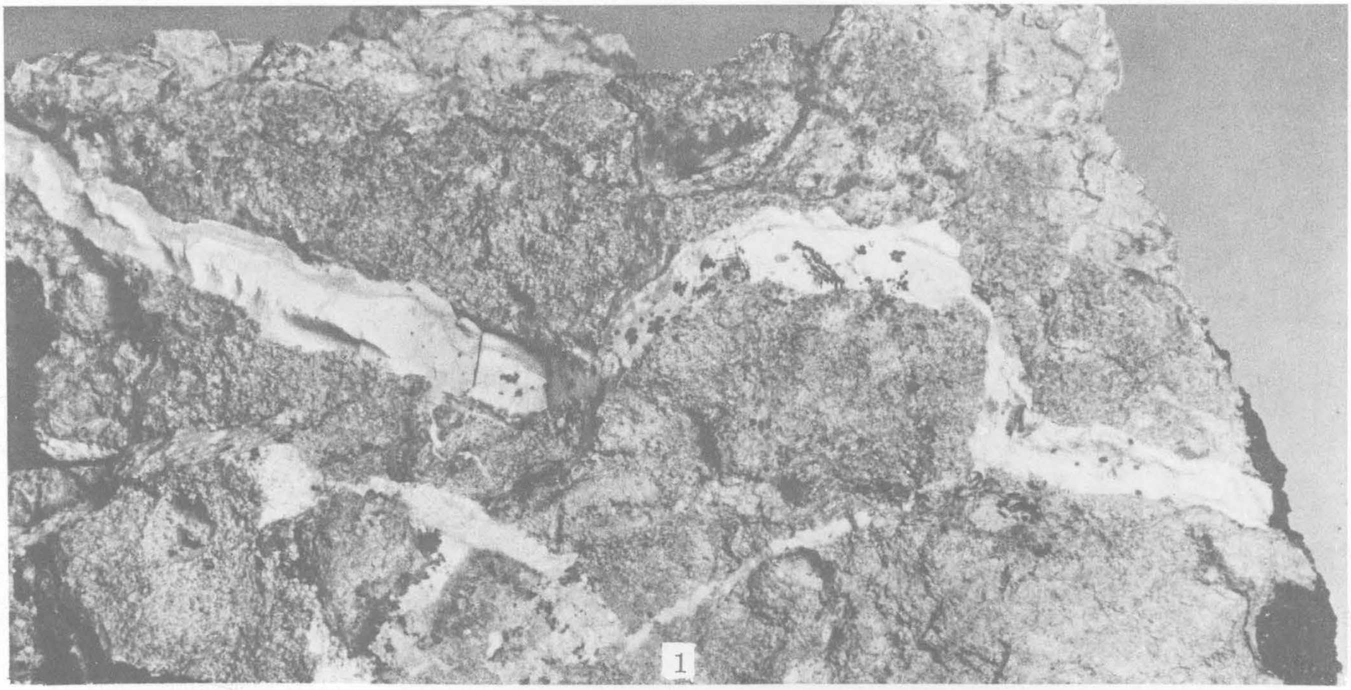
[Italic numbers indicate descriptions]

PLATES 250–254

PLATE 250

FIGURE 1. Volcanic tuff-breccia with cracks filled with white, partly phosphatized Eocene *Globigerina* ooze (MP 43 A). At the lower right, note the black crust of ferruginous oxide covering both the tuff-breccia and the crack filling. × 2.4.

2. Volcanic tuff-breccia with pockets and cracks filled, or partly filled, with partly phosphatized Eocene *Globigerina* ooze (MP 43 A). Note the pocket (lower right) containing indurated ooze and phillipsite crystals. × 3.0.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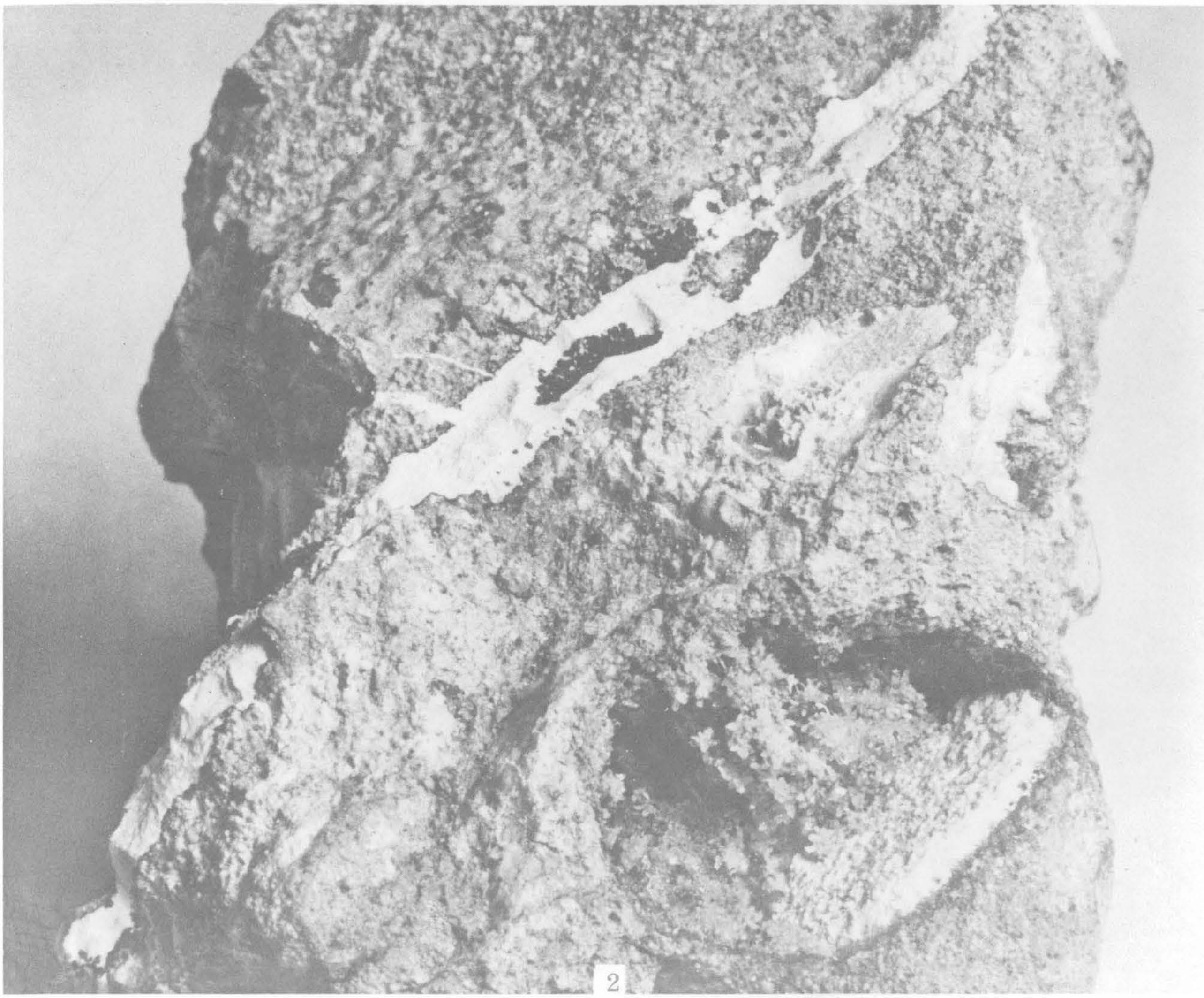

2

VOLCANIC TUFF-BRECCIA CONTAINING EOCENE *GLOBIGERINA* OOZE

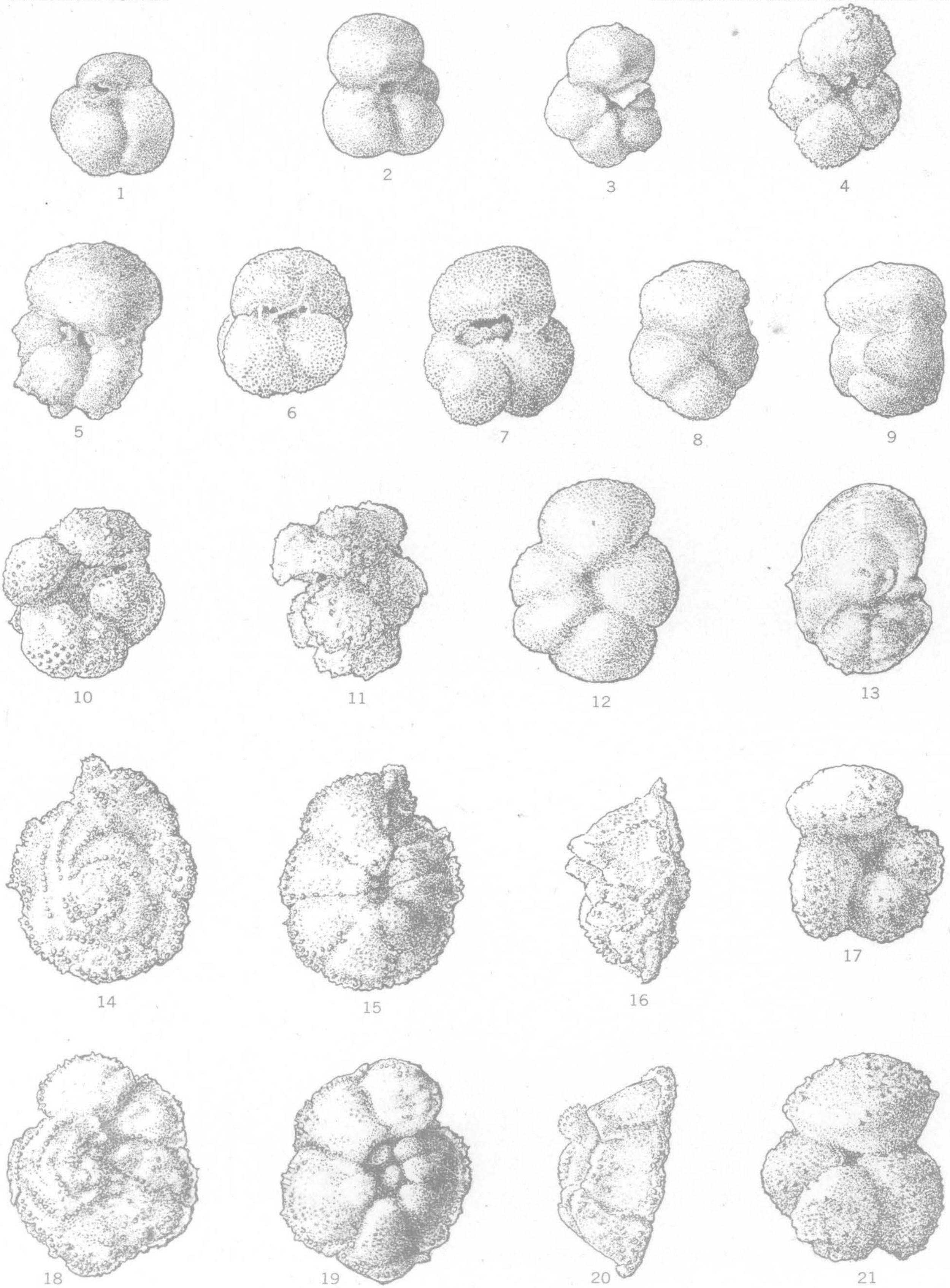
PHOTOMICROGRAPH OF EOCENE PLANKTONIC FORAMINIFERA

PLATE 251

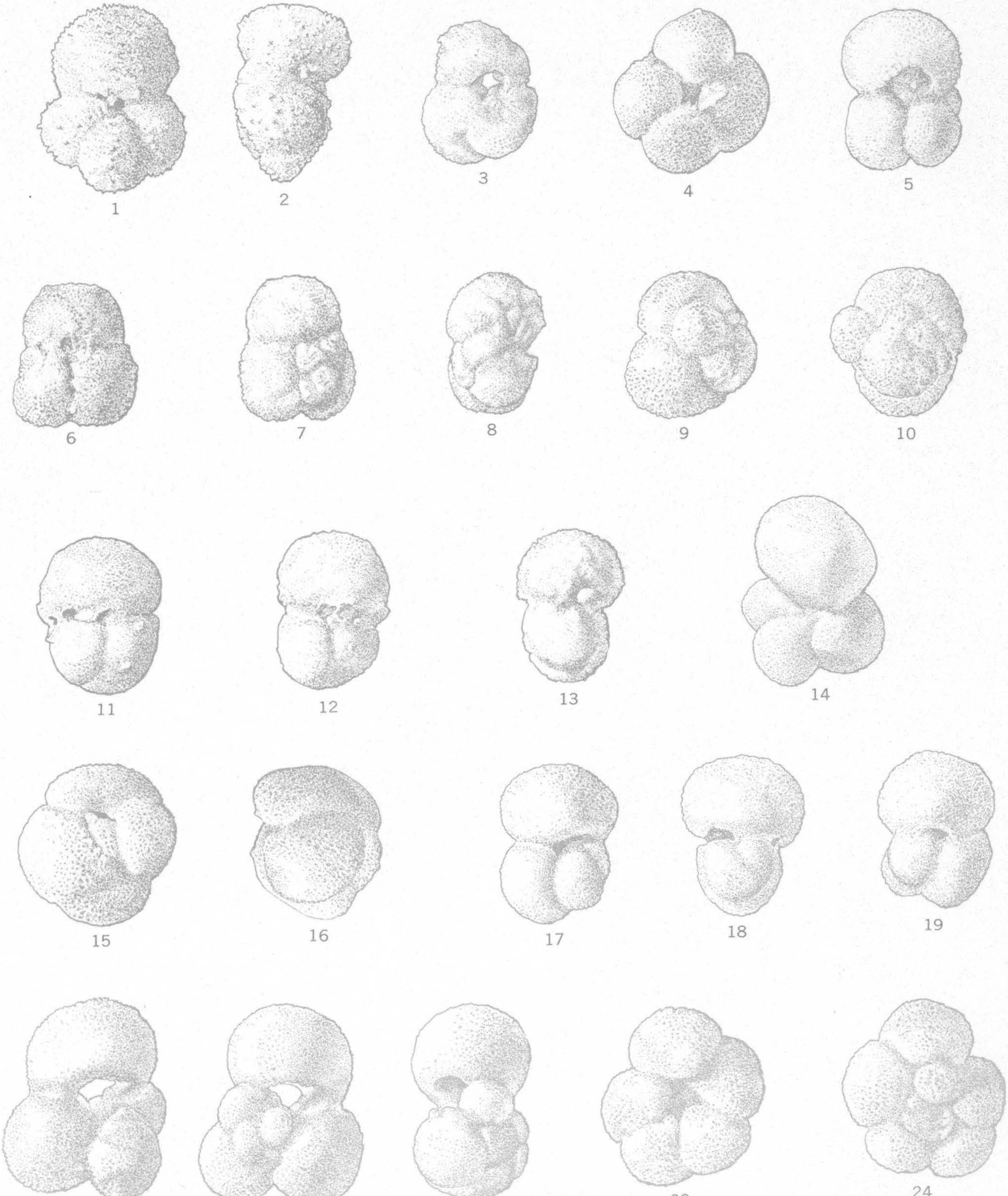
Photomicrograph of Eocene planktonic Foraminifera on the top surface of an indurated, partly phosphatized *Globigerina* ooze crack filling (MP 43 A). Black material near the center is ferruginous manganese oxide. Approximately × 60. Keeled *Globorotalia*, typical of lower Tertiary faunas, are indicated by arrows.

PLATE 252

FIGURE 1. *Globigerina rotundata* d'Orbigny var. *jacksonensis* Bandy. × 50 (p. 791).
2. *Globigerina triloculinoides* Plummer. × 66 (p. 792).
3. *Globigerina pseudobulloides* Plummer. × 82 (p. 791).
4. *Globigerina eocaena* Gümbel. × 85 (p. 791).
5. *Globorotalia crassata* (Cushman). × 74 (p. 793).
6. *Globigerina orbiformis* Cole. × 53 (p. 791).
7. *Globigerina apertura* Cushman. × 76 (p. 791).
8, 9. *Globorotalia crassata densa* (Cushman). × 64 (p. 793).
8, ventral view; 9, peripheral view.
10, 11. *Globigerina mckannai* White. × 58 (p. 791).
10, ventral view; 11, peripheral view.
12. *Globorotalia wilcoxensis* Cushman and Ponton. × 56 (p. 794).
13. *Globorotalia membranacea* (Ehrenberg). × 79 (p. 793).
14, 15, 16. *Globorotalia aragonensis* Nuttall. × 55 (p. 793).
14, dorsal view; 15, ventral view; 16, peripheral view.
17, 21. *Globigerina topilensis* Cushman. (p. 792).
17, × 21; 21, × 60.
18, 19, 20. *Globorotalia velascoensis* (Cushman). × 54 (p. 794).
18, dorsal view; 19, ventral view; 20, peripheral view.



LOWER EOCENE PLANKTONIC FAUNA



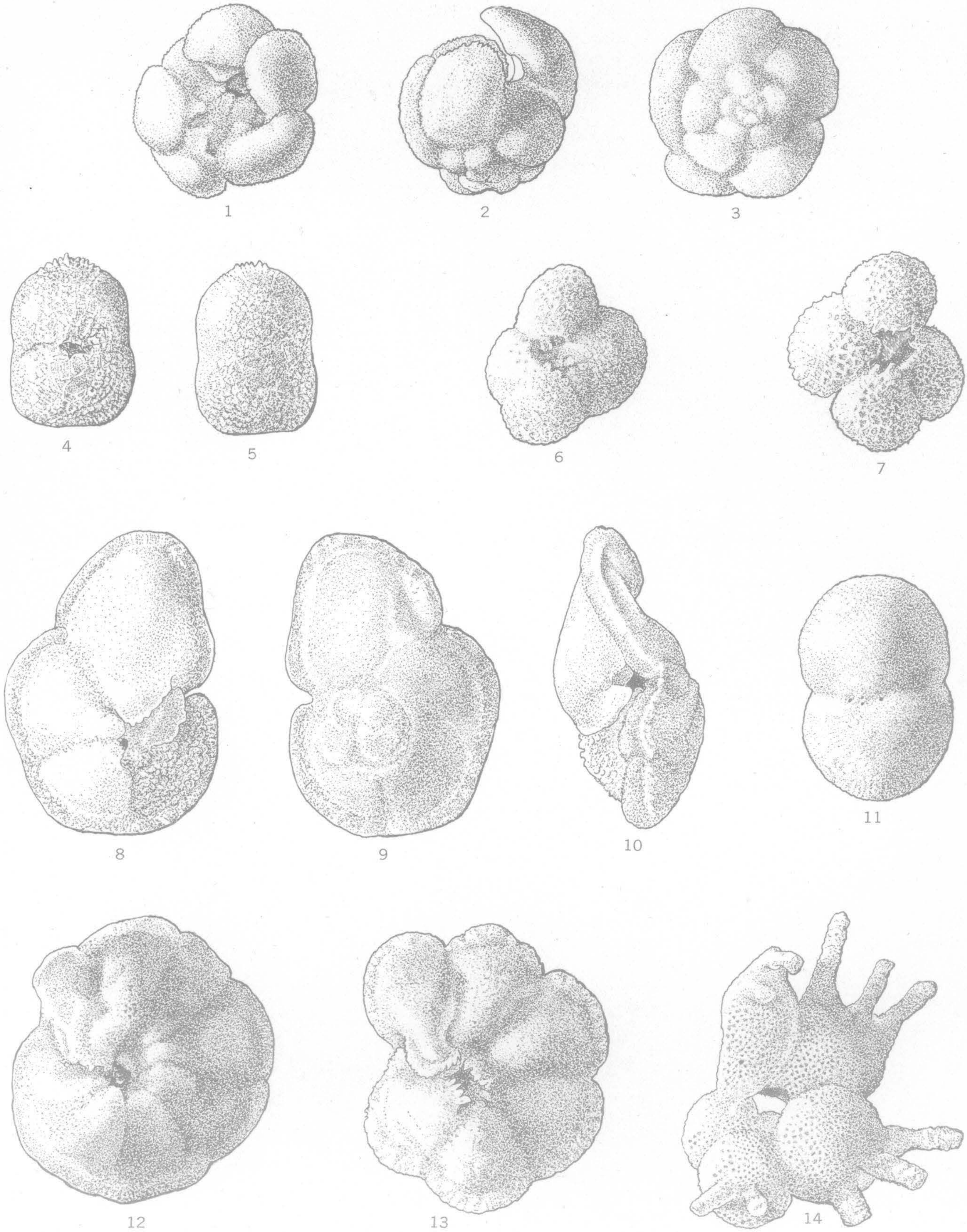
MIOCENE AND LOWER EOCENE PLANKTONIC FAUNA

PLATE 253

FIGURES 1, 2. *Globorotalia whitei* Weiss. × 66 (p. 794). From lower Eocene fauna of MP 43 A.
1, ventral view; 2, peripheral view.
3. *Globigerinoides sacculifera* (Brady). × 75 (p. 792).
4. *Globigerina ouchitaensis* Howe and Wallace var. *senilis* Bandy. × 58 (p. 791).
5. *Globigerinoides rubra* (d'Orbigny). × 63 (p. 792).
6, 7, 8. *Globigerinoides subquadrata* Bronnimann. × 57 (p. 792).
6, ventral view; 7, dorsal view; 8, peripheral view.
9, 10. *Globigerina dissimilis* Cushman and Bermudez. × 60 (p. 791).
9, ventral view; 10, peripheral view.
11, 12, 13. *Globigerinoides bispherica* Todd. × 64 (p. 792).
11, ventral view; 12, dorsal view; 13, peripheral view.
14. *Globigerina bulloides* d'Orbigny. × 77 (p. 791).
15, 16. *Globigerina venezuelana* Hedberg. × 73 (p. 792).
15, ventral view; 16, peripheral view of another specimen.
17, 18, 19. *Globigerinoides triloba* (Reuss). × 62 (p. 792).
17, ventral views; 18, peripheral view; 19, dorsal view.
20, 21, 22. *Globigerinoides sacculifera* (Brady). × 72 (p. 792).
20, ventral view; 21, dorsal view; 22, peripheral view.
23, 24. *Globigerina ciperoensis* Bolli. × 62 (p. 791).
23, ventral view; 24, dorsal view.

PLATE 254

FIGURES 1, 2, 3. *Globigerina altispira* Cushman and Jarvis. × 60 (p. 791).
1, ventral view; 2; peripheral view; 3, dorsal view.
4, 5. *Sphaeroidinella seminulina* (Schwager.) × 66 (p. 793).
4, ventral view; 5, dorsal view.
6. *Sphaeroidinella rutschi* Cushman and Renz. × 77 (p. 793).
7. *Sphaeroidinella multiloba* LeRoy. × 65 (p. 792).
8, 9, 10. *Globorotalia tumida* (Brady) cf. *G. tumida flexuosa* (Koch). × 66 (p. 793).
8, ventral view; 9, dorsal view; 10, peripheral view.
11. *Orbulina bilobata* (d'Orbigny). × 49 (p. 792).
12. *Globorotalia menardii* (d'Orbigny) var. *multicamerata* Cushman and Jarvis. × 61 (p. 793).
13. *Globorotalia menardii* (d'Orbigny) var. *fijiensis* Cushman. × 46 (p. 793).
14. *Globigerinoides sacculifera* (Brady) var. *fistulosa* (Schubert). × 68 (p. 792).



UPPER MIOCENE PLANKTONIC FAUNA