Neogloboquadrina dutertrei. The two phylogenetic hypotheses are shown in Figure 5*a,b.*

M. praeangulata is characterized by
(1) development of a pustulose wall surface;
(2) development of conical chambers;
(3) maintenance of 5 chambers in ultimate whorl.

M. praeangulata–M. apanthesma–M. aequa–M. subbotinae lineage is characterized by
(1) development of high to moderately high conical chambers in the transition to *Morozovella* from *Globanomalina*;
(2) increased rate of chamber expansion in *M. aequa* and *M. subbotinae.*

M. apanthesma–M. gracilis lineage is characterized by
(1) development of moderately high conical chambers in *M. gracilis*;
(2) a change to a higher rate of expansion of chambers in *M. gracilis.*

M. praeangulata–M. angulata–M. conicotruncata–M. velascoensis–M. pasionensis lineage is characterized by
(1) development of high conical chambers in *M. conicotruncata*;
(2) development of a strong muricate keel in *M. conicotruncata*;
(3) development of strongly muricate umbilical shoulders in *M. conicotruncata.*

M. pasionensis–M. occlusa lineage is characterized by
(1) development of low conical chambers in *M. occlusa*;
(2) development of a more tightly coiled test that narrows the umbilicus in *M. occlusa.*

M. pasionensis–M. acutispira lineage is characterized by
(1) development of low conical chambers in *M. acutispira*;
(2) increased rate of chamber expansion in *M. acutispira.*

Taxonomy

Family GLOBIGERINIDAE Carpenter, Parker, and Jones, 1862

(by R.K. Olsson, Ch. Hemleben, C. Liu, W.A. Berggren, and R.D. Norris)

ORIGINAL DESCRIPTION.—"Under the general designation *Globigerinida* we bring together, for the reasons already stated, all those hyaline or vitreous *Foraminifera* which have their shell-substance coarsely perforated for the exit of pseudopodia, so as to resemble that of *Globigerina*; a character by which they are differentiated from the *Lagenida* on the one hand, and from the *Nummulinida* on the other. They are further differentiated from the former of these families by the form and character of their aperture; for although there are instances in which the chambers communicate with each other, and the last chamber with the exterior, by circular pores, yet this is only in aberrant forms of the group; and the typical aperture is a crescent, which may either be contracted to a narrow fissure, or which may open-out so as to have the proportions of a gateway. There is not a like difference in the form of the aperture between *Globigerinida* and *Nummulinida*; but generally speaking, it is of much larger size, so as to permit a much freer communication between the segments of the body in the former group than in the latter." (Carpenter, Parker, and Jones, 1862:171.)

DIAGNOSTIC CHARACTERS.—Test lobulate, trochospiral or planispiral, usually with $3^1/_2$–6 globular chambers in final whorl; wall spinose, cancellate, or noncancellate; aperture interiomarginal, umbilical, a low to high arch, with or without a lip, may have supplementary apertures.

DISCUSSION.—A great variety of species and genera with diverse morphologies evolved from the simple trochospiral globigerine forms in the Paleocene. Only the genera *Eoglobigerina, Parasubbotina,* and *Subbotina* are represented in the Paleocene.

Genus *Eoglobigerina* Morozova, 1959

TYPE SPECIES.—*Globigerina (Eoglobigerina) eobulloides* Morozova, 1959, emended.

ORIGINAL DESCRIPTION.—"Test trochoid. Chambers subsphaerical. Wall thin, smooth. Aperture small, opening into the umbilicus or into the circumumbilical part of the marginal suture. From representatives of the subgenus Globigerina this one differs by its thin and smooth or not clearly microreticulate test wall and by the small size of the aperture. Family Globigerinidae. Senonian to Danian." (Morozova, 1959:1115; translated from Russian.)

DIAGNOSTIC CHARACTERS.—Low, trochospiral test with 10–16 chambers, 4–$6^1/_2$ globular chambers in ultimate whorl. Trochospire moderately to highly elevated; aperture interiomarginal, umbilical to slightly extraumbilical, a low, rounded arch bordered by a thin, narrow lip; umbilicus small and open to the apertures of surrounding chambers. Cancellate and spinose wall with spine holes situated along cancellate ridges.

DISCUSSION.—Hemleben et al. (1991) demonstrated that *Eoglobigerina* had a spinose morphology, which separates it from other cancellate forms in the Danian that are nonspinose. The concept of *Eoglobigerina* followed herein is similar to that of previous workers except that it is emended to include the spinose character.

Eoglobigerina edita (Subbotina, 1953)

FIGURE 7; PLATE 8: FIGURES 13–18; PLATE 9: FIGURES 1–6; PLATE 18: FIGURES 1–16

Globigerina edita Subbotina, 1953:62, pl. 2: fig. 1a–c [Zone of rotaliform *Globorotalia* (Danian Stage), Kuban River section, northern Caucasus].—

Fox and Olsson, 1969:1398, pl. 168: figs. 1–4 [lower Paleocene, Cannonball Fm., North Dakota].—Shutskaya, 1970b, pl. 18: fig. 14a–c [middle subzone of *Globigerina trivialis-Globoconusa conusa-Globorotalia compressa* Zone, Malyi Balkhan Ridge, western Turkmenia] [in part, not pl. 18: fig. 12a–c].

Globigerina edita Subbotina var. *polycamera* Khalilov, 1956:235, pl. 1: fig. 1a–c [Danian Stage, Akhchakuima, northeastern Azerbaizhan].—Shutskaya, 1970a:119, pl. 18: fig. 11a–c [middle subzone of *Globogerina trivialis-Globoconusa daubjergensis-Globorotalia compressa* Zone, Khazin-Don River section, northern Caucasus].

Globigerina (*Eoglobigerina*) *hemisphaerica* Morozova, 1961:11, pl. 1: fig. 4 [Zone Dn1 II, lower substage of Danian Stage, Tarkhankut Peninsula, Crimea].

Globigerina (*Eoglobigerina*) *pentagona* Morozova, 1961:13, pl. 1: fig. 3 [Zone Dn1 I, lower substage of Danian Stage, Tarkhankut Peninsula, Crimea].

Globigerina (*Eoglobigerina*) *tetragona* Morozova, 1961:13, pl. 1: fig. 2 [Zone Dn1 I, lower substage of Danian Stage, pre-Caspian Basin, Novouzensk].

Globigerina (*Eoglobigerina*) *theodosica* Morozova, 1961:11, pl. 1: fig. 6 [Zone Dn1 I, lower substage of Danian Stage, Tarkhankut Peninsula, Crimea].

Globorotalia (*Globorotalia*) *edita* (Subbotina).—Hillebrandt, 1962:130, pl. 11: figs. 14, 15 [Zone A, lower Paleocene, Reichenhall-Salzburg Basin, Austro-German border].

Eoglobigerina edita edita (Subbotina).—Blow, 1979:1210, pl. 61: figs. 2, 3, pl. 66: fig. 1 [Zone Pα, DSDP Hole 47.2/11/3: 148–150 cm], pl. 69: fig. 6 [Zone P1, DSDP Hole 47.2/11/3: 0–5 cm], pl. 72: figs. 6, 8 [Zone P1, DSDP Hole 47.2/11/3: fig. 6, 148–150 cm; fig. 8, top section; Shatsky Rise, northwestern Pacific Ocean], pl. 79: fig. 3 [Zone P2, DSDP Hole 20C/6/4: 72–74 cm; Brazil Basin, South Atlantic Ocean].

Eoglobigerina edita (Subbotina).—Hemleben, Mühlen, Olsson, and Berggren, 1991:126, pl. 7: fig. 4–6 [Zone Pα, Clayton Basal Sands, Millers Ferry, Alabama].—Berggren, 1992:562, pl. 1: figs. 5, 6 [Zone P1b, ODP Hole 747A/19H/CC; Kerguelen Plateau, southern Indian Ocean].—Olsson, Hemleben, Berggren, and Liu, 1992:197, pl. 2: figs. 1–5, 7 [figs. 1–4, Zone Pα, Clayton Basal Sands; figs. 5, 7, Zone P1a, Pine Barren Mbr., Clayton Fm., Alabama].

Eoglobigerina edita polycamera Khalilov.—Olsson, Hemleben, Berggren, and Liu, 1992:197, pl. 2: fig. 6 [Zone P1a, Pine Barren Mbr., Clayton Fm., Millers Ferry, Alabama].

ORIGINAL DESCRIPTION.—"Shell small, rounded, with tall spiral consisting of 2½–3 whorls. The last whorl is made up of 4½–5 spherical chambers, usually of almost equal size. Peripheral margin rounded, scalloped. The most characteristic feature of this species is the turret-like dorsal surface which is associated with the large size of the chambers in the earlier whorls.

"The ventral side is feebly convex compared with the dorsal. The umbilicus is small and shallow but distinct. The chambers of the early whorls are compactly arranged and closely packed together, those of the last whorl are arranged much more freely giving a scalloped appearance to the peripheral margin. Sutures deep, slightly curved. The orifice has the form of a small slit which extends along the marginal suture. Walls smooth, with small pores. Mean dimensions: diameter 0.25 mm, thickness 0.15 mm." (Subbotina, 1953:62; translated from Russian.)

DIAGNOSTIC CHARACTERS.—Species characterized by moderately high trochospiral test with 4½–5 (occasionally up to 7) globular chambers increasing gradually in size in ultimate whorl, and a strongly lobulate peripheral margin. Rounded umbilical to slightly extraumbilical aperture bordered by narrow lip. Umbilicus small but open to previous chambers. Cancellate wall weakly developed and spinose with numerous spine holes along cancellate ridges. Overall size of test generally < 250 μm.

DISCUSSION.—A considerable variation in the height of the initial coil and the position of the aperture from an umbilical toward an extraumbilical position occurs in this species. Blow (1979) discussed the high degree of variability among early eoglobigerinids and the apparent fact that few morphotypes exhibit a consistent expression of morphologic characters. Thus, he cautioned that strict morphologic limits cannot be as rigidly applied to early eoglobigerinids as to the later, more stable morphospecies of globigerinacean genera. Blow also distinguished as a subspecies of *edita* the morphospecies *praeedita,* which can be viewed as intermediate between *eobulloides* and *edita. Eoglobigerina edita* is an intermediate member of the *eobulloides-edita-spiralis* lineage, which terminated in Zone P2 (see also Pearson, 1993).

Examinations of the holotypes (Plate 8: Figures 13–18, Plate 9: Figures 1–6) of *Eoglobigerina hemisphaerica* Morozova, *E. theodosica* Morozova, *E. tetragona* Morozova, and *E. pentagona* Morozova suggest that these are junior synonyms of *edita* Subbotina. These Morozova species are all characterized by having a weakly cancellate test and an elevated initial whorl, which places them within the *edita* plexus. The difference between these morphotypes is the elevation of the spire (high in *hemisphaerica* and *pentagona,* lower in *theodosica* and *tetragona*) and the number of chambers in the ultimate whorl (5½ in *hemisphaerica,* 5 in *theodosica,* 4½ in *pentagona,* 4 in *tetragona*). The 5½-chambered, finely cancellate holotype of *hemisphaerica* has a distinctly elevated spiral side; Morozova (1961) drew attention to the "stepped nature" of the antepenultimate and penultimate whorls, which was said to serve to distinguish *hemisphaerica* from *edita.* We regard this as being within the range of variation of *E. edita.*

STABLE ISOTOPES.—No data.

STRATIGRAPHIC RANGE.—Zone Pα to Zone P1c; ? P2.

GLOBAL DISTRIBUTION.—Worldwide in high and low latitudes (Figure 7).

ORIGIN OF SPECIES.—This species evolved from *Eoglobigerina eobulloides* near the base of Zone Pα by an increase in the number of chambers in the last whorl and a slowing of the rate of growth of these chambers. In addition, there is a trend towards an elevated initial spire. An increase in the degree of spinosity is also evident in the evolution of *E. edita.*

REPOSITORY.—Holotype (No. 3975) deposited in the micropaleontological collections at VNIGRI, St. Petersburg, Russia. Examined by WAB.

Eoglobigerina eobulloides (Morozova, 1959)

FIGURE 8; PLATE 8: FIGURES 10–12; PLATE 19: FIGURES 1–15

Globigerina (*Eoglobigerina*) *eobulloides* Morozova, 1959:1115, text-fig. 1a–c [Zone I, zone of smooth-walled globigerinids (eoglobigerinids), lower Danian Stage (Uylinian Stage), Tarkhankut Peninsula, Crimea].

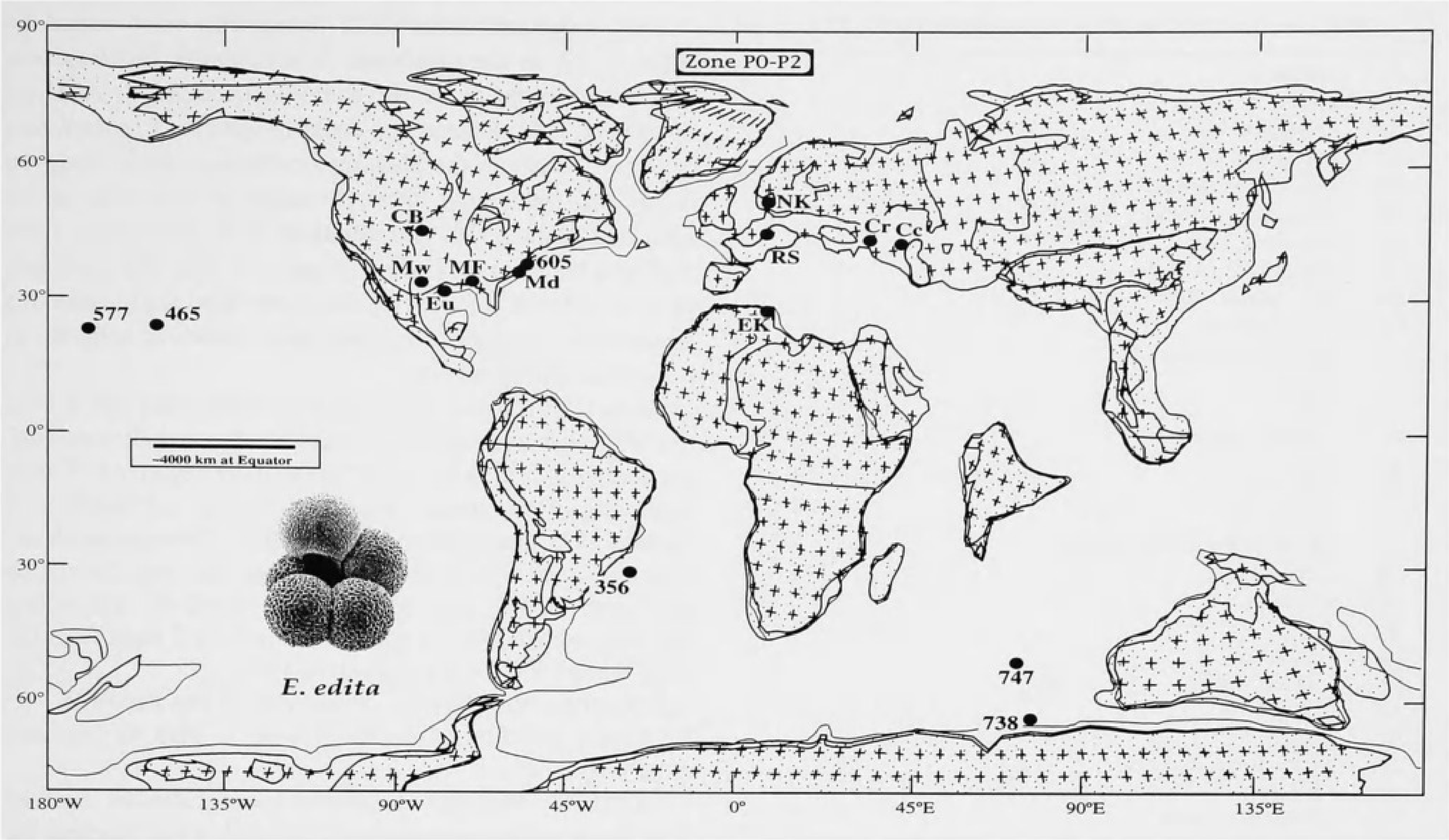


FIGURE 7.—Paleogeographic map showing distribution of *Eoglobigerina edita* (Subbotina) in Zone P1. Paleogeographic base map for this and following figures based on reconstruction by Barron (1987) for the Maastrichtian, with adjustments for the 60 mya continental distributions of Scotese and Denham (1988) and land-sea distributions in western Europe by Ziegler (1982). Abbreviations used in this and following figures given in Table 1.

Globigerina fringa Subbotina.—Premoli Silva and Bolli, 1973:541, pl. 7: figs. 6, 9 [Zone Pα, DSDP Site 152/10/1: 127–130 cm; eastern Caribbean Sea]. [Not Subbotina, 1953.]

Eoglobigerina eobulloides eobulloides (Morozova).—Blow, 1979:1214, pl. 60: fig. 9, pl. 61: fig. 1 [Zone Pα, DSDP Hole 47.2/11/4: 148–150 cm], pl. 65: figs. 8, 9, pl. 66: figs. 6, 9 [Zone Pα, DSDP Hole 47.2/11/3: 148–150 cm], pl. 70: figs. 3, 4 [Zone P1, DSDP Hole 47.2/11/3: 0–5 cm], pl. 73: fig. 6 [Zone P1, DSDP Hole 47.2/11/1: 148–150 cm; Shatsky Rise, northwestern Pacific Ocean].

Eoglobigerina fringa (Subbotina).—Smit, 1982:329, pl. 2: fig. 11a–c [base of Zone Pα, Gredero section, southeastern Spain].—Stott and Kennett, 1990:559, pl. 1: figs. 5, 6 [Zone APα, ODP Hole 690C/15X/4: 28–30 cm; Maud Rise, Weddell Sea, Southern Ocean]. [Not Subbotina, 1953.]

Eoglobigerina eobulloides (Morozova).—Huber, 1991c:461, pl. 2: figs. 9–11 [Zone AP1A, ODP Hole 738C/20R/5: 376.54 mbsf; Kerguelen Plateau, southern Indian Ocean].—Hemleben, Mühlen, Olsson, and Berggren, 1991:126, pl. 7: figs. 1–3 [Zone Pα, Clayton Basal Sands, Millers Ferry, Alabama].—Olsson, Hemleben, Berggren, and Liu, 1992:197, pl. 1: figs. 1–7 [Zone Pα, Clayton Basal Sands, Millers Ferry, Alabama].

ORIGINAL DESCRIPTION.—"Test with a flattish spiral; 4–4$^1/_2$ chambers per whorl. Diameter 0.225 mm., height 0.13 mm. Differentiated from *G.* (*Globigerina*) *bulloides* d'Orbigny and *G.* (*G.*) *pseudobulloides* Plummer by its small aperture and smooth or definitely micro-cellular test wall." (Morozova, 1959:1115; translated from Russian.)

DIAGNOSTIC CHARACTERS.—Spinose species with moderately elevated trochospire, globular chambers, an umbilical to slightly extraumbilical rounded aperture bordered by narrow, slightly flaring lip. Four to 4$^1/_2$ chambers in final whorl increase moderately in size. Umbilicus small but open to previous chambers. Cancellate wall texture very weakly developed and difficult to view with the light microscope, especially where wall preservation is poor. Pores average about 1 μm in diameter at narrowest point and occur at base of shallow pit surrounded by cancellate ridges. Wall ranges from 4-7 μm in thickness; overall size of test generally < 250 μm.

DISCUSSION.—Considerable uncertainty and confusion surrounds the identification of this species and *Globigerina fringa* Subbotina, 1953, due to the very small size and generalized drawing of the holotype of *G. fringa.* Examination of the holotype (WAB and FR) under a light microscope shows it to be similar to *E. eobulloides* in general morphology and, thus, a possible senior synonynm. Scanning electron micrographs (SEM) taken by FR (Plate 8: Figures 10–12, Plate 9: Figures 7–9) of the two holotypes, however, show that they are distinctly different species. *"Globigerina" fringa* has a coarsely cancellate wall similar to that of *Subbotina cancellata* Blow, 1979 (Plate 24: Figures 1–14). This type of cancellate

TABLE 1.—Abbreviations used in the paleobiogeographic maps.

AL	Alabama
Au	Austria
Az	Azerbaijan
BA	Bikini Atoll
BB	Bulgarian Black Sea
BG	Bongerooda Greensand, Australia
Bo	Bottacione, Italy
Br	Braggs River, Alabama
BR	Brazos River, Texas
CB	Cannonball Fm.
Cc	Northern Caucusus
Cr	Crimea
Cu	Cuba
Cv	Caravaca, Spain
Eg	Egypt
EK	El Kef, Tunisia
Eu	Eureka Core
FR	Flaxburne River, New Zealand
Gb	Gubbio, Italy
Gu	Guatemala
Ir	Iran
Ka	Kamchatka
Li	Lindi, Tanzania
Lo	Lodo Fm.
Md	Maryland
MF	Millers Ferry, Alabama
Mo	Morocco
Mw	Midway Fm., Texas
MW	Mid Waipara River, New Zealand
NE	Northeast Atlantic Ocean
Nf	Nanafalia Fm., Alabama
NF	Northwest Florida
Ng	Nûgssuaq, Greenland
Ni	Nigeria
NJ	New Jersey
NK	Nye Klov, Denmark
Nv	Navarro Fm., Texas
Pa	Papua New Guinea
PA	Paterno d'Adda, Italy
Pd	Pondicherry, India
Pk	Pakistan
PP	Pebble Point, Australia
RS	Reichehall-Salzburg
SB	Salzburg Basin
Se	Senegal
SF	South France
SI	Seymour Island, Antartica
SM	Salt Mountain Fm., Alabama
Tk	Turkey
Tr	Trinidad
Tu	Turkmenia
TU	Te Uri Stream, New Zealand
Va	Virginia
Vc	Veracruz, Mexico
Vo	Velasco Fm., Mexico
WC	Woodside Creek, New Zealand
Zu	Zumaya, Spain

wall texture is more advanced than that seen in Zone Pα globigerinids, which suggests that *fringa* was described from a higher Danian stratigraphic level. See "Discussion" under *Subbotina cancellata* for additional data on this species.

Four-chambered forms of *E. eobulloides* were named by Blow (1979) as the subspecies *E. eobulloides simplicissima*. This form seems to be the same as *Globigerina moskvini* Shutskaya, 1953, a name that could be used for *E. eobulloides* except that some of the Shutskaya collections were destroyed during the 1960s, and, thus, the usage of this name is not advisable. Blow's (1979) illustrations of *E. eobulloides* agree well with the holotype (Plate 8: Figures 10–12). The small size of *E. eobulloides* and its very thin pore-filled walls make this species very susceptible to dissolution, which is common in lowermost Danian sections.

STABLE ISOTOPES.—*Eoglobigerina eobulloides* has a $\delta^{13}C$ and $\delta^{18}O$ signature similar to *Parasubbotina* and *Globanomalina* but typically with heavier $\delta^{18}O$ and more negative $\delta^{13}C$ than coexisting *Praemurica* and *Woodringina* (D'Hondt and Zachos, 1993; Berggren and Norris, 1997). The species shows little change in $\delta^{18}O$ or $\delta^{13}C$ over a large size range (Berggren and Norris, 1997), although a positive size/$\delta^{13}C$ relationship has been reported for the species at small shell sizes from the early Danian (D'Hondt and Zachos, 1993).

STRATIGRAPHIC RANGE.—Upper Zone P0 to Zone P1b.

GLOBAL DISTRIBUTION.—Worldwide in high to low latitudes (Figure 8).

ORIGIN OF SPECIES.—*Eoglobigerina eobulloides* evolved from *Hedbergella monmouthensis* (Olsson) in late Biochron P0 by the development of a spinose cancellate wall texture (Liu and Olsson, 1994). It is the earliest spinose taxon of the Cenozoic, and, as such, it represents a completely new adaptive innovation (carnivory?) following the terminal Cretaceous event(s). Olsson et al. (1992) suggested that the spinose *E. eobulloides* lies at the base of an early Paleocene (Danian) radiation of normal perforate, cancellate spinose forms referable to *Eoglobigerina* and *Subbotina* (see also Pearson, 1993).

REPOSITORY.—Holotype No. 3508/1, Moscow, GAN. Examined by WAB and FR.

Eoglobigerina spiralis (Bolli, 1957)

FIGURE 9; PLATE 16: FIGURES 10–12; PLATE 20: FIGURES 1–11

Globigerina spiralis Bolli, 1957a:70, pl. 16: figs. 16–18 [*Globorotalia uncinata* Zone, lower Lizard Springs Fm., Trinidad].—Bolli and Cita, 1960:12, pl. 32: fig. 2a–c [*Globorotalia trinidadensis*-*Globigerina daubjergensis* Zone, Paderno d'Adda section, northern Italy].—Hillebrandt, 1962:130, pl. 11: figs. 14, 15 [Zone E, lower Paleocene, Reichenhall-Salzburg Basin, Austro-German border].

Eoglobigerina spiralis (Bolli).—Blow, 1979:1222, pl. 79: figs. 5–9 [Zone P2, DSDP Hole 20C/6/4: 72–74 cm; Brazil Basin, South Atlantic Ocean].

Igorina spiralis (Bolli).—Huber, 1991c:461, pl. 3: figs. 13–15 [Zone AP2, ODP Hole 738C/16R: 338.50 mbsf; southern Kerguelen Plateau, southern Indian Ocean].

ORIGINAL DESCRIPTION.—"Shape of test medium to high trochospiral, biconvex, spiral side distinctly convex, umbilical side less so; equatorial periphery lobate; axial periphery rounded. Wall calcareous, perforate, surface smooth. Chambers inflated, globular or slightly compressed laterally; about 15,

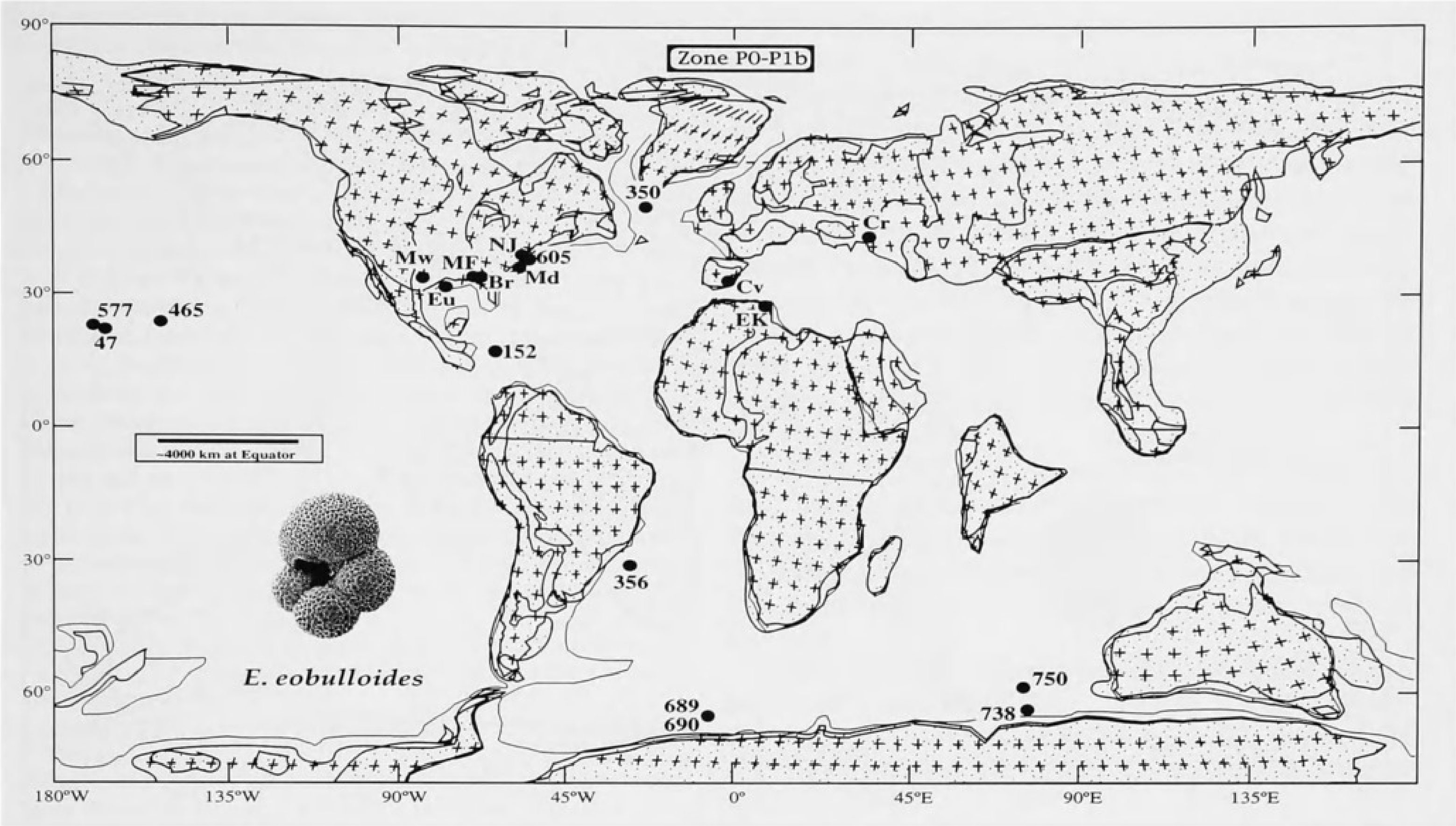


FIGURE 8.—Paleogeographic map showing distribution of *Eoglobigerina eobulloides* Morozova in Zone P1.

arranged in 3 whorls; the 5-6 chambers of the last whorl increase moderately in size. Sutures on spiral side radial or slightly curved, depressed; on umbilical side radial, depressed. Umbilicus narrow, open. Apertures distinct arches with faint lips, interiomarginal, umbilical; that of last chamber in some specimens tends to an extraumbilical-umbilical position. Coiling random. Largest diameter of holotype 0.28 mm." (Bolli, 1957a:70.)

DIAGNOSTIC CHARACTERS.—Spinose species with distinct elevated spire and 4½–5½ chambers in ultimate whorl. Chambers closely appressed with an umbilically directed aperture. Radially directed intercameral sutures on umbilical side appear as distinct valleys when surrounded by gametogenetic calcification. Aperture bordered by thin discontinuous lip. Wall texture more strongly developed than in ancestral species, *E. edita*. Umbilicus very small and often overlapped by ultimate chamber. Spine holes set along cancellate ridges appear not as numerous as in *E. edita*.

DISCUSSION.—Bolli (1957a) regarded *E. spiralis* as the immediate ancestor of *Igorina pusilla* (Bolli). Although Blow (1979) agreed with Bolli, he noted that the transition from *spiralis* to *pusilla* involved the loss of a porticus as well as the extraumbilical extension of the aperture. Blow placed great emphasis on the importance of the porticus as distinct from an apertural lip. The study of Olsson et al. (1992) on the wall texture of Danian globigerinids and globorotaliids, however, showed that the separation of these two kinds of apertural apparatuses is erroneous, as the apparent differences noted by Blow are due to ontogenetic and gametogenetic calcification. The fact that Blow (1979:1223) regarded the *spiralis–pusilla–albeari* lineage as "so remarkably taxonomically and stratigraphically isolated" indicates that he considered the morphological change involved in the origin of *pusilla* (i.e., *Igorina*) as quite distinct from the mainstream globigerinacean evolutionary history. His belief holds true to some degree in regards to the origin of the *Igorina* lineage (see "Discussion" under this genus). The ancestral relationship of *spiralis* to *pusilla* must be ruled out, however, because the former species has a spinose wall texture whereas the latter has a nonspinose, praemuricate wall texture. *Eoglobigerina spiralis* is the end member of the *eobulloides–edita–spiralis* lineage, which terminated in Zone P2 (see also Pearson, 1993).

Our work has revealed a spinose wall texture in *E. spiralis* and suggests that these spinose forms are unrelated to the nonspinose igorinids; however, we have recognized an apparently nonspinose wall texture in some specimens that we have initially attributed to *E. spiralis*. Indeed, the holotype of *E. spiralis* is too poorly preserved to verify the original presence or absence of spines. Consequentially, we are not completely sure of the generic designation of this species. Should the paratypes of *E. spiralis* prove to have a nonspinose wall texture, we would be forced to consider this taxon as a possible ancestor to

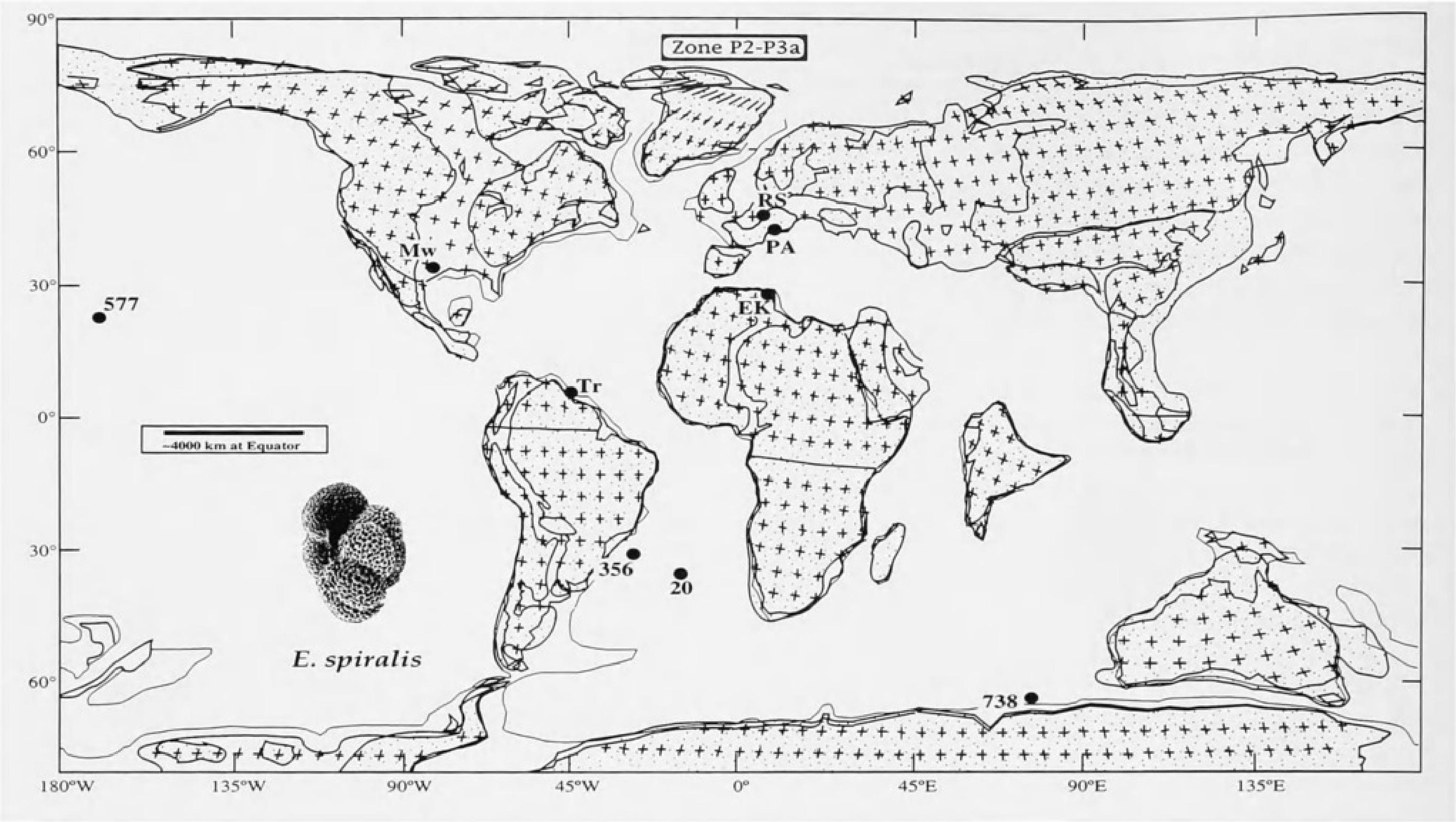


FIGURE 9.—Paleogeographic map showing distribution of *Eoglobigerina spiralis* (Bolli) in Zone P2.

I. pusilla as originally suggested by Bolli (1957a) and to regard the spinose homeomorphs as derivatives of *Eoglobigerina edita*.

STABLE ISOTOPES.—No data available.

STRATIGRAPHIC RANGE.—Zone P2; ? uppermost Zone P1c.

GLOBAL DISTRIBUTION.—Apparently worldwide in high to low latitudes (Figure 9).

ORIGIN OF SPECIES.—This species evolved from *E. edita* near the base of Zone P2 by the development of a tighter coil, a distinct elevated early coil of chambers, and a more strongly cancellate test wall.

REPOSITORY.—Holotype (USNM P5030) deposited in the Cushman Collection, National Museum of Natural History. Examined by WAB, BTH, and RKO.

Genus *Parasubbotina* Olsson, Hemleben, Berggren, and Liu, 1992

TYPE SPECIES.—*Globigerina pseudobulloides* Plummer, 1926.

ORIGINAL DESCRIPTION.—"Test very low trochospiral with 10–12 chambers, and with 4 to 5 chambers in the ultimate whorl. The chambers which are inflated globular and slightly ovoid in shape increase rapidly in size. The aperture is interiomarginal, umbilical to extraumbilical, a high rounded arch which is bordered by a narrow lip. The umbilicus is narrow, deep and open to the previous chambers. The wall is weakly to strongly cancellate and spinose. Spine holes are numerous and located at the juncture of and along the cancellate ridges. They may be obscured by gametogenetic and/or diagenetic calcification." (Olsson, Hemleben, Berggren, and Liu, 1992:197.)

DIAGNOSTIC CHARACTERS.—Genus distinguished by very low trochospiral test, chambers increasing rapidly in size in ultimate whorl, and high-arched umbilical-extraumbilical aperture. Number of chambers never exceeds 5 in ultimate whorl. Last two chambers may be offset toward umbilicus (*P. variospira*) giving test the appearance of a higher spire.

DISCUSSION.—In the lower Danian, low trochospiral, cancellate-walled, planktonic foraminiferal species are common and were thought to be phylogenetically linked together. Olsson et al. (1992) showed that two groups can be separated on the basis of a spinose or a nonspinose test morphology. In the earliest Danian, *Parasubbotina* and *Eoglobigerina* represent the spinose group and *Praemurica* represents the nonspinose group.

Parasubbotina pseudobulloides (Plummer, 1926)

FIGURE 10; PLATE 21: FIGURES 1–15

Globigerina pseudo-bulloides Plummer, 1926:133, pl. 8: fig. 9a–c [Zone P2, Wills Point Fm., Midway Group (upper Danian), Navarro Co., Texas].

Globigerina pseudobulloides Plummer.—Subbotina, 1950:106, pl. 4: figs. 8–10 [Danian Stage, northern Caucasus].—Troelsen, 1957:128, pl. 30: fig. 6a–c [*Tylocidaris oedumi* Zone, Hojerup, Stevns Klint], fig. 7a–c [basal Danian, Bogelund], fig. 8a–c [? *Tylocidaris oedumi* Zone, Hjerm] [all Danian Stage, Denmark].—Bolli and Cita, 1960:385, pl. 33: fig. 4a–c [*Globorotalia trinidadensis–Globorotalia pseudobulloides* Zone, Paderno d'Adda section, northern Italy].—Gohrbandt, 1963:44, pl. 1: figs. 7–9 [lower Paleocene, north of Salzburg, Austria].

Globorotalia pseudobulloides (Plummer).—Bolli, 1957a:73, pl. 17: figs. 19–21 [*Globorotalia pusilla pusilla* Zone, lower Lizard Springs Fm., Trinidad].—Loeblich and Tappan, 1957a:192, pl. 40: fig. 3a–c [*Tylocidaris oedumi* Zone, Danskekalk Fm., Stevns Klint, Denmark, type Danian Stage], pl. 41: fig. 1a–c [Zone P1, McBryde Fm., Maryland], pl. 42: fig. 3a–c [Zone P1, Brightseat Fm., Maryland], pl. 43: fig. 3a–c [Zone P1, Kincaid Fm., Midway Group, northeastern Texas], pl. 44: fig. 6a–c [Wills Point Fm., Midway Group, northeastern Texas], pl. 45: figs. 1a–2c [Zone P3, Matthews Landing Marl Mbr., Porters Creek Clay, Wilcox Co., Alabama], pl. 46: fig. 6a–c [Coal Bluff Marl Mbr., Naheola Fm., Wilcox Co., Alabama] [in part, not pl. 40: fig. 9a–c (= *Praemurica pseudoinconstans* (Blow)), pl. 43: fig. 4a–c (= indeterminate abortive individual), pl. 44: figs. 4, 5 (= indeterminate abortive individuals)].—Olsson, 1960:46, pl. 9: figs. 19–21 [Zone P1, Hornerstown Fm., New Jersey].

Globorotalia (*Globorotalia*) *pseudobulloides* (Plummer).—Hillebrandt, 1962:124, pl. 12: fig. 2a–c [lower Paleocene, Reichenhall-Salzburg Basin, Austro-German border].

Globorotalia (*Turborotalia*) *pseudobulloides* (Plummer).—Blow, 1979:1096, pl. 69: figs. 2, 3 [Zone P1, DSDP Hole 47.2/11/3: 0–5 cm], pl. 71: figs. 4, 5 [Zone P1, DSDP Hole 47.2/11/1: top section; Shatsky Rise, northwestern Pacific Ocean], pl. 75: figs. 2, 3 [Zone P1, Lindi area, Tanzania], pl. 248: figs. 6–8 [Zone P2, topotypes from Plummer locality 23, Navarro Co., Texas], pl. 255: figs. 1–6 [Zone P1c?, Karlstrup, Denmark; upper Danian].

Subbotina pseudobulloides (Plummer).—Berggren, 1992:563, pl. 1: figs. 7, 8 [Zone P1b, ODP Hole 747A/19H/CC; Kerguelen Plateau, southern Indian Ocean].

Parasubbotina pseudobulloides (Plummer).—Olsson, Hemleben, Berggren, and Liu, 1992:197, pl. 3: figs. 1–7 [figs. 1–5: Zone P1a, Pine Barren Mbr., Clayton Fm., Alabama; figs. 6, 7: Zone P2, upper Midway Fm., Texas].

ORIGINAL DESCRIPTION.—"Test rotaliform, very obtusely trochoid to plane dorsally, composed of about two and one-half convolutions, of which the last consists most generally of 5 (rarely 6) highly ventricose chambers increasing rapidly in size; periphery broadly rounded and lobate; shell wall thin and distinctly punctate but finely reticulate; superior face bearing a spire of small chambers only very slightly elevated, if at all, above the circumambient chambers of the final whorl; inferior face less convex and with a very distinct, though not large, umbilical depression; aperture a single, moderately large, lunate opening on the last chamber extending from the margin to the umbilicus and edged with a narrow, delicate, flaring lip. Diameter up to .4 mm." (Plummer, 1926:133.)

DIAGNOSTIC CHARACTERS.—Test very low trochospiral with 10–12 chambers, and with 5 chambers in ultimate whorl. Inflated, globular chambers slightly ovoid in shape and increase rapidly in size. Aperture interiomarginal, umbilical-extraumbilical, with high rounded arch bordered by narrow lip. Umbilicus narrow, deep, and open to previous chambers. Cancellate spinose wall weakly developed in early forms of species but become stronger in later forms. Spine holes numerous, located at the juncture of and along cancellate ridges, possibly obscured by gametogenetic and/or diagenetic calcification. Overall test size generally > 250 μm.

DISCUSSION.—The demonstration that *P. pseudobulloides* has a cancellate, spinose wall texture (Olsson et al., 1992) and that it is a member of a relatively minor offshoot of the early eoglobigerinid radiation, has given pause to long-held notions about early Paleocene planktonic foraminiferal phylogenies (see also Pearson, 1993). This is because it has been commonly accepted for nearly 40 years that *P. pseudobulloides* was the ancestor of the post-Danian muricate morozovellid radiation (Bolli, 1957a; Blow, 1979). *Parasubbotina pseudobulloides* is a member of a lineage that includes *P. varianta* and apparently *P. variospira*.

The identification of *P. pseudobulloides* must be made with care because of the general, superficial similarity with *Praemurica pseudoinconstans* (see also Blow, 1979). The fundamental difference in wall texture between *Parasubbotina* and *Praemurica* may not be evident in poorly preserved specimens.

STABLE ISOTOPES.—*Parasubbotina pseudobulloides* has a positive $\delta^{18}O$ and negative $\delta^{13}C$ similar to *Subbotina, Eoglobigerina,* and *Globanomalina*. Both $\delta^{18}O$ and $\delta^{13}C$ display little size-related variability (D'Hondt and Zachos, 1993; Berggren and Norris, 1997).

STRATIGRAPHIC RANGE.—Uppermost Zone Pα to Zone P3a; ? P3b.

GLOBAL DISTRIBUTION.—Worldwide in low to high latitudes (Figure 10).

ORIGIN OF SPECIES.—This species evolved from 4½–5-chambered, weakly cancellate, spinose morphotypes identified as *Parasubbotina* sp. aff. *pseudobulloides* (Olsson et al., 1992, pl. 4: figs. 1–4) that occur at the top of Zone P0 and in Zone Pα. They are not the same as the 5–6-chambered forms identified as *G.* (*T.*) aff. *pseudobulloides* by Blow (1979), which he regarded as having a phylogenetic relationship with *pseudoinconstans.*

REPOSITORY.—Cotypes: Walker Museum Collection 33076, Station 23. Examined by BTH and RKO.

***Parasubbotina* aff. *pseudobulloides* (Plummer, 1926)**

PLATE 22: FIGURES 1–5

Parasubbotina aff. *pseudobulloides* (Plummer).—Olsson, Hemleben, Berggren, and Liu, 1992:197, pl. 4: figs. 1–4 [upper Zone P0 and Zone Pα, Millers Ferry, Alabama].

DIAGNOSTIC CHARACTERS.—Small, very low trochospiral test with 4½–5 chambers in ultimate whorl, globular chambers increase rapidly in size, high arched umbilical-extraumbilical aperture with a thin lip, weakly developed cancellate wall, spinose. Maximum diameter < 225 μm.

DISCUSSION.—This small morphotype apparently has often been identified as *Globigerina fringa* Subbotina, 1953. This species, however, has a coarsely cancellate wall and morphol-

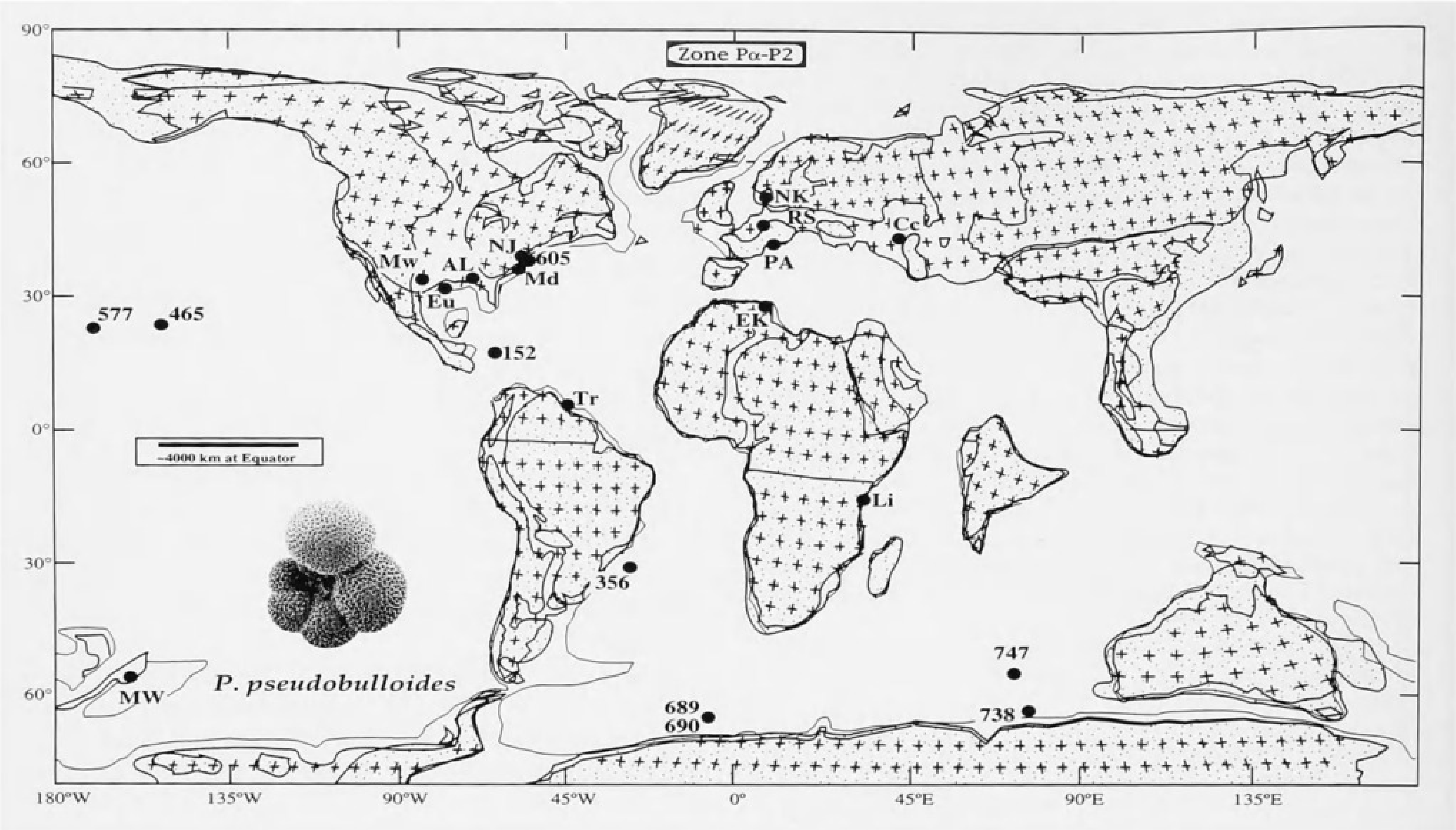


FIGURE 10.—Paleogeographic map showing distribution of *Parasubbotina pseudobulloides* (Plummer) in Zone P1.

ogic characters belonging to *Subbotina*. *Parasubbotina* aff. *pseudobulloides* is smaller than *P. pseudobulloides*, and it has a very weakly developed cancellate wall in contrast to the strongly developed cancellate wall of *pseudobulloides*. The spinose condition is already present. As the cancellate wall becomes more strongly developed, along with an increase in size, this morphotype grades into *P. pseudobulloides*. Because of this fact, it is often difficult to consistantly identify the first occurrence of *P. pseudobulloides* and hence the base of Zone P1a. A more useful criterion for the base of Zone P1a is the last occurrence of *Parvularugoglobigerina eugubina* (Luterbacher and Premoli Silva).

STABLE ISOTOPES.—There are no existing isotope data that are unambiguously attributed to this taxon. Data for *P. pseudobulloides* from the early Danian show that this taxon has $\delta^{18}O$ and $\delta^{13}C$ similar to *Eoglobigerina* and distinctly heavier $\delta^{18}O$ than *Woodringina* (D'Hondt and Zachos, 1993).

STRATIGRAPHIC RANGE.—Upper Zone P0 to Zone Pα.

GLOBAL DISTRIBUTION.—Probably widespread, but few reliable identifications have been made.

ORIGIN OF SPECIES.—*Parasubbotina* aff. *pseudobulloides* evolved from *Hedbergella monmouthensis* in Biochron P0 by achieving a more rapid increase in chamber size, by the development of a primitive cancellate wall texture, and by becoming spinose.

REPOSITORY.—Micropaleontology collections, University of Tübingen, träger 9120-27; 9121-10. Examined by ChH and RKO.

Parasubbotina varianta (Subbotina, 1953)

FIGURE 11; PLATE 9: FIGURES 16–18; PLATE 22: FIGURES 6–16

Globigerina varianta Subbotina, 1953:63, holotype: pl. 3: fig. 5a–c; paratypes: pl. 3: figs. 6a–7c, 10a–11c [zone of rotaliform *Globorotalia*, Elburgan Fm., Kuban River section, northern Caucasus], pl. 3: fig. 12a–c [zone of compressed *Globorotalia*, base of lower White Series, Murzai-Tai, Mangyshlak Peninsula, southwestern Russia], pl. 4: figs. 1a–3c [zone of rotaliform *Globorotalia*, base Foraminiferal Layer F1, Khieu River section, near Nal'chik, northern Caucasus] [in part, not pl. 3: figs. 7a–c, 8a–c, pl. 15: figs. 1a–c, 2a–c, 3a–c].

Globorotalia (*Globorotalia*) *varianta* (Subbotina).—Hillebrandt, 1962:125, pl. 12: figs. 10a–c, 11a,b [Zone D, Reichenhall-Salzburg Basin, Austro-German border].

Globorotalia (*Turborotalia*) *quadrilocula* Blow, 1979:1109, holotype: pl. 87: fig. 7 [Zone P3, DSDP Hole 47.2/10/1: 72–74 cm], paratypes: pl. 75: fig. 8 [Zone P1, Lindi, Tanzania], pl. 78: figs. 2–4 [Zone P2, DSDP Hole 20C/6/4: 72–74 cm; Brazil Basin, South Atlantic Ocean], pl. 83: fig. 3 [Zone P2, DSDP Hole 47.2/10/3: 78–80 cm; Shatsky Rise, northwestern Pacific Ocean], pl. 87: fig. 8 [Zone P1, Lindi, Tanzania].

Subbotina varianta (Subbotina).—Berggren, 1992:563, pl. 1: fig. 3 [ODP Hole 747A/19H/CC; southern Kerguelen Plateau, southern Indian Ocean].

ORIGINAL DESCRIPTION.—"Shell globigerinelliform plano-convex, oval outline, consisting of 2 whorls with 4 chambers to

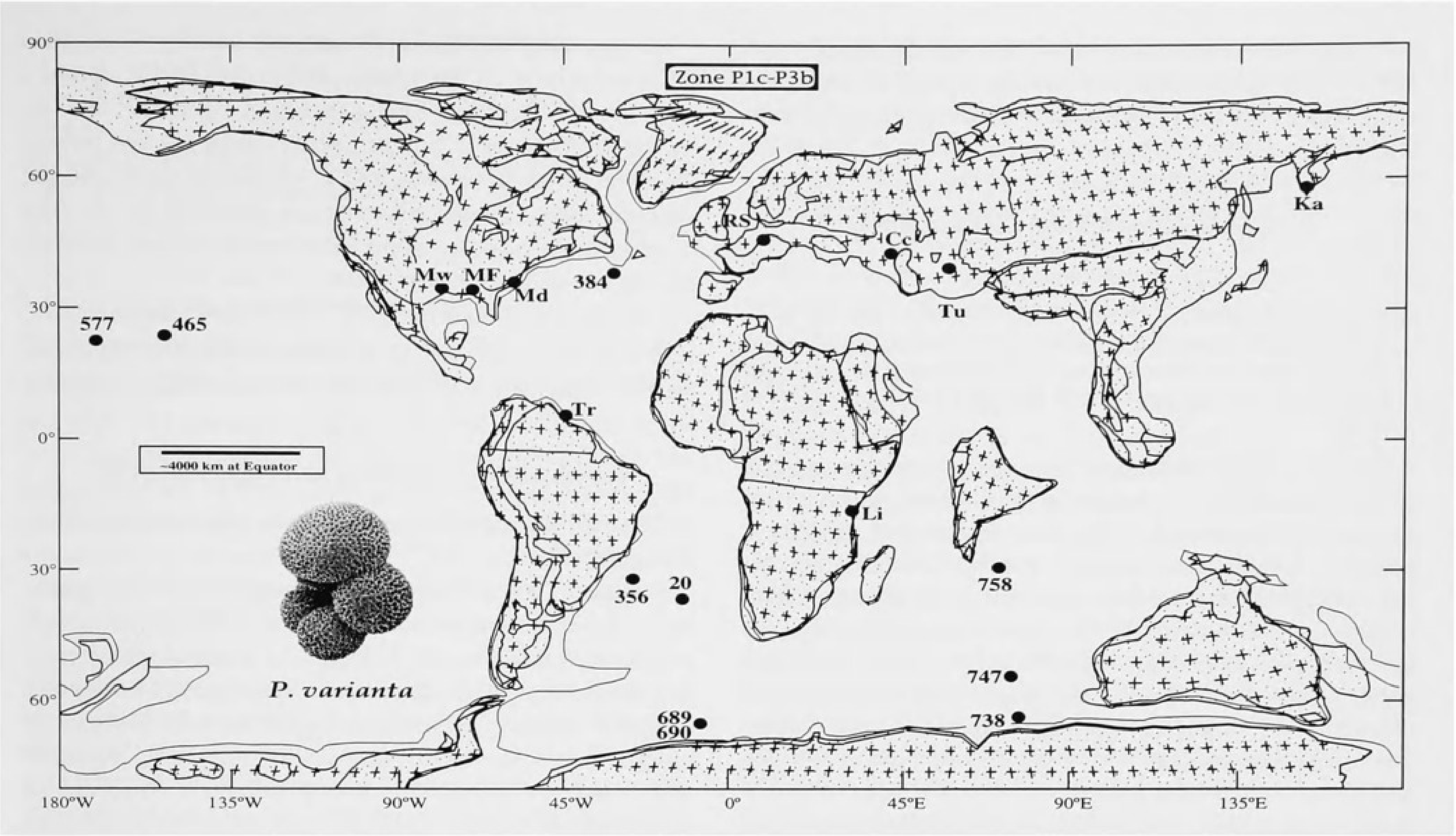


FIGURE 11.—Paleogeographic map showing distribution of *Parasubbotina varianta* (Subbotina) in Zones P1 and P2.

the last whorl, rapidly increasing in size and closely packed together. The chambers to the last whorl, as is usual in the genus, are strongly inflated.

"Dorsal side compressed, ventral convex. The chambers on the dorsal side are clearly defined and compressed whereas on the ventral side they are inflated and hemispherical. The last chamber is particularly large and is almost spherical. Sutures short, very slightly curved almost straight. On the dorsal side they are not deeply incised, on the central side they are strongly incised. Peripheral margin broadly rounded and coarsely scalloped. Umbilicus always distinct though small and having the form of a shallow depression in the middle of the ventral surface. Orifice slit-like, usually with small, indistinct lips forming a lamelliform border to the slit. Orifice along marginal suture. Dimensions: diameter 0.28–0.50 mm, thickness 0.12–0.24 mm." (Subbotina, 1953:63; translated from Russian.)

DIAGNOSTIC CHARACTERS.—Test a very low trochospiral, generally with four rapidly expanding chambers in ultimate whorl. Wall cancellate spinose with spine holes on interpore ridges. Umbilical-extraumbilical aperture a rounded high arch bordered by fairly broad continuous lip. Small, rounded umbilicus deep and open to surrounding chambers.

DISCUSSION.—The species is smaller and has fewer chambers in the ultimate whorl than does the closely related *Parasubbotina pseudobulloides.* Blow (1979) regarded *P. varianta* as an ecophenotypic variant of *P. pseudobulloides* comprising a rather specialized side branch of the *pseudobulloides* plexus. At the same time he erected the species *Globorotalia* (*Turborotalia*) *quadrilocula,* which he considered to have originated from a "four-chambered last-whorl variant" (Blow, 1979:1110) of *pseudobulloides.* The holotype of *P. varianta* (Plate 9: Figures 16–18) is a 4-chambered form with an ultimate chamber somewhat more inflated than Blow's concept of *quadrilocula.* We regard *G.* (*T.*) *quadrilocula* as falling within the morphologic range of variability of *P. varianta.*

STABLE ISOTOPES.—*Parasubbotina varianta* has a $\delta^{13}C$ and $\delta^{18}O$ signature similar to that of *P. pseudobulloides, Subbotina triloculinoides,* and *Globanomalina compressa* but typically with heavier $\delta^{18}O$ and more negative $\delta^{13}C$ than coexisting *Praemurica* and *Morozovella.* The species shows little change in $\delta^{18}O$ or $\delta^{13}C$ over a large size range.

STRATIGRAPHIC RANGE.—Zone P1c to Zone P5.

GLOBAL DISTRIBUTION.—Worldwide in high and low latitudes (Figure 11).

ORIGIN OF SPECIES.—Blow's (1979) observations on the close relationship of this species with *P. pseudobulloides* is supported by our observations. The species evolved in Zone P1c from *P. pseudobulloides* by a reduction in the number of chambers in the ultimate whorl and a tightening of the whorl.

REPOSITORY.—Holotype (No. 3994) and paratypes (Nos. 3995–4003, 4215), deposited in the micropaleontological collections, VNIGRI (378/20), St. Petersburg, Russia. Examined by FR.

Parasubbotina variospira (Belford, 1984)

PLATE 23: FIGURES 1–16

Globorotalia (*Turborotalia*) *variospira* Belford 1984:18, pl. 24: figs. 15–17, pl. 25: figs. 1–7 [WABAG Sheet area, Papua, New Guinea].
Morozovella variospira (Belford).—Van Eijden and Smit, 1992:113, text-fig. 26A–D, pl. 5: figs. 1–8 [Zone P3, ODP Hole 758A/30X/CC; eastern Indian Ocean].

ORIGINAL DESCRIPTION.—"Test large, trochoid, consisting of about 12 chambers arranged in three whorls, usually 5 but sometimes 4 chambers visible from ventral side. Equatorial periphery lobate, axial periphery rounded. Chambers increasing only slowly in size, four chambers in penultimate whorl, coiling in most specimens then becoming looser and more open, generally with five chambers in final whorl, umbilicus wide, open, shallow. Occasional specimens with final chamber directed towards umbilicus, coiling also becoming tighter, 4–4$^1/_2$ chambers visible from ventral side. Sutures on both dorsal and ventral sides narrow, deeply depressed, radial. Test wall perforate, with small pustules at umbilical margin of early chambers of last whorl, otherwise finely pitted. Aperture interiomarginal, umbilical-extraumbilical, low elongate, not clearly observed." (Belford, 1984:18.)

DIAGNOSTIC CHARACTERS.—Large (~0.4 to > 0.7 mm in diameter), low to (less frequent) moderately high, loosely coiled trochospiral test with strongly lobulate outline; any or all of last 3–4 chambers with inwardly projecting umbilical "teeth," aperture an interiomarginal, umbilical-extraumbilical arch; loose coiling between chambers in final whorl occasionally produce secondary spiral apertures with apertural lips, wall texture spinose and distinctly cancellate with large pore pits.

DISCUSSION.—Although described a decade ago, this species has been overlooked in studies of Paleocene planktonic foraminiferal faunas. This absence of attention is surprising because *P. variospira* is large and homeomorphic with the Neogene species *Neogloboquardina dutertrei* (d'Orbigny). Van Eijden and Smith (1992) drew attention to the distinct features of this large mid-Paleocene taxon and noted its globoquadrinid-like umbilical "teeth" that are unique among Paleocene species. *Parasubbotina variospira* overlaps for a short stratigraphic interval with *Globanomalina pseudomenardii* and early members of the acarininid radiation (*nitida, mckannai, subsphaerica*) within the lowermost part of Zone P4.

STABLE ISOTOPES.—*Parasubbotina variospira* has a $\delta^{13}C$ and $\delta^{18}O$ signature similar to *P. pseudobulloides, P. varianta, Subbotina triloculinoides,* and *Globanomalina compressa,* but it typically has a heavier $\delta^{18}O$ and more negative $\delta^{13}C$ than coexisting Morozovella.

STRATIGRAPHIC RANGE.—Zone P3a to Zone P4 (lower part).

GLOBAL DISTRIBUTION.—This species has been observed at (sub)tropical sites in the Atlantic, Indian, and Pacific oceans.

ORIGIN OF SPECIES.—This species evolved from *P. varianta* by the development of a more loosely coiled test and inflated chambers. Both *P. varianta* and *P. variospira* share enlarged apertural flaps. These structures are restricted to the final chamber of *P. varianta* but are found on the last 3–4 chambers in the final whorl of *P. variospira.*

REPOSITORY.—Holotype (CPC 21919) and paratypes (CPC 21920–21922) deposited in Commonwealth Paleontological Collection, Bureau of Mineral Resources, Canberra, Australia.

Genus *Subbotina* Brotzen and Pożaryska, 1961

TYPE SPECIES.—*Globigerina triloculinoides* Plummer, 1926, emended.

ORIGINAL DESCRIPTION.—"Le génotype est la *Globigerina triloculinoides* Plummer. La figure 3[4] (1961, op. cit., pl. 4) montre aussi la surface de l'holotype. Le diamètre des pores est de 1 à 2 microns et ils débouchent à la surface dans un double entonnoir entouré d'une couronne de rayons. Le diamètre de l'entonnoir varie entre huit à douze microns. Entre les différents entonnoirs et leurs courrones radiales, la surface est divisée en petites papilles, prismes, qui ont pent-être porté de fines épines calcaires. La même construction de surface est représentée chez Brady (1884, Rept. Challenger Expedition, Zool., pt. 22, vol. 9, pl. 77, fig. 1). On y voit une *Globigerina* représentée comme *Globigerina bulloides* d'Orbigny, mais elle doit, selon toute certitude, représenter un tout autre type. Là aussi, le mince canal du pore débouche dans un grand entonnoir et d'après le dessin, la couronne radiale elle-même porte les longues et fines épines calcaire. Toute l'image montre une espèce typique de *Globigerina* à surfaces reticulée qui, à notre point de vue, s'oppose à la *Globigerina* s. str. et doir être traité comme une *Subbotina.* Si l'on prend de telles étrudes de détails comme point de départ, l'observation du diamètre des pores et de leur répartition devient sans valeur si elles ne tiennent pas compte des détails de structure." (Brotzen and Pożaryska, 1961:160.)

DIAGNOSTIC CHARACTERS.—Low trochospiral, tripartite test with 10–12 chambers, with 3–4 rapidly inflating, globular chambers in ultimate whorl. Aperture interiomarginal, umbilical to slightly extraumbilical in some species, a low arch. Apertural lip varies from narrow to fairly broad and distinct apparatus extending over umbilicus. Umbilicus small and nearly closed by tight coiling. Wall cancellate and spinose; spines set at juncture of the cancellate ridges with or without spine collars. Cancellate texture varies from weak to very strong and from moderate to very coarse or distinctly honeycombed.

DISCUSSION.—Olsson et al. (1992) showed that *Subbotina* was spinose. The concept of the genus followed herein is similar to that of previous workers except that it is emended to include the spinose character.

Subbotina cancellata Blow, 1979

PLATE 9: FIGURES 7–9; PLATE 24: FIGURES 1–14;
PLATE 25: FIGURES 1–15

?*Globigerina fringa* Subbotina, 1953:62, pl. 3: fig. 3 [Danian, Pecten horizon, Azov-Black Sea flysch, Anapa, Caucasus].

Subbotina triangularis cancellata Blow, 1979:1284, holotype: pl. 80: fig. 7 [Zone P2, DSDP Hole 20C/6/4: 72–74 cm], paratypes: pl. 80: figs. 2–6, 8, 9 [Zone P2, DSDP Hole 20C/6/4: 72–74 cm; Brazil Basin, South Atlantic Ocean], pl. 238: fig. 6 [enlargement of pl. 80: fig. 4].

ORIGINAL DESCRIPTION.—"The test is coiled in a low trochospire with about 10–12 chambers comprising the spire and with four chambers visible in the last convulution of the test. The chambers of the last whorl are inflated and subglobular but are moderately appressed and embracing. The dorsal intercameral sutures are depressed but not incised and are radially or subradially disposed. The ventral intercameral sutures are also depressed, slightly incised and are disposed. The equatorial profile is lobulate and oval in outline whilst the axial profile is smoothly rounded. The umbilicus is small, but open and deep, and the umbilical depression is fairly sharply delimited by the umbilical shoulders of the last whorl of chambers. The aperture is virtually limited in lateral extent to the limits of the umbilical depression although it extends a little further towards the anterior side of the last chamber than it does towards the posterior side of this chamber. Thus, the aperture is a low arched opening slightly asymmetrically placed with respect to the centre of the umbilicus. The aperture is bordered by a strongly developed porticus which can be seen clearly cutting across the surface structures of the primary wall of the last chamber; from this, the porticus can be seen to be a structure additional to the primary wall of the last chamber and is not a simple, direct, reflexed continuation of the chamber wall. The porticus is not significantly thickened. The primary walls of the test bear large mural-pores which open into very large, sharply defined pore-pits with massively developed inter-pore ridges. Maximum diameter of holotype 0.29 mm." (Blow, 1979:1285.)

DIAGNOSTIC CHARACTERS.—Tightly coiled test with $3^1/_2$–4 chambers in ultimate whorl; an umbilically directed aperture bordered by broad, somewhat irregular lip; and coarse cancellate wall on all chambers of the test. Test compact, rounded in outline, and slightly lobulate.

DISCUSSION.—Blow (1979) recognized the significance of the coarsely cancellate wall as a primary taxonomic character. The coarsely cancellate wall is a diagnostic feature of the *cancellata–velascoensis* lineage. Blow's figures only showed umbilical views of his new taxon. Spiral views (Plate 24) show a rounded, somewhat lobulate outline, with the ultimate chamber varying in size from slightly smaller to distinctly larger than the penultimate chamber, and the coarse cancellate wall of the earlier chambers. The axial periphery is broadly rounded.

In his discussion of this species, Blow (1979) emphasized the apertural lip, which he identified as a porticus. He believed that the porticus was a feature that was added as a later ontogenetic structure to the test. He based his belief on his study of the structure, which in a SEM (1979, pl. 238: fig. 6) he interpreted as an infilling of pore-pits. At that time little was known about the ontogeny and gametogenesis of planktonic foraminifera. It is quite clear now that the lip forms as an extension of the primary chamber wall and that the cancellate texture develops throughout ontogeny and is enhanced during gametogenesis. The cancellate texture does not develop on the apertural lip, which, apparently, led Blow to interpret it as a separate, late-stage structure.

Blow named *cancellata* as a subspecies of *Subbotina triangularis* (White); however, *triangularis* has a distinctly different wall texture (Plate 2: Figures 15, 16, Plate 26) than *cancellata*. The recognition of a coarsely cancellate *Subbotina* lineage separates *cancellata* from *triangularis* and elevates it to species level.

Considerable confusion exists on the correct identification of *Globigerina fringa* Subbotina, 1950. The species is mostly identified in the lower Danian in Cretaceous/Paleogene boundary sections and is regarded as one of the earliest Danian species. The small size of the original figures of the holotype and its morphologic similarity to *Eoglobigerina eobulloides* Morozova, 1959, suggested that these species are synonymous (see Toumarkine and Luterbacher, 1985). SEMs taken by FR of the holotypes of the two species, however, shows this not to be the case (Plate 8: Figures 10–12, Plate 9: Figures 7–9). The distinguishing characteristic of *G. fringa* is a coarsely cancellate wall texture, which is similar to that in *Subbotina cancellata* Blow (1979). Furthermore, the coarsely cancellate wall texture observed in *G. fringa* is an advanced development in the evolution of wall texture in the Danian and is not present in Zone Pα stratigraphic levels. In fact, *G. fringa* was described from the "Pecten Horizon," which is apparently an upper Danian horizon in the Elburgan Formation in the northwest Caucasus.

Coarsely cancellate *Subbotina cancellata* morphotypes (Plate 25: Figures 1–15) occur in Zone P1c at DSDP Site 356 in the Southern Atlantic Ocean. They appear to be quite similar to the SEM of the holotype of *Globigerina fringa* Subbotina, 1953, shown on Plate 9: Figures 7–9. These morphotypes are smaller than typical *S. cancellata* and have 4–$4^1/_2$ chambers in the ultimate whorl. Although Subbotina described this species as having 4 chambers in the ultimate whorl, she chose a $4^1/_2$-chambered specimen as the holotype. Most of the specimens in a suite of adults from DSDP Site 356 are 4-chambered (Plate 25). Small immature specimens often have $4^1/_2$ chambers in the ultimate whorl, and these specimens have an umbilical to a slightly extraumbilical aperture (Plate 25: Figures 4, 10). In the adult specimens, the inner whorl is composed of $4^1/_2$ chambers. This ontogenetic progression proceeds from an *Eoglobigerina* morphotype to a *Subbotina* morphotype and suggests that *S. cancellata* may have evolved from *E. eobulloides*; however, the strong cancellate wall texture is a distinctive characteristic of *Subbotina*. In general test morphology the *cancellata* morphotypes at DSDP Site 356 are similar to *Subbotina trivialis* Subbotina, 1953, suggesting that *cancellata* evolved from this species by enhancement of the cancellate wall.

The development of a coarsely cancellate wall begins a lineage that extends through *S. cancellata* to *Subbotina velascoensis* (Cushman, 1925). Although it is tempting to apply the name *fringa* to the DSDP Site 356 *cancellata* morphotypes, we recommend that this not be done pending further study on the morphologic characteristics of this taxon and on the stratigraphy and phylogeny of the coarsely cancellate *Subbotina*s in Zone P1.

Thus, it is clear that identification of *fringa* and its taxonomy should be considered carefully when using literature data in interpretative studies. For example, Brinkhuis and Zachariasse (1988) included *fringa* (together with *edita*) in the monophyletic genus *Parvularugoglobigerina* Hofker, 1978, emended, which is characterized by having a microperforate, nonspinose wall texture. Similarly, specimens identified by Keller (1988) as *fringa* (and indeed, other forms as cf. *edita, hemisphaerica,* and *taurica*) from the basal Paleocene of El Kef (Tunisia) are microperforate, nonspinose forms referable to *Parvularugoglobigerina.*

STABLE ISOTOPES.—No data available.

STRATIGRAPHIC RANGE.—Zone P1c to Zone P4, currently known range.

GLOBAL DISTRIBUTION.—The full geographic extent of this species at this time is unknown. The species has been identified from North Atlantic (Site 549) and South Atlantic (Sites 20C, 356) DSDP drill sites.

ORIGIN OF SPECIES.—*Subbotina cancellata* is believed to have evolved from *S. trivialis* in the middle part of Zone P1, possible P1b. It is the first species of the coarsely cancellate *Subbotina* lineage. A reduction in the number of chambers in the ultimate whorl to $3^{1}/_{2}$ and an increase in test size characterizes Zones P2 to P4 morphotypes.

REPOSITORY.—Holotype (BP Cat. No. 41/31) and paratypes (BP Cat. Nos. 41/9, 41/13–41/15, 41/18, 41/20, 41/22) deposited in The Natural History Museum, London.

Subbotina triangularis (White, 1928)

PLATE 26: FIGURES 1–13

Globigerina triangularis White, 1928:195, pl. 28: fig. 1a–c [Paleocene, Velasco Fm., Mexico].—Bolli, 1957a:71, pl. 15: figs. 12–14 [*Globorotalia pseudomenardii* Zone, lower Lizard Springs Fm., Trinidad].—Shutskaya, 1970a:104, pl. 3: fig. 5a–c [lower part *Acarinina tadjikistanensis djanensis* Zone, Khieu River section, Nal'ckik, northern Caucasus]; 1970b:118, pl. 20: fig. 7a–c [*Globorotalia angulata* Zone, Chaaldzhin Group, Malyi Balkhan Ridge, western Turkmenia], p. 220, pl. 23: fig. 1a–c [lower part of *Acarinina tadjikistanensis djanensis* Zone, Khieu River section, Nal'ckik, northern Caucasus], p. 224, pl. 25: fig. 1a–c [upper part of *Acarinina tadjikistanensis djanensis* Zone, Khieu River section, Nal'chik, northern Caucasus] [in part, not pl. 17: fig. 14a–c (= *Subbotina triloculinoides*)].

Globigerina inaequispira Subbotina.—Loeblich and Tappan, 1957a:181, pl. 52: figs. 1a–2c [Zone P4, Vincentown Fm., New Jersey] [in part, not pl. 49: fig. 2a–c, pl. 56: fig. 7a–c, pl. 61: fig. 3a–c (= *Acarinina coalingensis*), pl. 62: fig. 2a–c].

Globigerina triloculinoides Plummer.—Loeblich and Tappan, 1957a:183, pl. 62: fig. 3a–c [Zone P4, Velasco Fm., Mexico] [in part, not pl. 62: fig. 4a–c and other illustrations of *Subbotina triloculinoides*]. [Not Plummer, 1926.]

Globigerina gerpegensis Shutskaya, 1970a:104, pl. 3: fig. 3a–c [holotype; upper part of *Acarinina tadjikistanensis djanensis* Zone, Kachan Stage, lower Danatin Subgroup, Malyi Balkhan Ridge, western Turkmenia].

Globigerina pseudotriloba Shutskaya, 1970a:85, pl. 2: fig. 7a–c [*Acarinina conicotruncana* Zone, Urukh River section, N. Ossetiya, northern Caucasus]. [Not White, 1928.]

Globigerina uruchaensis Shutskaya, 1970a:87, pl. 2: fig. 6a–c [holotype; *Acarinina conicotruncana* Zone, Urukh River section, N. Ossetiya, northern Caucasus].

Subbotina patagonica/triangularis group Tjalsma, 1977:510, pl. 4: fig. 2 [Zone P5, DSDP Site 329/32/4: 67–68 cm], figs. 3–6 [Zone P6, DSDP Site 329/32/4: 139–141 cm; flank of Falkland Plateau, southwestern Atlantic Ocean].

Subbotina triangularis triangularis (White).—Blow, 1979:1281, pl. 91: figs. 7, 9 [Zone P4, DSDP Hole 21A/3/6: 74–76 cm; South Atlantic Ocean], pl. 98: fig. 6 [Zone P4, given as P5, Lindi area, Tanzania], pl. 107: figs. 8, 9 [Zone P4, given as P6, DSDP Hole 20C/6/3: 76–78 cm; Brazil Basin, South Atlantic Ocean].

ORIGINAL DESCRIPTION.—"Test triangular, composed of about two coils arranged in a low trochoid spire; chambers inflated, somewhat appressed, three sub-equal chambers comprising the last whorl; sutures deep; aperture must be in the small umbilicus.

"Diameter of type specimen, 0.4 mm.; thickness, 0.2 mm." (White, 1928:195.)

DIAGNOSTIC CHARACTERS.—Test a somewhat loose coil of $3^{1}/_{2}$ chambers in ultimate whorl, with narrow, deep umbilicus sometimes obscured by an overlapping ultimate chamber. Shape of test triangular in umbilical view, ultimate chamber often smaller than penultimate one, low oval in shape. Axial periphery broadly rounded. Aperture umbilical to slightly extraumbilical, bordered by thin, sometimes irregular lip. Wall cancellate, spinose with an asymmetrically developed pore pattern and well-developed coalescing spine collars.

DISCUSSION.—Shutskaya's (1970a, 1970b) references to *pseudotriloba, triangularis, uruchaensis,* and *gerpegensis* are all considered synonymous with *Subbotina triangularis.* The criteria she provided to distinguish between these forms and her text-illustrations are insufficient for consistent discrimination. Moreover, she (1970a:104) included Bolli's illustration of *G. triangularis* (1957a, pl. 15: figs. 12–14) in the synonym of her new taxon, *G. gerpegensis.*

The distinctive spinose wall texture of *Subbotina triangularis* sets it apart from the *trivialis–triloculinoides* lineage and the *cancellata–velascoensis* lineage. *Subbotina triangularis* may be a stem form for a separate lineage that links with Eocene species, but this possibility has not been investigated. It may be linked with *Globigerina praebulloides,* which has a similar wall texture (compare Plate 2: Figures 14–16).

STABLE ISOTOPES.—*Subbotina triangularis* displays a more positive $\delta^{18}O$ and more negative $\delta^{13}C$ than coexisting *Morozovella* and *Acarinina* (D'Hondt et al., 1994). The species shows little change in $\delta^{18}O$ or $\delta^{13}C$ over a large size range (D'Hondt et al., 1994).

STRATIGRAPHIC RANGE.—Zone P2 to Zone P5, ? P6.

GLOBAL DISTRIBUTION.—Apparently this species has a global distribution in the low to middle latitudes.

ORIGIN OF SPECIES.—This species probably evolved from *S. triloculinoides* in Zone P3 by developing a more evolute coil, by increasing its test size, and by achieving a more asymmetical pore pattern with well-developed coalescing spine collars.

REPOSITORY.—Columbia University Paleontology Collection (No. 19881, locality No. 11); collection now at the American Museum of Natural History, New York.

Subbotina triloculinoides (Plummer, 1926)

FIGURE 12; PLATE 9: FIGURES 13–15; PLATE 14: FIGURES 15, 16; PLATE 27: FIGURES 1–13

Globigerina triloculinoides Plummer, 1926:134, pl. 8: fig. 10a–b [Zone P2, Wills Point Fm., Midway Group, Navarro Co., Texas, Station 23].—Bolli, 1957a:70, pl. 15: figs. 18–20 [*Globorotalia pusilla pusilla* Zone, Lizard Springs Fm., Trinidad] [in part, not pl. 17: figs. 25, 26].—Loeblich and Tappan, 1957a:183, pl. 40: fig. 4a–c [*Tylocidaris oedumi* Zone, Danian Stage, western Denmark], pl. 41: fig. 2a–c [Zone P1c, McBryde Limestone of Clayton Fm., Wilcox Co., Alabama], pl. 42: fig. 2a–c [Zone P1c, Brightseat Fm., Maryland], pl. 43: fig. 5a–c [Zone P1, Kincaid Fm., Travis Co., Texas], pl. 43: figs. 8a,b, 9a–c [Zone P2, Wills Point Fm., Midway Group, Navarro Co., Texas], pl. 45: fig. 3a–c [Zone P3, Matthews Landing Marl, Naheola Landing, Tombigbee River, Alabama] [in part, not pl. 46: fig. 1a–c, pl. 47: fig. 2a–c, pl. 52: figs. 3–7, pl. 56: fig. 8a–c, pl. 62: figs. 3, 4].—Bolli and Cita, 1960:13, pl. 31: fig. 1a–c [*Globorotalia trinidadensis–Globigerina daubjergensis* Zone, Paderno d'Adda section, northern Italy].—Berggren, 1962:86, pl. 14: figs. 1a–2b [Zone P1b, type Danian, Stevns Klint, Denmark].—Hillebrandt, 1962:119, pl. 11: fig. 1a–c [Danian Stage, Richenhall–Salzburg Basin, Austro–German border].—Shutskaya, 1970b:118, pl. 18: fig. 1a–c [upper subzone of *Globigerina trivialis–Globoconusa daubjergensis–Globorotalia compressa* Zone, Malyi Balkhan Ridge, western Turkmenia], pl. 19: fig. 3a–c [*Acarinina inconstans* Zone, Malyi Balkhan Ridge, western Turkmenia], pl. 21: fig. 5a–c [*Acarinina praepentacamerata* Zone, Urukh River section, northern Caucasus], pl. 23: fig. 12a–c [lower subzone of *Acarinina tadjikistanensis djanensis* Zone, Malyi Balkhan Ridge, western Turkmenia].

Globigerina pseudotriloba White, 1928:194, pl. 27: fig. 17a,b [Velasco Fm., Mexico].

Globigerina stainforthi Brönnimann, 1952:23, pl. 3: figs. 10–12 [Paleocene, Trinidad].

Globigerina (Globigerina) microcellulosa Morozova, 1961:14, pl. 1: fig. 11 [Danian, Tarkhankut, Crimea].

Subbotina triloculinoides (Plummer).—Brotzen and Pożaryska, 1961:160, text-fig. 2, pl. 4: fig. 4 [lower Paleocene, Midway Group, Texas].—Belford, 1967:7, pl. 1: figs. 1–5 [Paleocene, Australia].—Stott and Kennett, 1990:559, pl. 2: fig. 12 [Zone AP1a, ODP Hole 690C/15X/2: 46–50 cm; Maud Rise, Weddell Sea, Southern Ocean].

Subbotina triloculinoides triloculinoides (Plummer).—Blow, 1979:1287, pl. 74: fig. 6 [Zone P1, DSDP Hole 47.2/11/1: 148–150 cm; Shatsky Rise, northwestern Pacific Ocean], pl. 80: fig. 1 [Zone P2, DSDP Hole 20C/6/4: 72–74 cm; Brazil Basin, South Atlantic Ocean], pl. 98: fig. 7 [Zone P4, given as P5, Lindi area, Tanzania], pl. 238: fig. 5 [same specimen as pl. 98: fig. 5], pl. 248: figs. 9, 10 [topotypes, Zone P2, Navarro Co., Texas], pl. 255: fig. 9 [Zone D2 of Bang, 1969, probably Zone P1c, Karlstrup, Denmark], pl. 257: fig. 9 [Zone P1c, upper Danian, Klagshamn, Sweden].

ORIGINAL DESCRIPTION.—"Test spiral, trochoid, composed of about 2 convolutions, the last of which is composed of 3$^1/_2$ very rapidly increasing and highly globose chambers; periphery very broadly rounded and distinctly lobate; shell surface strongly reticulate; superior face rounded with a very low spire of neatly coiled tiny chambers of the preceding whorl; inferior face rounded with a very shallow umbilical depression; aperture a small arched slit on the last chamber and edged with a more or less prominent, delicately notched flap that extends from a point near the periphery to the umbilical depression.

"Greatest diameter up to .35 mm.; usually less." (Plummer, 1926:134.)

DIAGNOSTIC CHARACTERS.—Medium sized, lobulate, trilobate test with 3–3$^1/_2$ chambers in ultimate whorl increasing moderately in size, ultimate chamber occupies up to $^1/_2$ of test size. Intercameral sutures depressed, straight to slightly curved on umbilical and spiral sides of test. Umbilicus narrow, deep, often covered by well-developed apertural lip. Aperture umbilical, slightly asymmetrical towards an extraumbilical direction. Test walls strongly cancellate, spinose, with spines occurring at the juncture of and along cancellate ridges.

DISCUSSION.—Together with *Parasubbotina pseudobulloides* (Plummer), this taxon is probably one of the most cited, yet most frequently misidentified, taxa of the Paleocene. The detailed analysis of Blow (1979) may serve as a guide to a reasonably consistent delineation of the main characteristics of this species. Although *S. triloculinoides* has a strongly cancellate wall texture, its does not possess the symmetrical, coarsely cancellate wall of the *cancellata–velascoensis* lineage. The ancestral *S. trivialis* is more weakly cancellate, and *S. triangularis* has an asymmetrical cancellate surface with distinct spine collars. Unlike Blow (1979), we do not recognize the two subgroups (aside from *S. triloculinoides* sensu stricto) to which some sort of formal nomenclature may be applied: *S. triloculinoides stainforthi* Blow and *S. triloculinoides nana* Blow. The former is interpreted as a junior synonym of *S. triloculinoides,* as has been more or less suggested by Bolli (1957a), and the "taxon" *nana* Khalilov is a squat, subquadrate form with a *linaperta*-like aperture referable to *S. velascoensis* (Cushman) and not to *S. triloculinoides* (verified by examination of the holotype by WAB). Khalilov (1967) indicated that the range of *nana* is upper Paleocene to lower Eocene in the Malyi Caucasus (Azerbaizhan) and Malyi Balkhan (Turkmenia); the morphology of *velascoensis* (= *nana*), however, already appears in Zone P3. The SEMs of the holotype (Plate 9: Figures 13–15) of *S. microcellulosa* (Morozova) show this taxon to be a junior synonym of *triloculinoides.*

STABLE ISOTOPES.—*Subbotina triloculinoides* has a $\delta^{13}C$ and $\delta^{18}O$ signature similar to *P. pseudobulloides, P. varianta, G. compressa,* and *G. planocompressa,* but it typically has a heavier $\delta^{18}O$ and more negative $\delta^{13}C$ than coexisting *Praemu-*

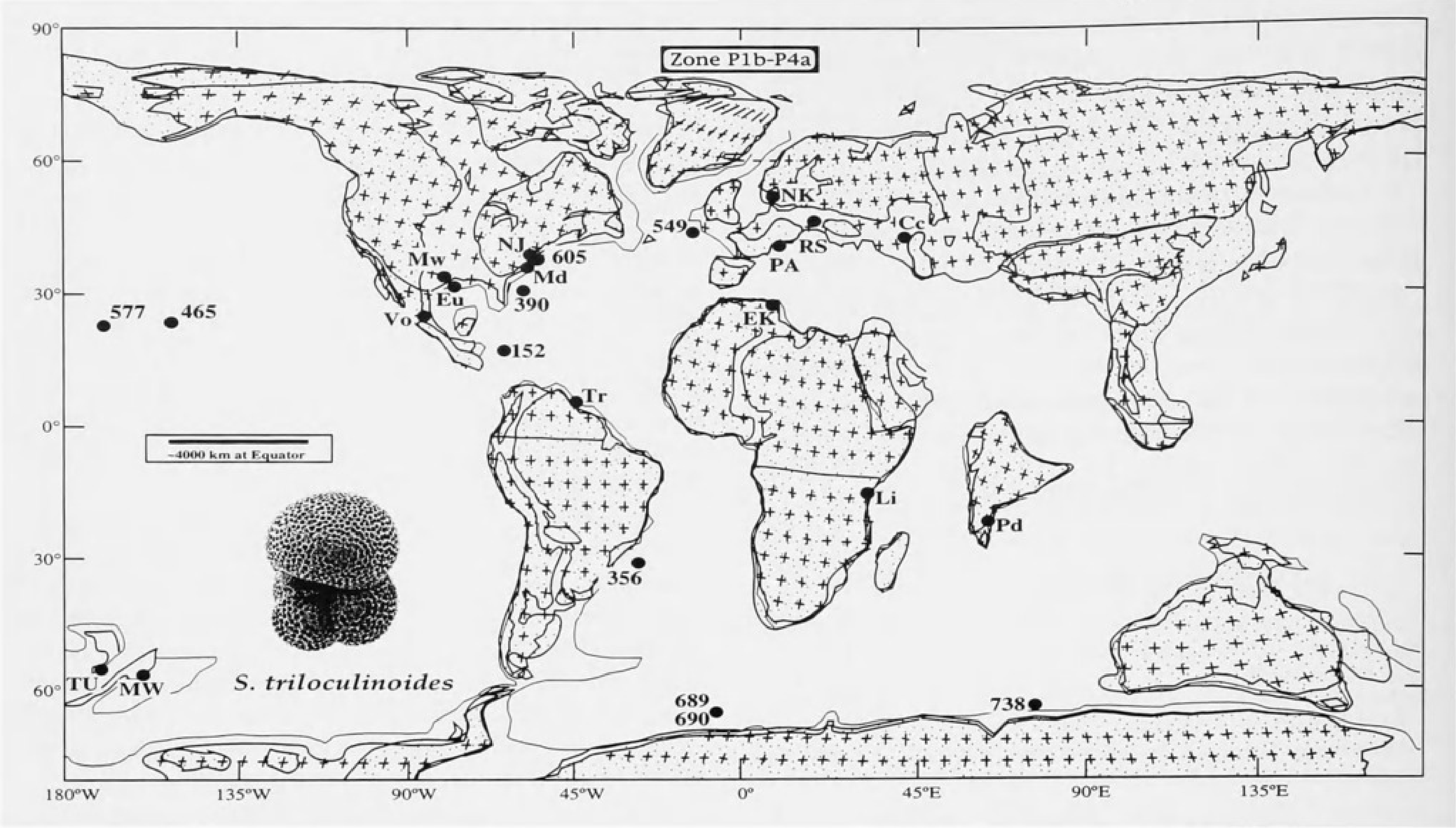


FIGURE 12.—Paleogeographic map showing distribution of *Subbotina triloculinoides* (Plummer) in Zones P1 to P3.

rica and *Morozovella*. The species shows little change in $\delta^{18}O$ or $\delta^{13}C$ over a large size range (Berggren and Norris, 1997).

STRATIGRAPHIC RANGE.—Zones P1b to P4. Although its upper stratigraphic limit remains somewhat equivocal, we have not observed it above Zone P4 and believe it is restricted to the Paleocene.

GLOBAL DISTRIBUTION.—Essentially a worldwide distribution in the low to high latitudes (Figure 12).

ORIGIN OF SPECIES.—Although Blow (1979) was of the opinion that the origin of *S. triloculinoides* lay in the plexus of forms that radiate from *Eoglobigerina eobulloides* sensu lato toward *E. trivialis* and *S. triloculinoides,* and, more specifically, with *F eohulloides simplicissima,* we view its evolution from *S. trivialis* to be more likely (see also Olsson et al., 1992).

REPOSITORY.—Holotype: Walker Museum Collection 33076, Station 23, now in the Field Museum, Chicago. Paratype (USNM 370088) deposited in the Cushman Collection, National Museum of Natural History. Holotype examined by WAB; paratype examined by BTH.

Subbotina trivialis (Subbotina, 1953)

PLATE 9: FIGURES 10–12; PLATE 28: FIGURES 1–13

Globigerina trivialis Subbotina, 1953:64, holotype: pl. 4: fig. 4a–c; paratypes: pl. 4: figs. 5a–7c [zone of rotaliform *Globorotalia* (= P1), basal Elburgan Fm., Kuban River section, northern Caucasus] [in part, not pl. 4: fig. 8a–c (same horizon; = *S. triloculinoides*)].—Shutskaya, 1970b:118, pl. 18: fig. 2a–c [upper subzone of *Globigerina trivialis–Globoconusa daubjergensis–Globorotalia compressa* Zone, Malyi Balkhan Ridge, western Turkmenia], pl. 18: fig. 16a–c [middle subzone of *Globigerina trivialis–Globoconusa daubjergensis–Globorotalia compressa* Zone, Malyi Balkhan Ridge, western Turkmenia] [in part, not pl. 21: fig. 3a–c, pl. 23: fig. 6a–c].

Eoglobigerina trivialis (Subbotina).—Blow, 1979:1224, pl. 65: figs. 1–3, pl. 66: figs. 4, 7 [Zone Pα, DSDP Hole 47.2/11/3: 148–150 cm], pl. 69: fig. 9, pl. 70: fig. 8 [Zone P1, DSDP Hole 47.2/11/3: 0–5 cm; Shatsky Rise, northwestern Pacific Ocean], pl. 70: figs. 1, 2 [Zone P2, DSDP Hole 20C/6/4: 72–74 cm; Brazil Basin, South Atlantic Ocean].—Stott and Kennett, 1990:559, pl. 2: fig. 11 [Zone AP1, ODP Hole 690C/15X/2: 46–50 cm; Maud Rise, Weddell Sea, Southern Ocean].—Berggren, 1992:563, pl. 1: fig. 1 [ODP Hole 747C/19H/CC; Kerguelen Plateau, southern Indian Ocean].

Eoglobigerina aff. *trivialis* (Subbotina).—Blow, 1979:1228, pl. 61: fig. 8 [Zone Pα, DSDP Hole 47.2/11/4: 148–150 cm], pl. 69: fig. 8 [Zone P1, DSDP Hole 47.2/11/3: 0–5 cm], pl. 74: figs. 7, 8 [Zone P1, DSDP Hole 47.2/11/1: 148–150 cm; Shatsky Rise, northwestern Pacific Ocean].

Eoglobigerina cf. *trivialis* (Subbotina).—Blow, 1979:1229, pl. 55: fig. 9 [Zone Pα, DSDP Hole 47.2/11/5: 148–150 cm; Shatsky Rise, northwestern Pacific Ocean].

Subbotina trivialis (Subbotina).—Huber, 1991c:461, pl. 3: figs. 16, 17 [Zone AP1, ODP Hole 738C/17R: 350.45 mbsf; Kerguelen Plateau, southern Indian Ocean].—Olsson, Hemleben, Berggren, and Liu, 1992:202, pl. 4: figs. 5–8 [Zone P1a, Pine Barren Mbr., Clayton Fm., Millers Ferry, Alabama].

ORIGINAL DESCRIPTION.—"Shell inflated with tall first whorls which are 2 in number and large in size. The last whorl consists of 4–4$^{1}/_{2}$ almost regular, spherical chambers which differ very slightly in size. The chambers are closely packed together and partially overlap each other. Because of this the shell is very compact. Peripheral margin broadly undulate; septal sutures curved, deeply incised as is characteristic of species with strongly inflated shells. Orifice small, and forming a slightly curved or straight slit which is situated along the marginal suture and near to, or more rarely above, the umbilicus. Walls with relatively large pores and a cellular pattern. Mean dimensions: diameter 0.40 mm, thickness 0.23 mm." (Subbotina, 1953:64; translated from Russian.)

DIAGNOSTIC CHARACTERS.—Low trochospiral, tightly coiled test with $3^1/_2$ chambers in ultimate whorl, umbilical aperture with thin lip. Ultimate chamber equal to, or slightly smaller than, penultimate one. Wall weakly cancellate and spinose. Spines set at junctures of cancellate ridges (Plate 28: Figures 12, 13). Umbilicus small and nearly closed by tight coiling. Overall size of test generally < 250 μm.

DISCUSSION.—Although Subbotina's original description refers to $4-4^1/_2$ chambers in the final whorl, her illustrations of the holotype and paratypes show only $3^1/_2$ chambers. Blow (1979) presented a thorough analysis of this morphospecies with which we in large part agree. Like Blow, we have not observed individuals as large as 0.4 mm in diameter as noted by Subbotina (1953) for her holotype from the northern Caucasus. In fact, remeasurement of her holotype (Plate 9: Figures 10–12) shows a diameter of 0.35 mm. Blow (1979) also described forms with more closely appressed chambers and abortively developed final chambers (as *Eoglobigerina* cf. *trivialis*) and forms with a turreted, high-spired umbilical side (as *Eoglobigerina* aff. *trivialis*). We include these morphotypes here in the concept of *trivialis,* as they do not appear to have any significant numerical representation or stratigraphic continuity in occurrence.

STABLE ISOTOPES.—No data available.

STRATIGRAPHIC RANGE.—Zone Pα to Zone P2.

GLOBAL DISTRIBUTION.—Essentially a worldwide distribution in the low to high latitudes.

ORIGIN OF SPECIES.—Although we agree with Blow (1979) that the distinction between the wall texture of eoglobigerinids and subbotinids is one of degree rather than kind, we view *trivialis* as the earliest representative of *Subbotina* (in contrast to Blow, 1979, who retained it in *Eoglobigerina*) and the main lineage that ultimately gave rise to the late Paleogene–Neogene spinose globigerinid radiation (see also Pearson, 1993; Liu and Olsson, 1994).

REPOSITORY.—Holotype (No. 4004) and paratypes (Nos. 4005–4007) deposited in the micropaleontological collections, VNIGRI, St. Petersburg, Russia. Examined by FR.

Subbotina velascoensis (Cushman, 1925)

FIGURE 13; PLATE 29: FIGURES 1–12

Globigerina velascoensis Cushman, 1925:19, pl. 3: fig. 6a–c [Paleocene, Velasco Fm., Tamalte Arroyo, Hacienda el Limon, San Luis Potosi, Mexico].—White, 1928:196, pl. 28: fig. 2a,b [Paleocene, Velasco Shale, Tampico Embayment, eastern Mexico].—Bolli, 1957a:71, pl. 15: figs. 9–11 [Zone P4, Lizard Springs Fm., Trinidad].—Bolli and Cita, 1960:374, pl. 34: fig. 8a–c [*Globorotali pseudomenardii* Zone, Paderno d'Adda section, northern Italy].—Hillebrandt, 1962:120, pl. 11: fig. 4a,b [Paleocene, Reichenhall-Salzburg Basin, Austro-German border].—Gohrbandt, 1963:47, pl. 2: figs. 1–3 [upper Paleocene, north of Salzburg, Austria].—Shutskaya, 1970a:94, pl. 4: figs. 3a–4c, 6a–c [figs. 3, 6: *Acarinina subsphaerica* Zone, Kambileevka River, Black Mountains, northern Caucasus; fig. 4: *Acarinina subsphaerica* Zone, Tarkhankut Peninsula, Crimea].

Globigerina velascoensis Cushman var. *compressa* White, 1928:196, pl. 28: fig. 3a,b [Velasco Fm., Tampico Embayment, eastern Mexico].

Globigerina quadritriloculinoides Khalilov, 1956:237, pl. 1: fig. 5a–c [holotype, upper Paleocene, Akhchakuima, NE foothills of Malyi Caucasus, Nakhichevan Autonomous Republic, Azerbaizhan].

Globigerina triloculinoides Plummer *nana* Khalilov, 1956:236, pl. 1: fig. 4a–c [holotype, upper Paleocene, from Akhchakuima, NE foothills of Malyi Caucasus, Nakhichevan Autonomous Republic, Azerbaizhan].

ORIGINAL DESCRIPTION.—"Test much compressed, the dorsal side with all the chambers visible, ventral side only those of the last-formed coil, sides nearly parallel, periphery broadly rounded; chambers distinct, three or four making up the last-formed coil, early chambers subglobular, later ones becoming more compressed, and the inner margin fairly straight; wall finely and evenly reticulate; aperture on the ventral side, elongate.

"Diameter 0.45 mm.; thickness 0.25 mm." (Cushman, 1925:19.)

DIAGNOSTIC CHARACTERS.—Tightly coiled test with compressed chambers and subquadrate test shape with umbilical aperture. Ultimate chamber much compressed, elongate oval-shaped, about one-half test size, and typically overhanging earlier chambers. Aperture bordered by thin elongate lip; lip extending less than full length of aperture and squared off at termination. Test wall coarsely and symmetrically cancellate, spinose.

DISCUSSION.—Although the holotype specimen is deformed, Bolli (1957a) defined the concept of this species, which is followed herein. The species was described from the Velasco Shale from which White (1928) illustrated better preserved specimens that he identified with Cushman's species. White's concept was followed by Bolli. White's figures, although drawings, illustrate a quadrate-shaped test with much compressed chambers. Furthermore, his drawings clearly indicate a symmetrical, coarsely cancellate test wall. Cushman (1925) in his description referred to an evenly reticulate wall, which suggests that he observed the wall texture that characterizes this species.

Bolli (1957a) and Blow (1979) considered that *S. velascoensis* evolved from *S. triangularis* at, or near, the Zone P3/P4 boundary and believed that *S. velascoensis* represented a dead-end lineage. *Subbotina velascoensis* has a much different wall texture than does *S. triangularis*. The latter species has a finer asymmetrical cancellate wall with coalescing spine collars, whereas *S. velascoensis* has a symmetrical, coarsely cancellate wall texture. In *S. velascoensis,* the spines are set at the intersection of the cancellate ridges and are not supported

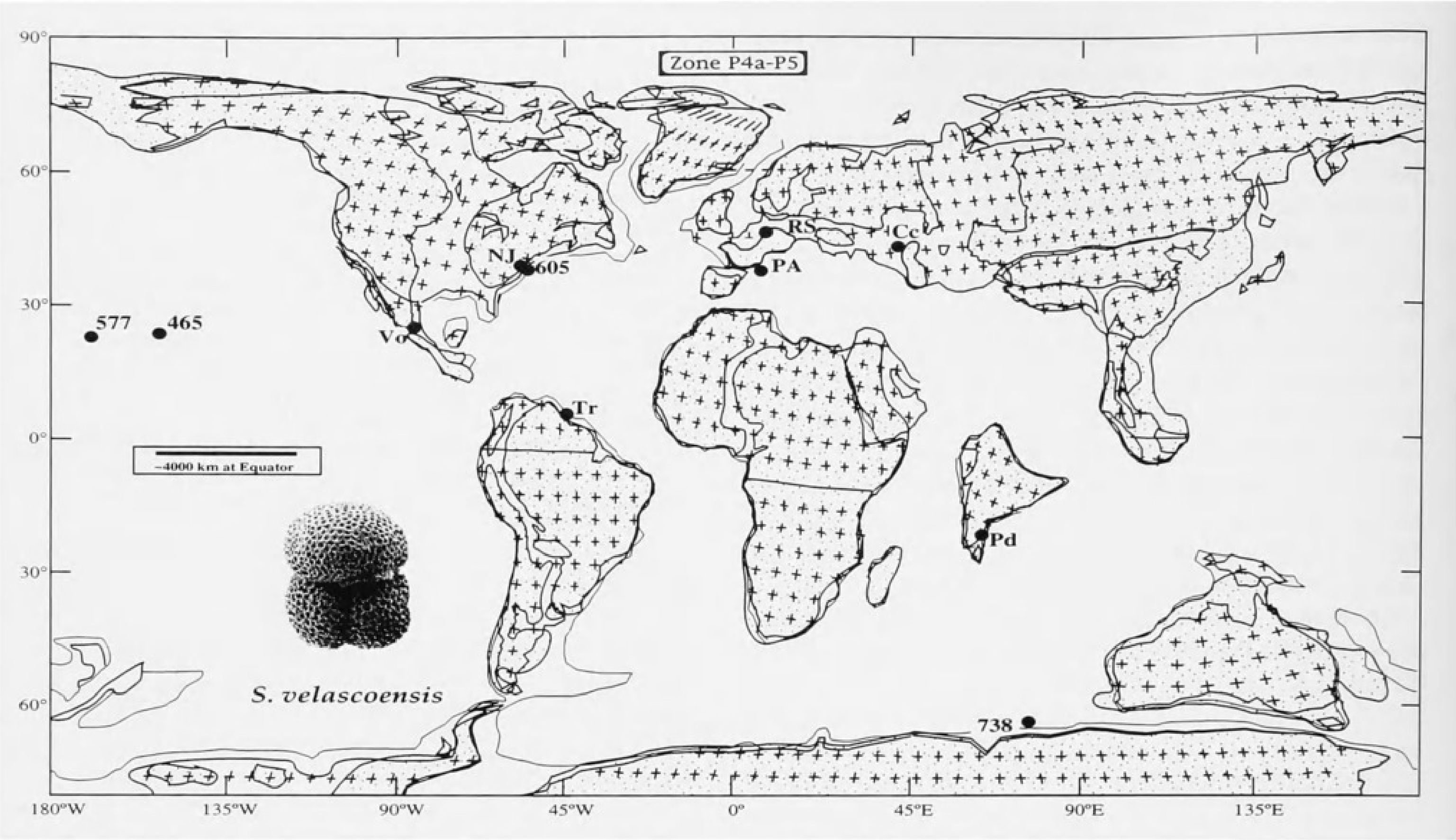


FIGURE 13.—Paleogeographic map showing distribution of *Subbotina velascoensis* (Cushman) in the upper Paleocene.

by spine collars (Plate 29: Figure 11) as in *S. triangularis* (Plate 26: Figures 12, 13). We consider *S. velascoensis* as the end member of the symmetrical coarsely cancellate lineage that begins with *S. cancellata. Subbotina cancellata,* gives rise to *S. velascoensis* at, or near, the Zone P3/P4 boundary. We agree with Bolli and Blow that *S. velascoensis* represents a dead-end lineage. *Globigerina quadritriloculinoides* Khalilov (1956) from the upper Paleocene of Azerbaizhan exhibits the characteristic quadrate-shaped morphology of *S. velascoensis.* The holotype figures show a coarsely cancellate wall, also typical of *S. velascoensis.*

STABLE ISOTOPES.—*Subbotina velascoensis* has a $\delta^{13}C$ and $\delta^{18}O$ signature similar to *P. varianta, G. compressa,* and *G. pseudomenardii,* but it typically has a heavier $\delta^{18}O$ and more negative $\delta^{13}C$ than coexisting *Acarinina* and *Morozovella* (Berggren and Norris, 1997).

STRATIGRAPHIC RANGE.—Zone P3b to Zone P6a.

GLOBAL DISTRIBUTION.—Essentially a worldwide distribution in the low to middle latitudes, with preferential development in the middle to higher latitudes as is common with the subbotinids (Figure 13).

ORIGIN OF SPECIES.—This species evolved from *S. cancellata* by the development of a more tightly coiled, quadrate test and compressed chambers.

REPOSITORY.—Holotype (USNM CC4348) deposited in the Cushman Collection, National Museum of Natural History. Examined by WAB and RKO.

Family HEDBERGELLIDAE Loeblich and Tappan, 1961

(by R.K. Olsson, Ch. Hemleben, and C. Liu)

ORIGINAL DESCRIPTION.—"Primary aperture only, commonly with prominent aperture lip, those of previous chambers remaining as projections into the umbilical region." (Loeblich and Tappan, 1961:309.)

DIAGNOSTIC CHARACTERS.—Test trochospiral with umbilical-extraumbilical aperture with a prominent lip. Apertures of earlier formed chambers remain visible around the umbilicus.

DISCUSSION.—The vast majority of hedbergellids are represented by Cretaceous genera. Only one genus, *Hedbergella,* a very common form throughout the Cretaceous, survived into the Cenozoic where it gave rise to *Globanomalina* in the early Danian.

Genus *Hedbergella* Brönnimann and Brown, 1958

TYPE SPECIES.—*Anomalina lorneiana* d'Orbigny var. *trochoidea* Gandolfi, 1942.

PLATE 2

Gametogenetic Calcification (Spinose Wall Texture)

FIGURE 1.—*Globigerinoides ruber* (d'Orbigny), view of test wall showing a cancellate structure with spines on the interpore ridges (bar = 10 μm). Recent, plankton net catch, off Bermuda.

FIGURE 2.—*Globigerinoides sacculifer* (Brady), view of test wall showing gametogenic calcification covering the spine holes (bar = 10 μm). Live specimen, off Bermuda.

FIGURE 3.—*Subbotina linaperta* (Finlay), view of test wall showing spine holes and incipient gametogenic calcification (bar = 20 μm). Upper Eocene, DSDP Hole 362A/7/5: 24–26 cm; Walvis Ridge, eastern South Atlantic Ocean.

FIGURE 4.—*Subbotina linaperta* (Finlay), view of test wall showing different stages of gametogenetic calcification (bar = 20 μm). Upper Eocene, DSDP Hole 362A/7/5: 24–26 cm; Walvis Ridge, eastern South Atlantic Ocean.

FIGURE 5.—*Subbotina linaperta* (Finlay), enlarged view of test wall showing partial gametogenetic overgrowth of a spine hole (bar = 4 μm). Upper Eocene, DSDP Hole 362A/7/5: 24–26 cm; Walvis Ridge, eastern South Atlantic Ocean.

FIGURE 6.—*Subbotina cancellata* Blow, view of test wall showing gametogenic calcification covering the spine holes (bar = 10 μm). Paleocene, Zone P4, DSDP Site 549/20/5: 20–22 cm; Goban Spur, eastern North Atlantic.

FIGURES 7–9.—*Parasubbotina pseudobulloides* (Plummer): 7, view of test wall showing a cancellate surface texture with spine holes and rather heavy corrosion; 8, spine holes and gametogenic calcification; 9, well-preserved specimen showing typical gametogenic calcification (bar = 10 μm). Paleocene, Zone P2, Midway Group, Texas, sample 8030.

FIGURE 10.—*Globigerinoides ruber* (d'Orbigny), view of test wall showing a less well-developed cancellate surface texture with gametogenic calcification (bar = 10 μm). Recent, plankton net catch, off Bermuda.

FIGURES 11–13.—*Eoglobigerina eobulloides* Morozova: 11, view of test wall showing cancellate wall texture, spine holes, and gametogenic calcification; 12, corroded surface (lower left) and gametogenic calcification; 13, well-preserved specimen showing rather thick gametogenic calcification (bar = 10 μm). Paleocene, Zone Pα, Core 226, samples 8, 21, 84, respectively, Millers Ferry, Alabama.

FIGURE 14.—*Globigerina praebulloides* Blow, view of test wall showing spine holes and spine bases (bar = 10 μm). Upper Eocene, DSDP Hole 362A/7/5: 24–26 cm; Walvis Ridge, eastern South Atlantic Ocean.

FIGURES 15, 16.—*Subbotina triangularis* (White), views of test wall showing spine holes, spine bases, and gametogenic calcification. Compare to Figure 11 (bar = 10 μm). Paleocene, Zone P4, Glendola Well, New Jersey, sample 286–287 feet.

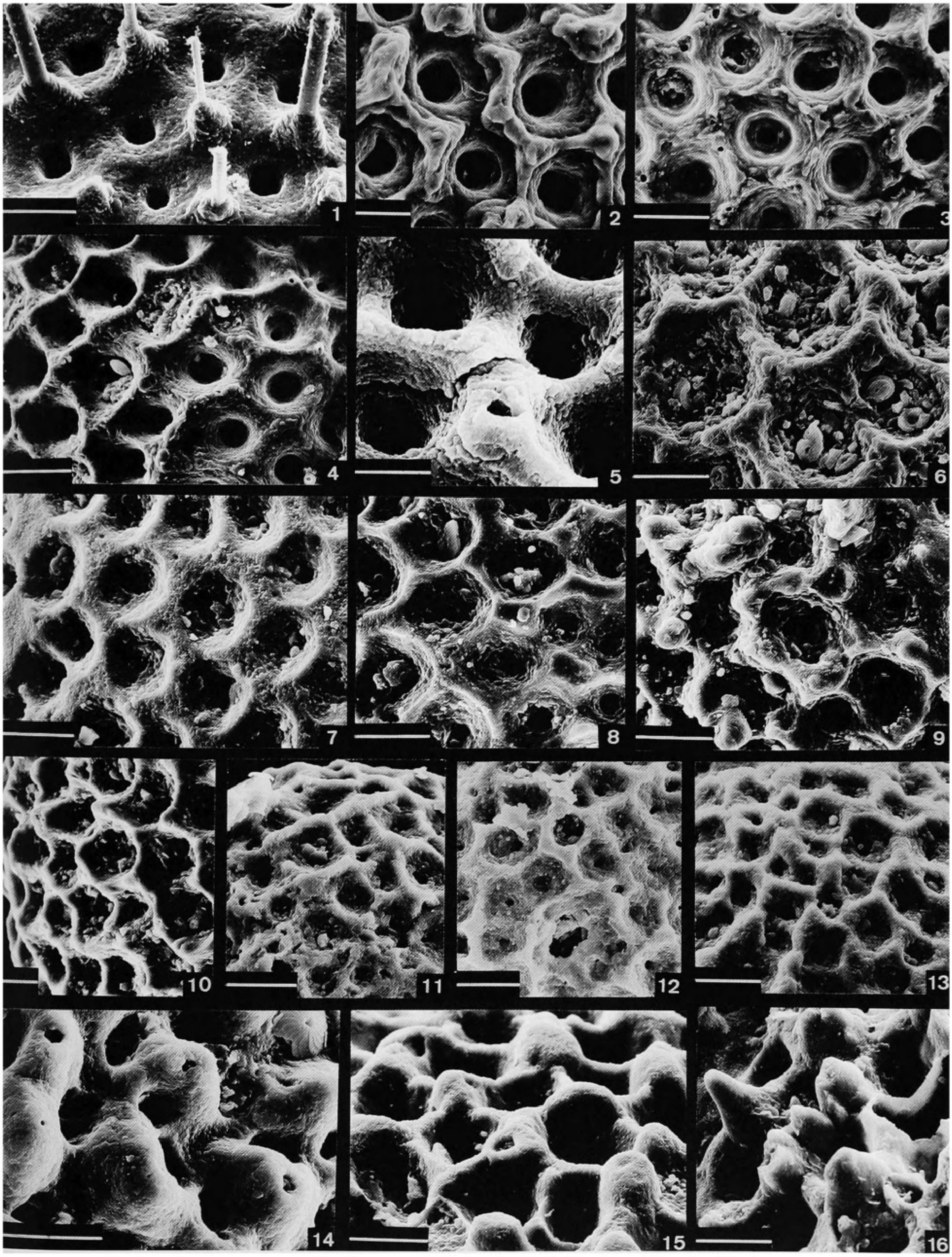

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

PLATE 8

Russian Primary Type Specimens

(bars = 100 μm)

FIGURES 1–3.—*Guembelitria irregularis* Morozova, 1961:17, pl. 1: fig. 9, holotype no. 3510/13a, Moscow GAN; Danian, Tarkhankut, Crimea. See "Discussion" for *Guembelitria cretacea.*

FIGURES 4–6.—*Globigerina* (*Eoglobigerina*) *trifolia* Morozova, 1961:12, pl. 1: fig. 1, holotype no. 3510/4, Moscow GAN; Danian, Tarkhankut, Crimea. See "Discussion" for *Globoconusa daubjergensis.*

FIGURES 7–9.—*Acarinina multiloculata* Morozova, 1961:15, pl. 2: fig. 5, holotype no. 3510/10, Moscow GAN; Montian, Balka Nasypkoiskaya, Crimea. Probably a reworked specimen of *Hedbergella planispira* (Tappan, 1940).

FIGURES 10–12.—*Globigerina* (*Eoglobigerina*) *eobulloides* Morozova, 1959:1115, text-fig. 1a–c, holotype no. 3508/1, Moscow GAN; Danian, Tarkhankut, Crimea. See *Eoglobigerina eobulloides.*

FIGURES 13–15.—*Globigerina* (*Eoglobigerina*) *hemisphaerica* Morozova, 1961:11, pl. 1: fig. 4, holotype no. 3510/3, Moscow GAN; Danian, Tarkhankut, Crimea. See "Discussion" for *Eoglobigerina edita.*

FIGURES 16–18.—*Globigerina* (*Eoglobigerina*) *theodosica* Morozova, 1961:11, pl. 1: fig. 6, holotype no. 3510/2, Moscow GAN; Danian, Tarkhankut, Crimea. See "Discussion" for *Eoglobigerina edita.*

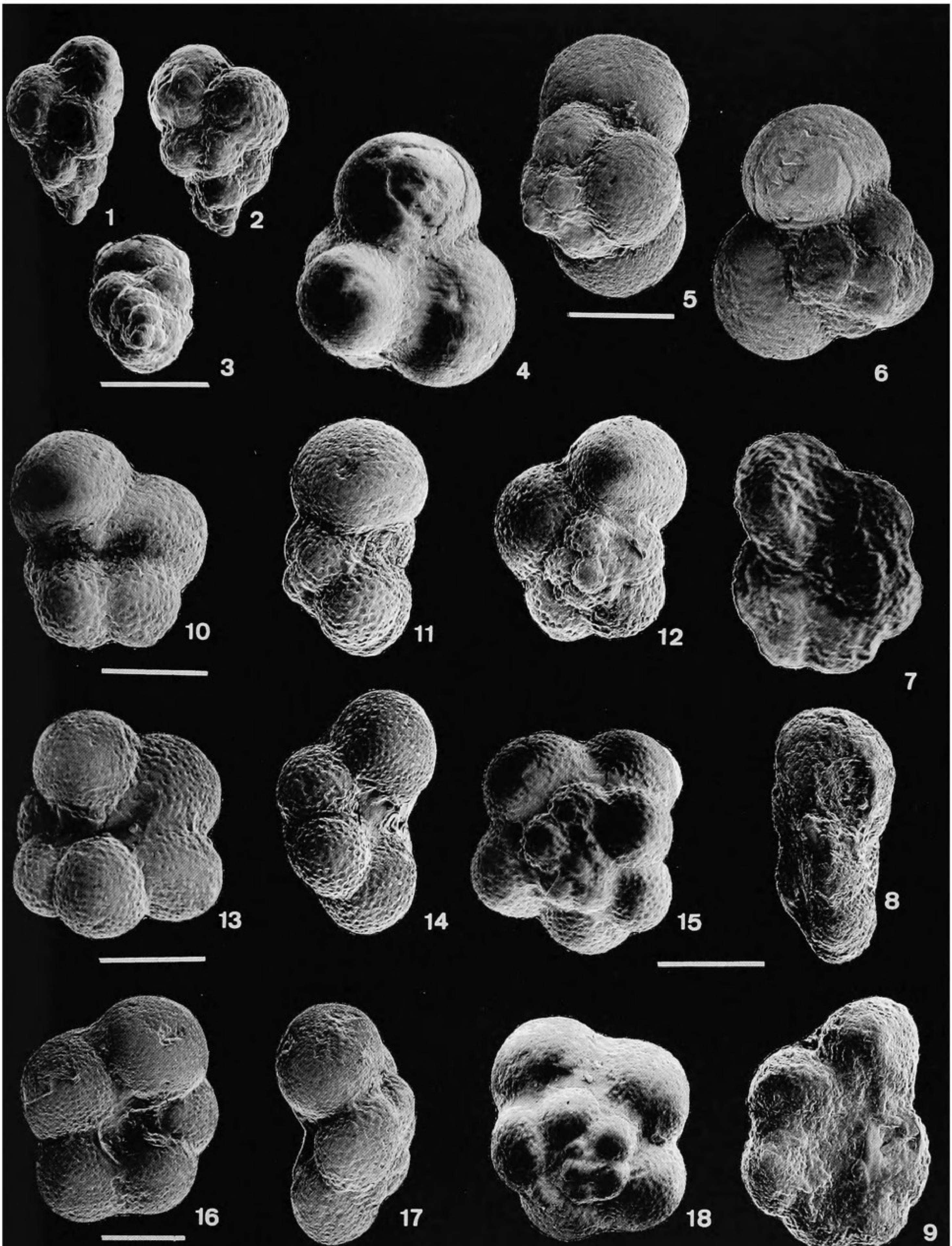

1
2
3
4
5
6
10
11
12
7
13
14
15
8
16
17
18
9

PLATE 9

Russian Primary Type Specimens

(bars = 100 μm)

FIGURES 1–3.—*Globigerina* (*Eoglobigerina*) *tetragona* Morozova, 1961:13, pl. 1: fig. 2, holotype no. 3510/5, Moscow GAN; Danian, Pre-Caspian Basin, Novouzensk. See "Discussion" for *Eoglobigerina edita*.

FIGURES 4–6.—*Globigerina* (*Eoglobigerina*) *pentagona* Morozova, 1961:13, pl. 1: fig. 3, holotype no. 3510/6, Moscow GAN; Danian, Tarkhankut, Crimea. See "Discussion" for *Eoglobigerina edita*.

FIGURES 7–9.—*Globigerina fringa* Subbotina, 1953:62, pl. 3: fig. 3, holotype no. 2175, St. Petersburg VNIGRI (323/39); Danian, Pecten horizon, Azov-Black Sea flysch, Anapa, Caucasus. See "Discussion" for *Subbotina cancellata*.

FIGURES 10–12.—*Globigerina trivialis* Subbotina, 1953:64, pl. 4: fig. 4a–c, holotype no. 4004, St. Petersburg VNIGRI (378/30); Elburgan Fm., Kuban River section, northern Caucasus. See *Subbotina trivialis*.

FIGURES 13–15.—*Globigerina* (*Globigerina*) *microcellulosa* Morozova, 1961:14, pl. 1: fig. 11, holotype no. 3510/7, Moscow GAN; Danian, Tarkhankut, Crimea. See "Discussion" for *Subbotina triloculinoides*.

FIGURES 16–18.—*Globigerina varianta* Subbotina, 1953:63, pl. 3: fig. 5a–c, holotype no. 3994, St. Petersburg VNIGRI (378/20); zone of rotaliform *Globorotalia*, Elburgan Fm., Kuban River section, northern Caucasus. See *Parasubbotina varianta*.

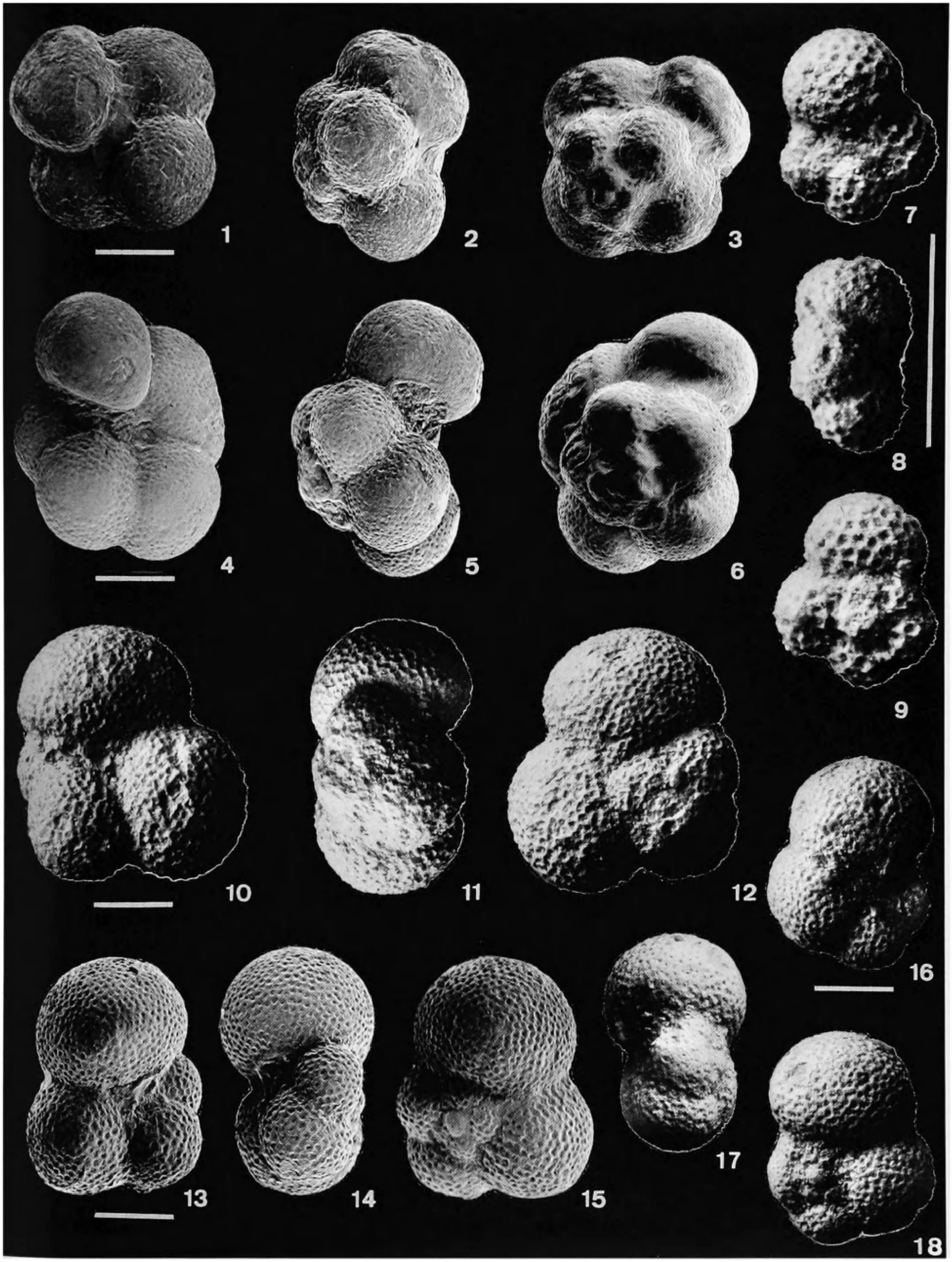

1
2
3
7
8
4
5
6
9
10
11
12
16
13
14
15
17
18

PLATE 14

USNM Primary Type Specimens

(bars = 50 μm)

FIGURES 1–3.—*Globigerina compressa* Plummer, 1926, lectotype, Chicago Field Museum UC55091; upper Danian, Zone P2, Wills Point Fm., Midway Group, Navarro Co., Texas.

FIGURES 4, 8, 12.—*Globorotalia ehrenbergi* Bolli, 1957, holotype, USNM P5060; upper Paleocene, Lizard Springs Fm., Trinidad.

FIGURES 5–7.—*Globorotalia pseudomenardii* Bolli, 1957, holotype, USNM P5061; *Globorotalia pseudomenardii* Zone, Lizard Springs Fm., Trinidad.

FIGURES 9–11.—*Globorotalia uncinata* Bolli, 1957, holotype, USNM P5048; *Globorotalia uncinata* Zone, lower Lizard Springs Fm., Trinidad.

FIGURES 13, 14.—*Globorotalia trinidadensis* Bolli, 1957 (= *Praemurica inconstans* (Subbotina)), holotype, USNM P5044; *Globorotalia trinidadensis* Zone, lower Lizard Springs Fm., Trinidad.

FIGURES 15, 16.—*Globigerina triloculinoides* Plummer, 1926, paratype, USNM 370088; Zone P2, Wills Point Fm., Midway Group, Navarro Co., Texas, Plummer station 23.

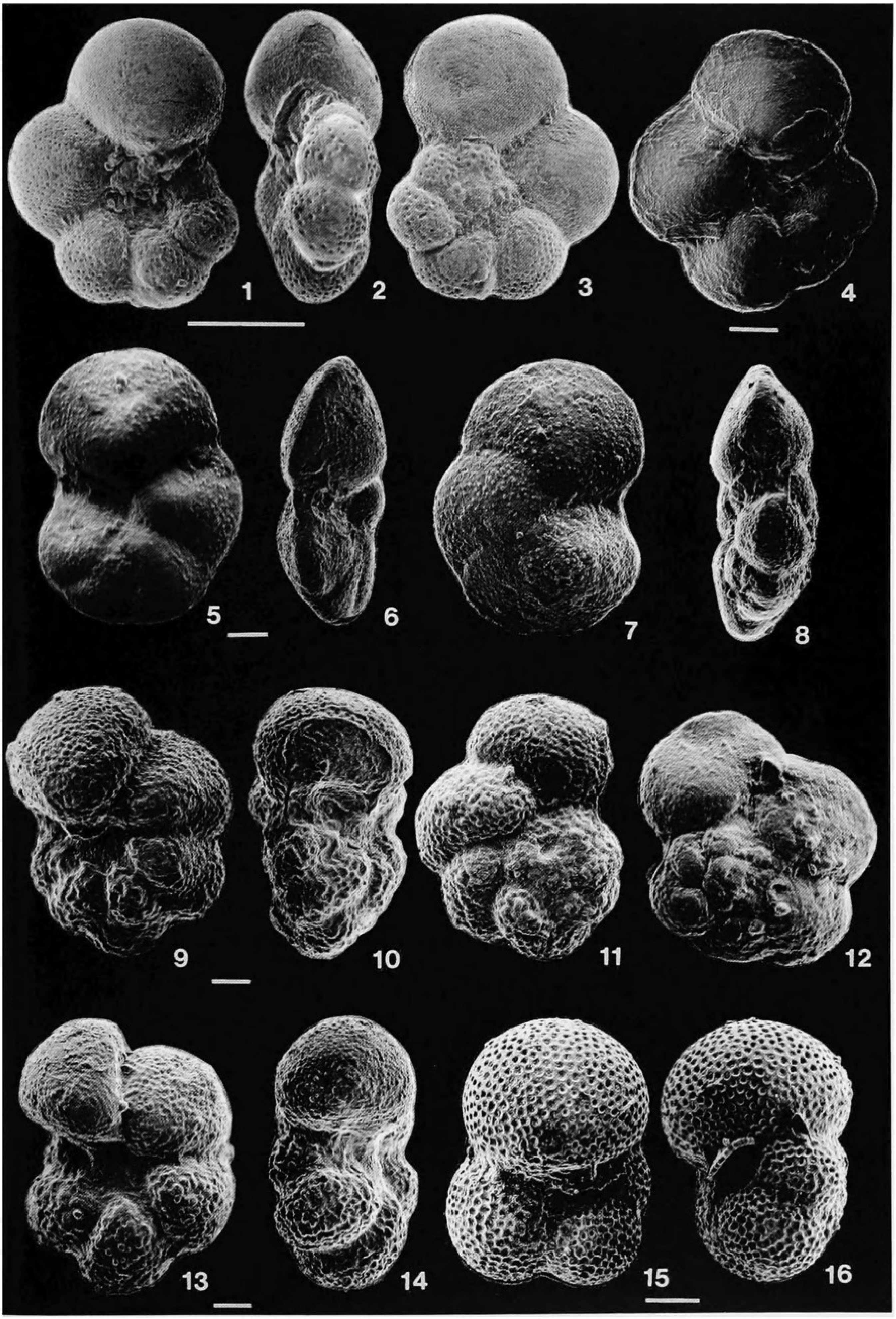

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

PLATE 16

USNM Primary Type Specimens

(bars = 50 μm)

FIGURES 1–3.—*Globorotalia albeari* Cushman and Bermúdez, 1949, holotype, USNM CC47413; *Globorotalia pseudomenardii* Zone, Madruga Fm., Cuba.

FIGURES 4–6.—*Globorotalia pusilla laevigata* Bolli, 1957 (= *Igorina albeari* (Cushman and Bermúdez)), holotype, USNM P5065; *Globorotalia pseudomenardii* Zone, Lizard Springs Fm., Trinidad.

FIGURES 7–9.—*Globorotalia pusilla pusilla* Bolli, 1957, holotype, USNM P5064; *Globorotalia pusilla pusilla* Zone, Guayaguayare Well 159, Trinidad Leasholds, Ltd., Lizard Springs Fm., Trinidad.

FIGURES 10–12.—*Globigerina spiralis* Bolli, 1957, holotype, USNM P5030; *Globorotalia uncinata* Zone, lower Lizard Springs Fm., Trinidad.


1
2
3
4
5
6
7
8
9
10
11
12

PLATE 18

Eoglobigerina edita (Subbotina, 1953)

(Figures 1–14: bars = 50 μm; Figure 15: bar = 20 μm; Figure 16: bar = 10 μm)

FIGURE 1.—Zone Pα, Millers Ferry, Alabama, core 226, sample 85.

FIGURES 2, 3, 5, 6.—Zone P1a, DSDP Site 356/28/2: 144–145 cm; São Paulo Plateau, South Atlantic Ocean.

FIGURES 4, 15, 16.—Zone P1a, Millers Ferry, Alabama, core 225, sample 194; Figures 15, 16, views of wall texture of 3rd chamber of Figure 4.

FIGURE 7.—Zone P1a, Millers Ferry, Alabama, core 225, sample 216.

FIGURES 8–14.—Zone P1c, Brightseat Fm., Maryland.

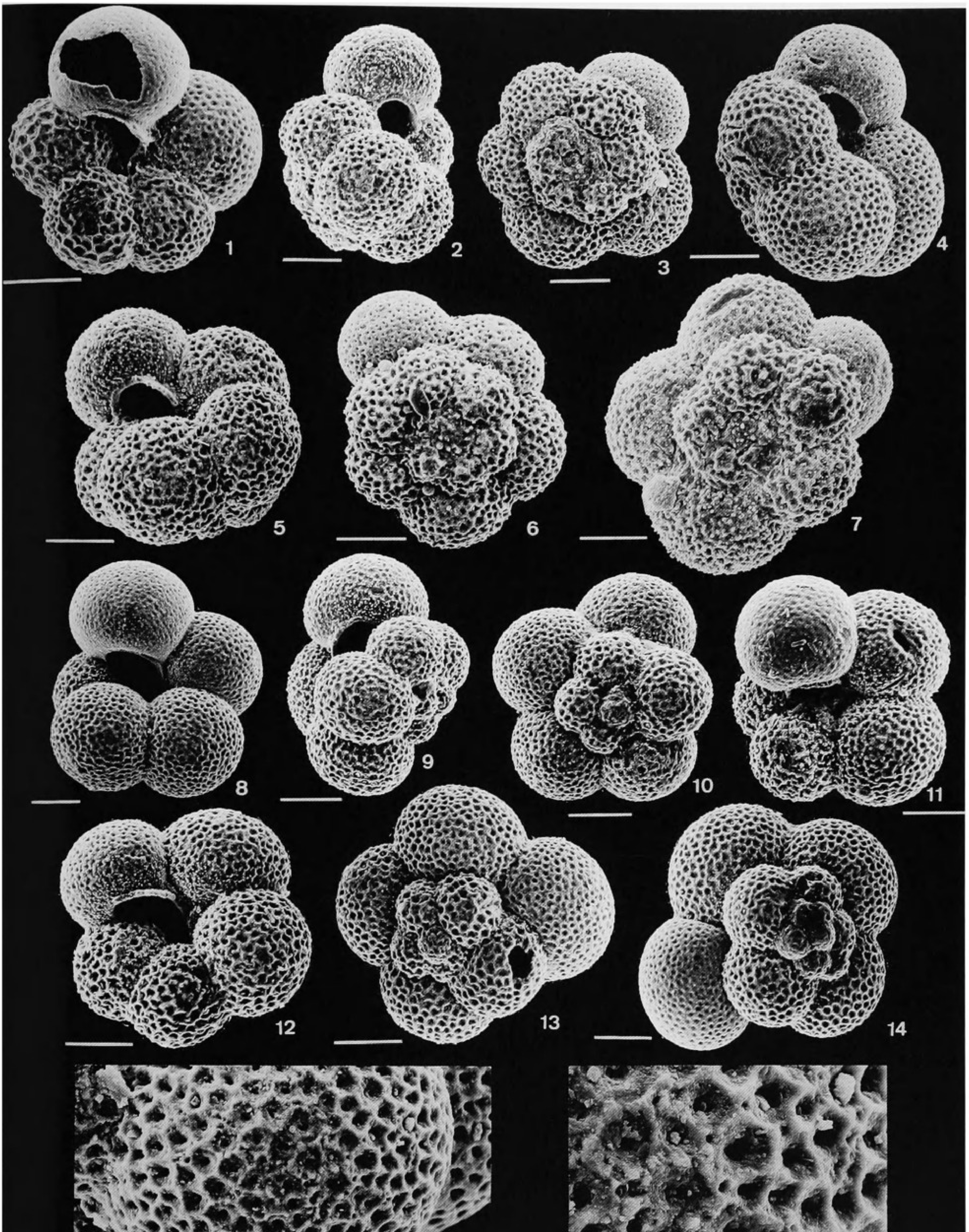

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

PLATE 19

Eoglobigerina eobulloides Morozova, 1959

(Figures 1–12: bars = 50 µm; Figures 13, 15: bars = 10 µm; Figure 14: bar = 4 µm)

FIGURES 1, 2, 5, 13–15.—Zone Pα, Millers Ferry, Alabama, core 226, sample 85; Figures 13–15, views of 3rd chamber of Figure 5 showing spinose cancellate wall texture.

FIGURES 3, 7, 11, 12.—Zone P1a, Millers Ferry, Alabama, core 226, sample 216.

FIGURES 4, 6.—Zone P1a, DSDP Hole 350A/11/4: 80–82 cm; Greenland.

FIGURE 8.—Zone P0, Millers Ferry, Alabama, core 225, sample 349.

FIGURE 9.—Zone Pα, Millers Ferry, Alabama, core 226, sample 84.

FIGURE 10.—Zone P1c, Brightseat Fm., Maryland.

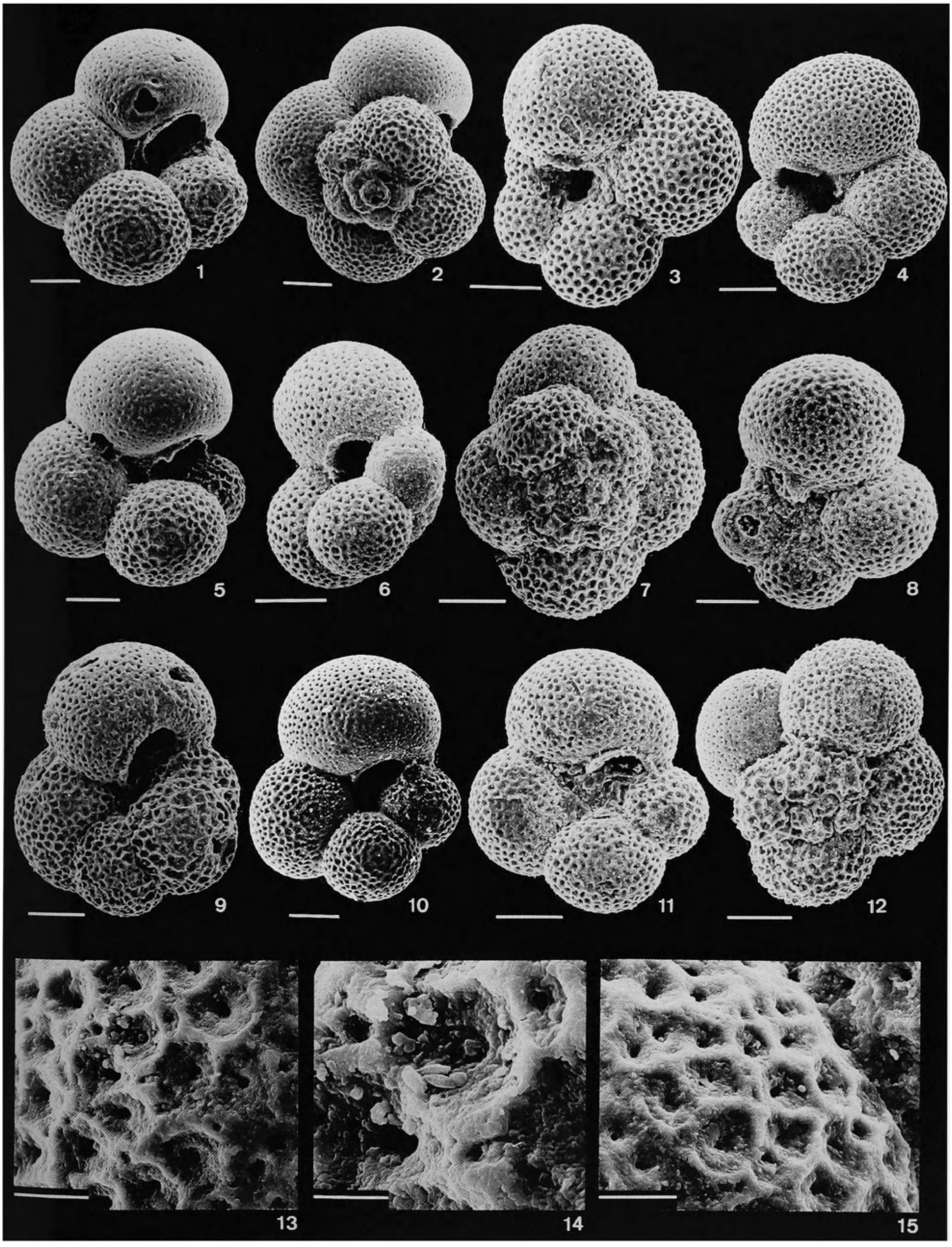


PLATE 20

Eoglobigerina spiralis (Bolli, 1957)

(Figures 1–9, 11: bars = 50 μm; Figure 10: bar = 4 μm)

FIGURES 1–6, 10.—Zone P1c, Midway Fm., Texas, Plummer station 14; Figure 10, view of 5th chamber of Figure 5 showing spinose wall texture.

FIGURES 7–9.—Zone P2, DSDP Site 356/25/5: 109–111 cm.

FIGURE 11.—Zone P2, DSDP Site 356/26/4: 30–32 cm; São Paulo Plateau, South Atlantic Ocean.

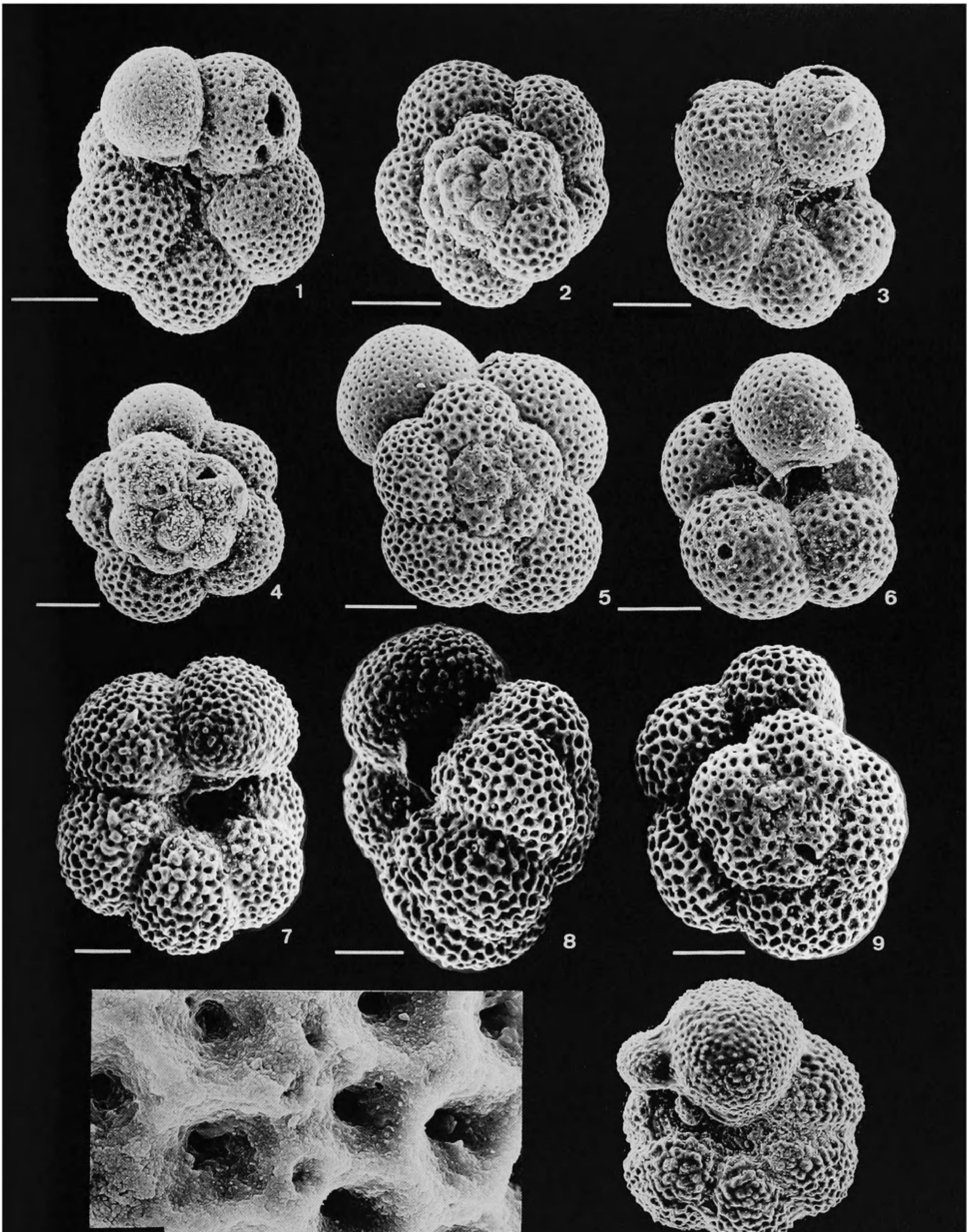

1
2
3
4
5
6
7
8
9
10
11

PLATE 21

Parasubbotina pseudobulloides (Plummer, 1926)

(Figures 1–11: bars = 50 μm; Figures 12–15: bars = 5 μm)

FIGURES 1–4, 8, 12.—Zone P2, Midway Group, Texas, sample 8030; Figure 12, view of 2nd chamber of Figure 4 showing cancellate spinose wall texture.

FIGURES 5, 9.—Zone P1a, Millers Ferry, Alabama, surface sample 30 feet.

FIGURES 6, 10, 11, 13, 14.—Zone P1a, Millers Ferry, Alabama, core 225, sample 216; Figures 13, 14, views of 4th chamber of Figure 6 showing cancellate spinose wall texture.

FIGURES 7, 15.—Zone P1a, Millers Ferry, Alabama, core 226, sample 85; Figure 15, view of 2nd chamber of Figure 7 showing cancellate spinose wall texture.

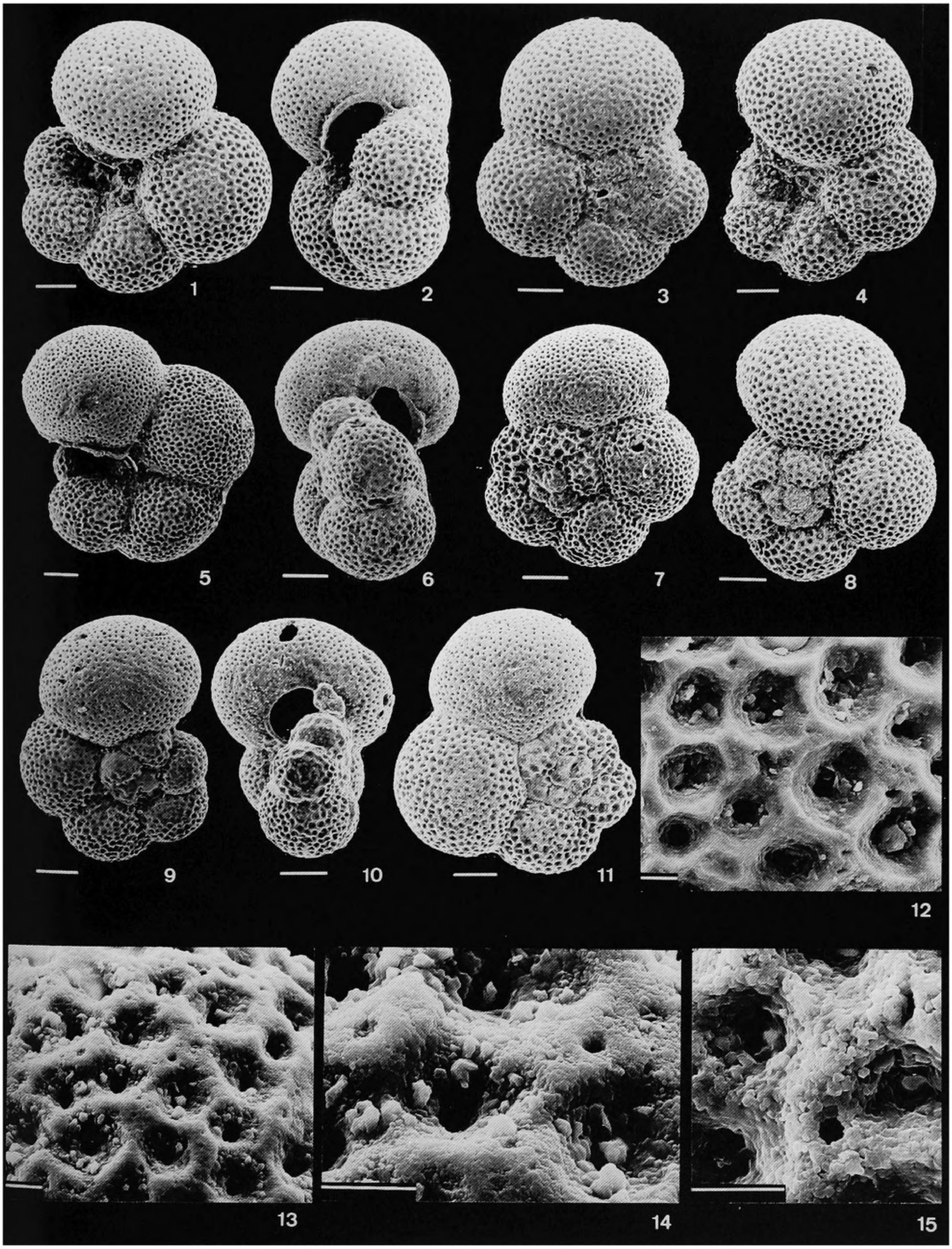

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

PLATE 22

Parasubbotina aff. *pseudobulloides* (Plummer, 1926)

(Figures 1–3: bars = 50 μm; Figures 4, 5: bars = 10 μm)

FIGURES 1–5.—Zone Pα, Millers Ferry, Alabama, core 226, sample 85; Figures 4, 5, views of 2nd chamber of Figure 3 showing weakly developed cancellate spinose wall texture, slightly recrystallized.

Parasubbotina varianta (Subbotina, 1953)

(Figures 6–13: bars = 50 μm; Figures 14, 15: bars = 10 μm; Figure 16: bar = 4 μm)

FIGURES 6–8, 10–12, 14–16.—Zone P2, DSDP Site 356/25/5: 148–150 cm; São Paulo Plateau, South Atlantic Ocean; Figure 14 (view of 2nd chamber of Figure 6) and Figure 15 (view of 3rd chamber of Figure 12), showing cancellate spinose wall texture.

FIGURE 9.—Zone P1c, Mexia Clay Mbr., Midway Group, Texas.

FIGURE 13.—Zone P1a, Millers Ferry, Alabama, core 225, sample 194.

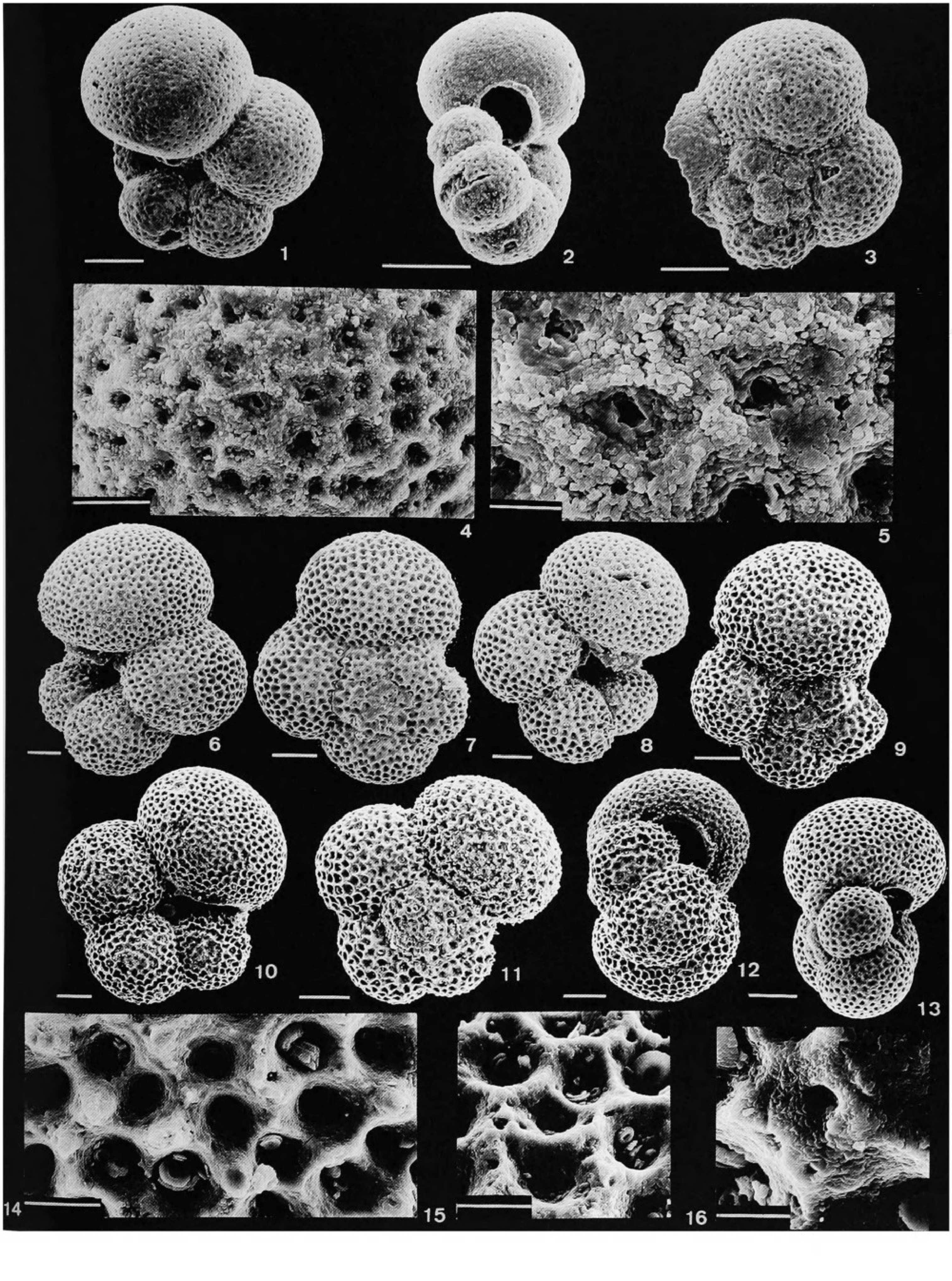

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

PLATE 23

Parasubbotina variospira (Belford, 1984)

(Figures 1–14, 16: bars = 100 μm; Figure 15: bar = 200 μm)

FIGURES 1–10, 13, 15, 16.—Zone P3, DSDP Site 384/10/CC.

FIGURES 11, 12, 14.—Zone P3, DSDP Site 384/9/CC; southeast Newfoundland Ridge, North Atlantic Ocean.

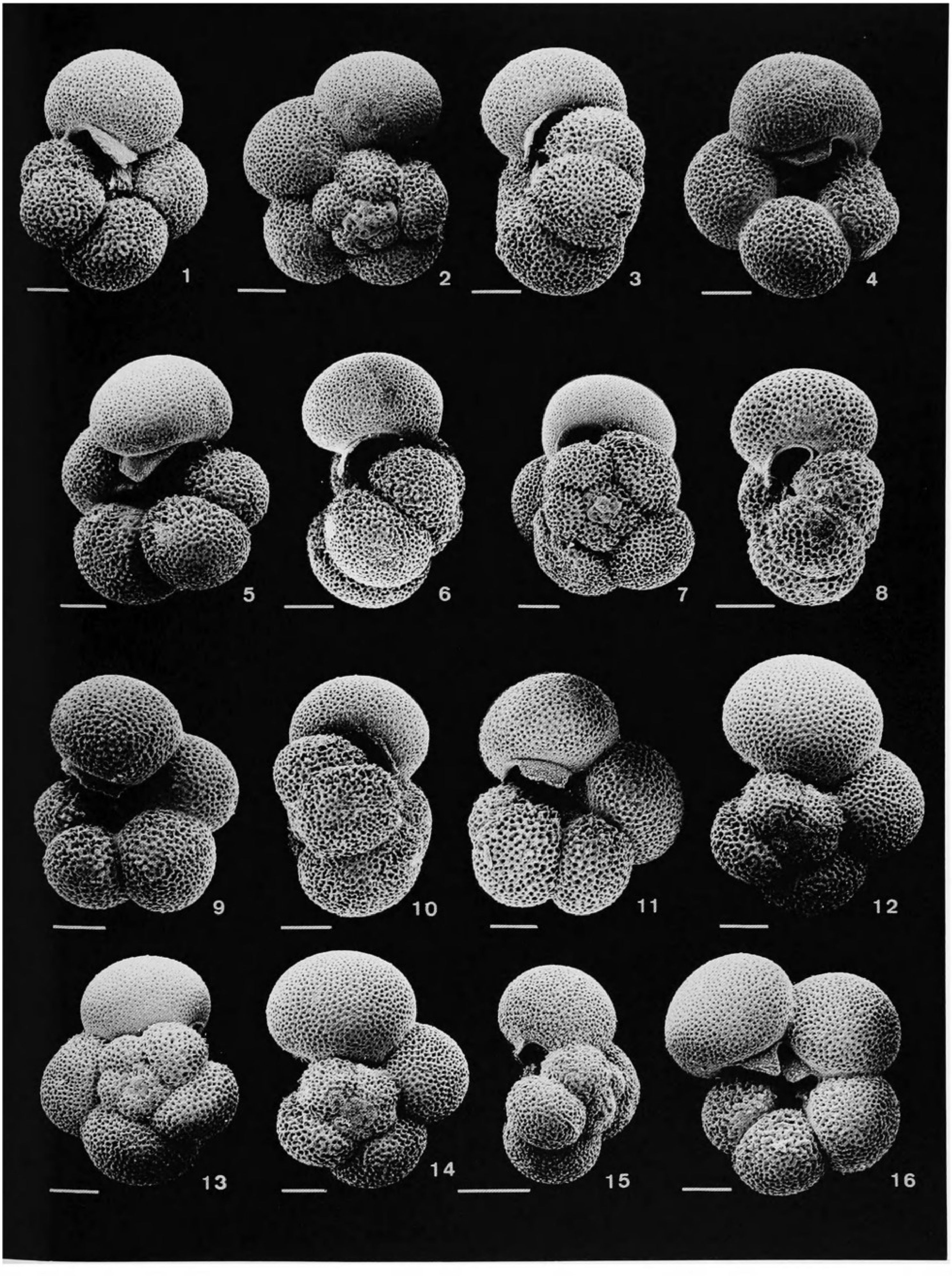

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

PLATE 24

Subbotina cancellata Blow, 1979

(bars = 100 μm)

FIGURES 1–12.—Zone P1c, DSDP Site 356/26/3: 90–92 cm; São Paulo Plateau, South Atlantic Ocean.

FIGURE 13.—Zone P4, Vincentown Fm., Glendola Well, New Jersey, sample 286–287 feet.

FIGURE 14.—Zone P4, DSDP Site 549/20/5: 20–22 cm; Goban Spur, eastern North Atlantic Ocean.

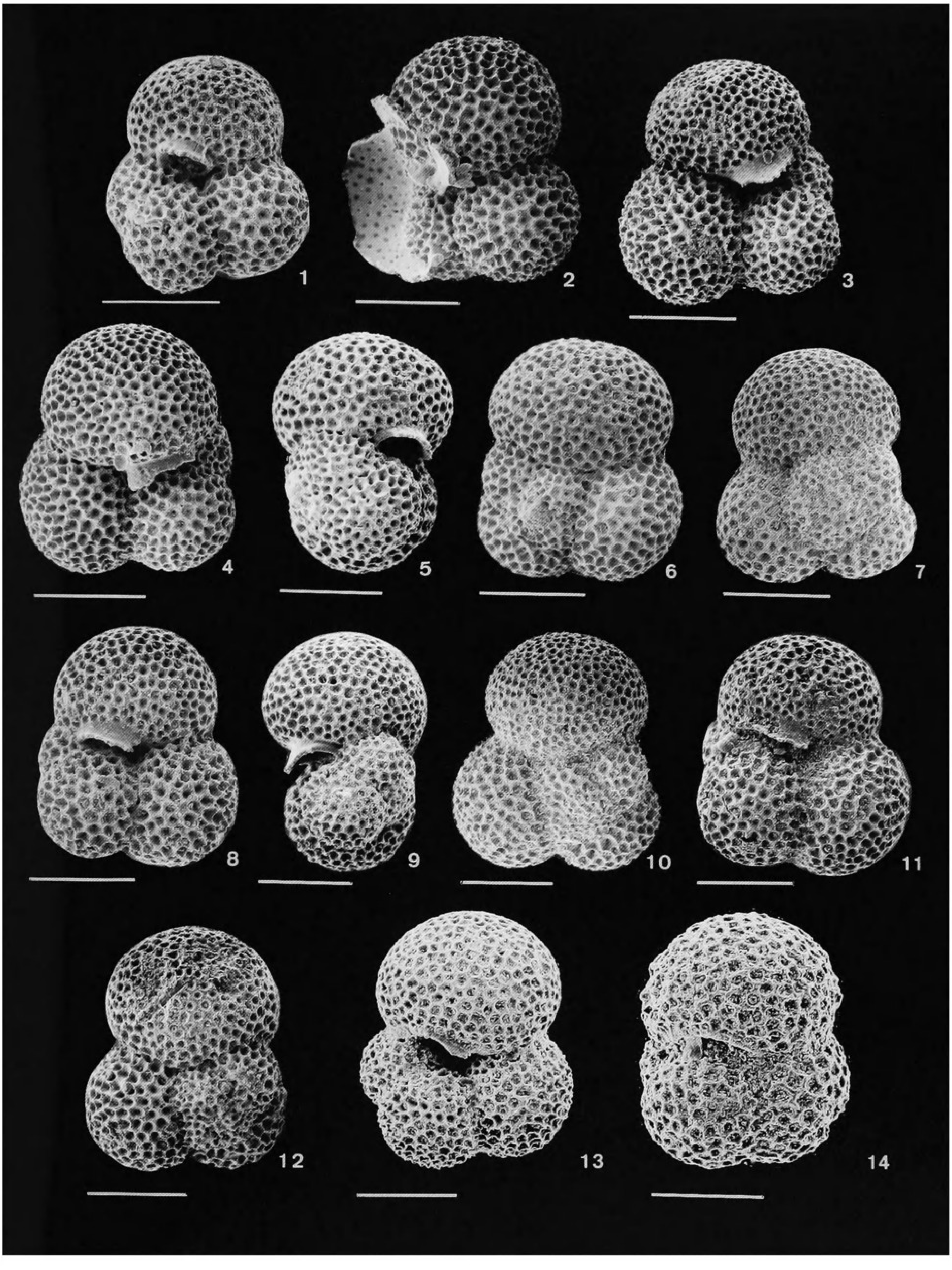

1
2
3
4
5
6
7
8
9
10
11
12
13
14

PLATE 25

Subbotina cancellata Blow, 1979

(Figures 1–14: bars = 50 μm; Figure 15: bar = 10 μm)

FIGURES 1–15.—Morphotypes showing a range of variation in the number of chambers in the final whorl and in the coarseness of the cancellate wall texture; Figure 7 shows transitional morphology to *Subbotina trivialis* (Subbotina, 1953). See "Discussion" under *S. cancellata* on the relationship with *Globigerina fringa* Subbotina, 1950. Zone P1c, DSDP Site 356/27/6: 38–40 cm; São Paulo Plateau, South Atlantic Ocean.

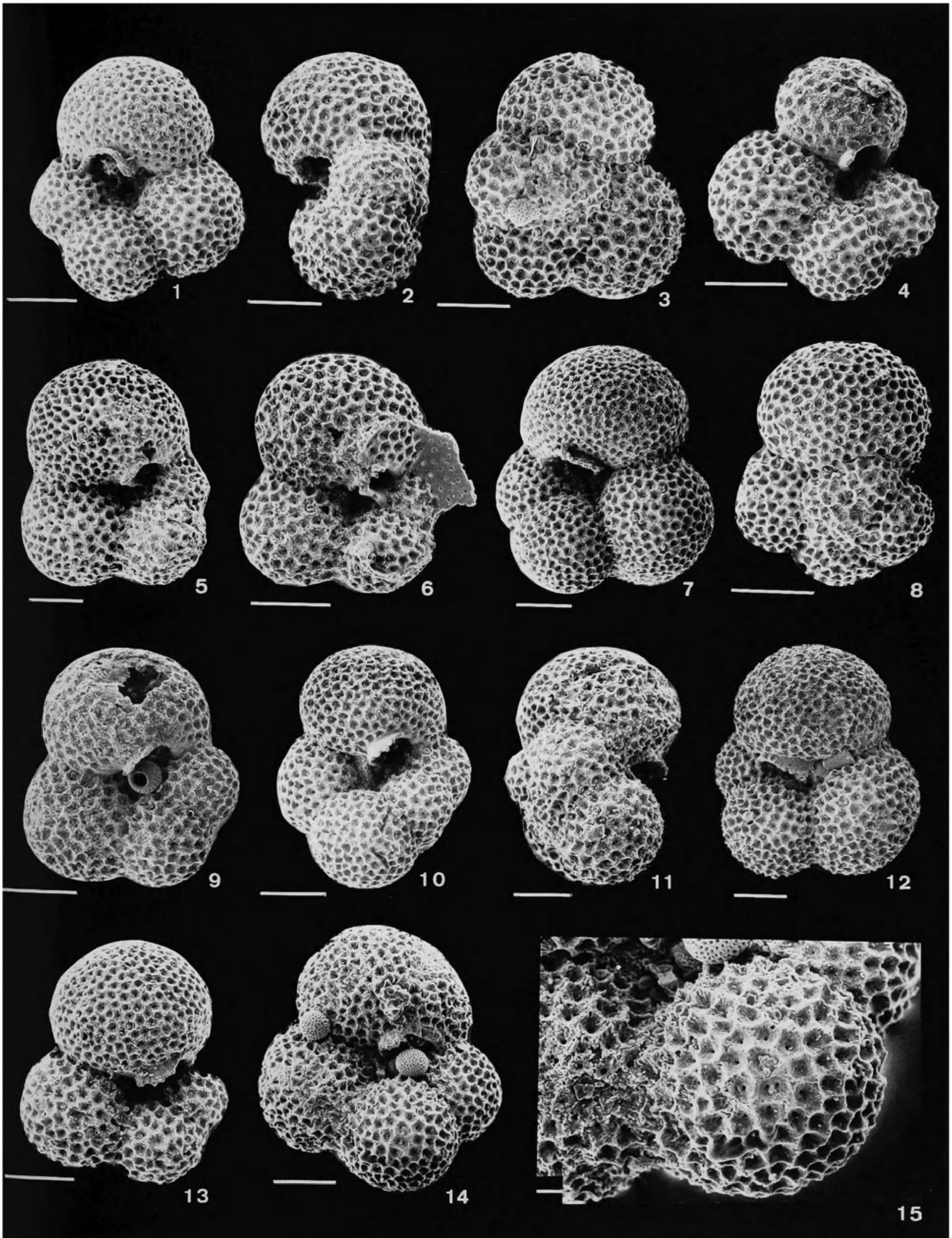

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

PLATE 26

Subbotina triangularis (White, 1928)

(Figures 1–11: bars = 100 μm; Figure 12: bar = 10 μm; Figure 13: bar = 4 μm)

FIGURES 1, 3, 7, 8, 12, 13.—Zone P4, Vincentown Fm., Glendola Well, New Jersey, sample 286–287 feet; Figure 12 (view of 3rd chamber of Figure 11) and Figure 13 (view of 2nd chamber of Figure 8) showing spinose wall texture.

FIGURES 2, 4–6, 9, 11.—Zone P4, Velasco Fm., Tamaulipas, Mexico.

FIGURE 10.—Upper Paleocene, Khieu River, foraminifer beds.

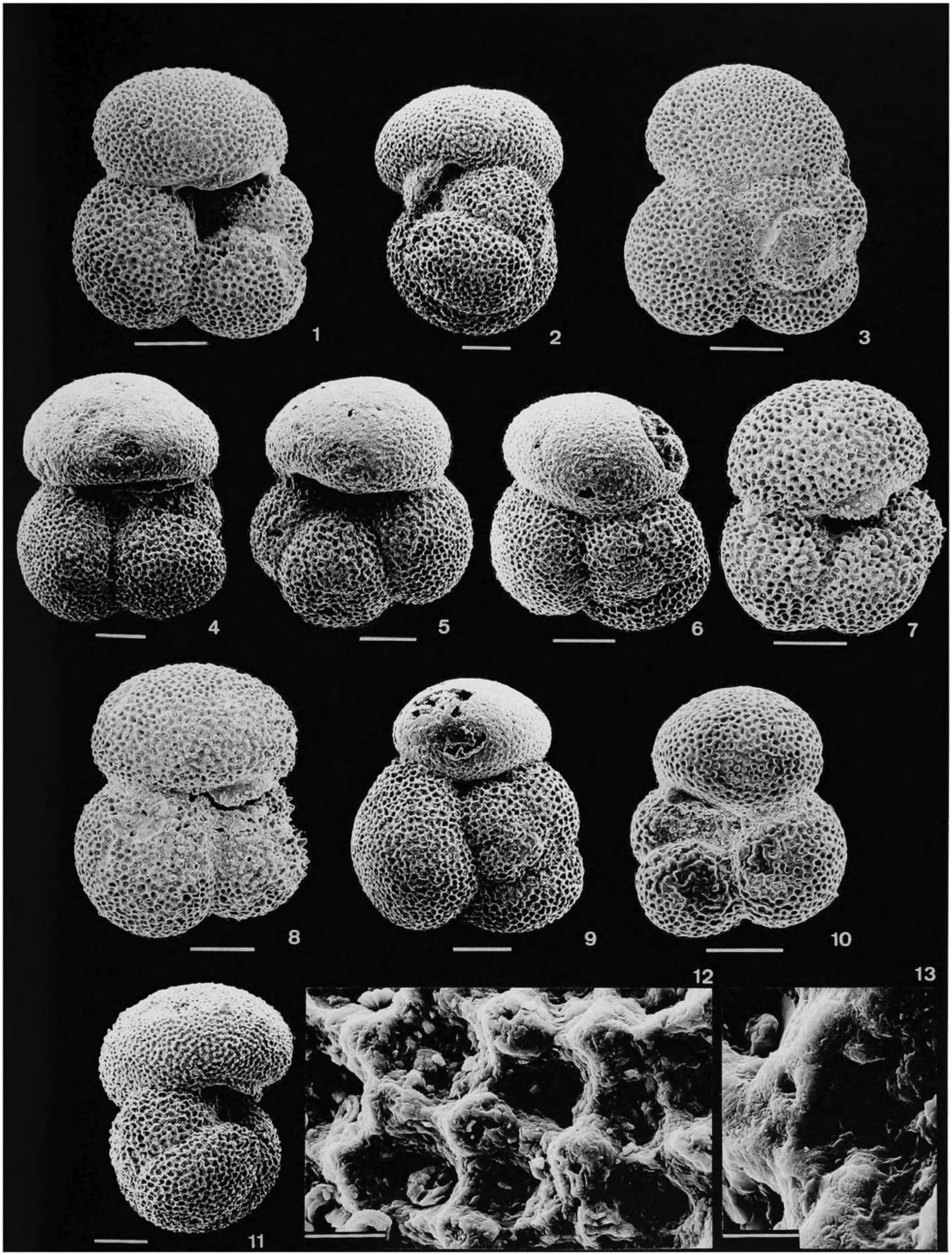

1
2
3
4
5
6
7
8
9
10
11
12
13

PLATE 27

Subbotina triloculinoides (Plummer, 1926)

(Figures 1–11: bars = 50 μm; Figures 12, 13: bars = 5 μm)

FIGURE 1.—Zone P4, DSDP Site 549/20/2: 69–71 cm.

FIGURES 2, 6, 7.—Zone P1c, Mexia Clay Mbr., Midway Group, Texas.

FIGURES 3, 10.—Zone P1b, Eureka Core, Gulf of Mexico, sample 6817–6817.5 feet.

FIGURES 4, 9, 12, 13.—Zone P1c, Wills Point Fm., Milam Co., Texas; Figure 12, view of 2nd chamber of Figure 9 showing cancellate spinose wall texture; Figure 13, view of spine hole on interpore ridge.

FIGURE 5.—Zone P1b, Eureka Core, Gulf of Mexico, sample 6820–6820.5 feet.

FIGURE 8.—Zone P1, DSDP Hole 390A/11/4: 80–82 cm; Blake-Bahama Basin, North Atlantic Ocean.

FIGURE 11.—Zone P4, DSDP Site 549/20/5: 20–22 cm; Goban Spur, eastern North Atlantic Ocean.

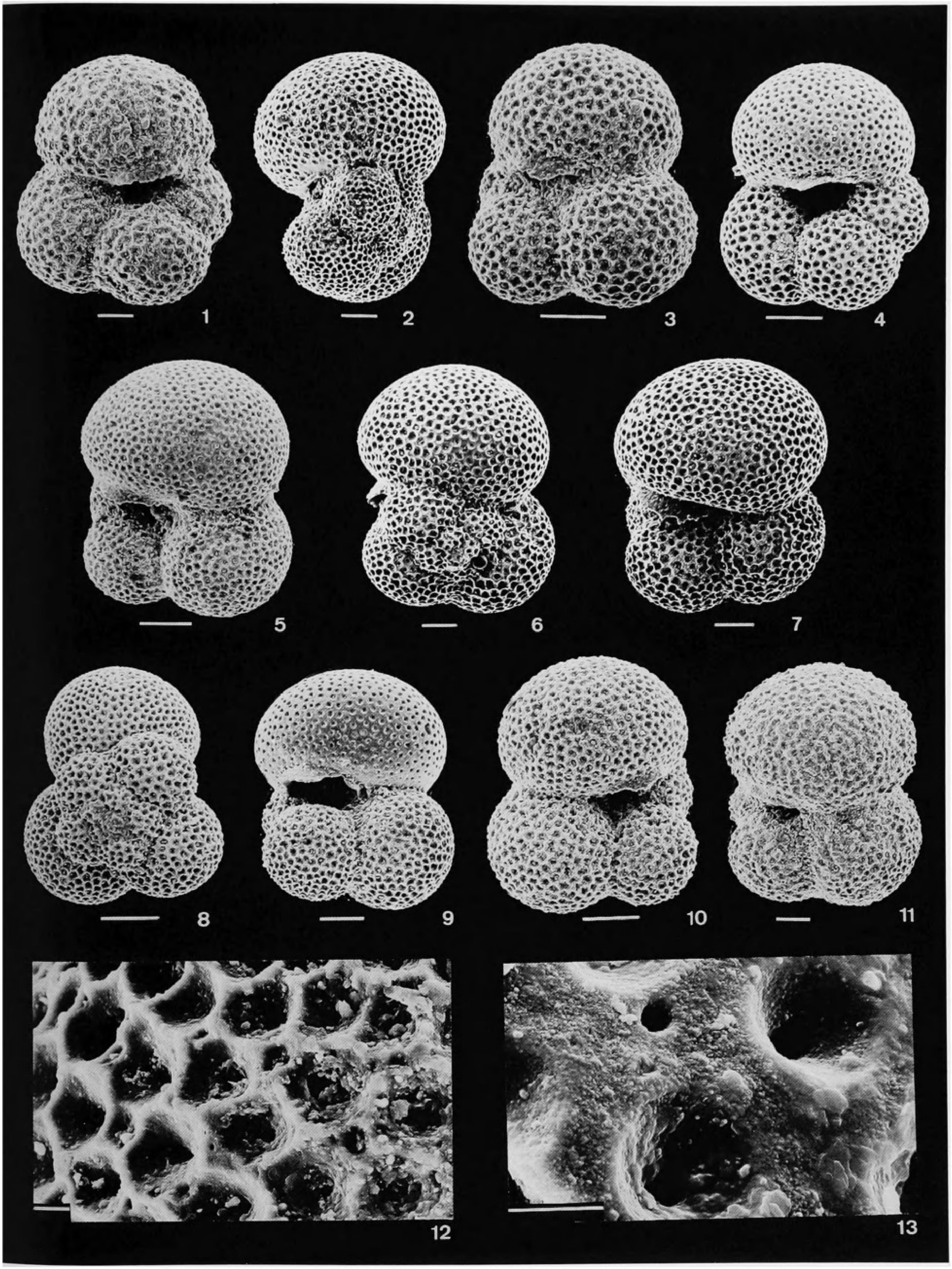

1
2
3
4
5
6
7
8
9
10
11
12
13

PLATE 28

Subbotina trivialis (Subbotina, 1953)

(Figures 1–11: bars = 100 μm; Figure 12: bar = 10 μm; Figure 13: bar = 4 μm)

FIGURE 1.—Zone P1c, upper Midway, Milam Co., Texas, sample 8030.

FIGURES 2, 5, 9.—Zone P1, DSDP Hole 390A/11/4: 80–82 cm; Maud Rise, Southern Ocean.

FIGURES 3, 10, 12, 13.—Zone P1a, Millers Ferry, Alabama, core 225, sample 194; Figures 12, 13, views of wall of Figure 10 showing cancellate spinose wall texture.

FIGURE 4.—Zone P1a, Eureka Core, Gulf of Mexico, sample 6826.5–6827.0 feet.

FIGURES 6–8, 11.—Zone P1a, DSDP Site 356/28/2: 144–145 cm; São Paulo Plateau, South Atlantic Ocean.

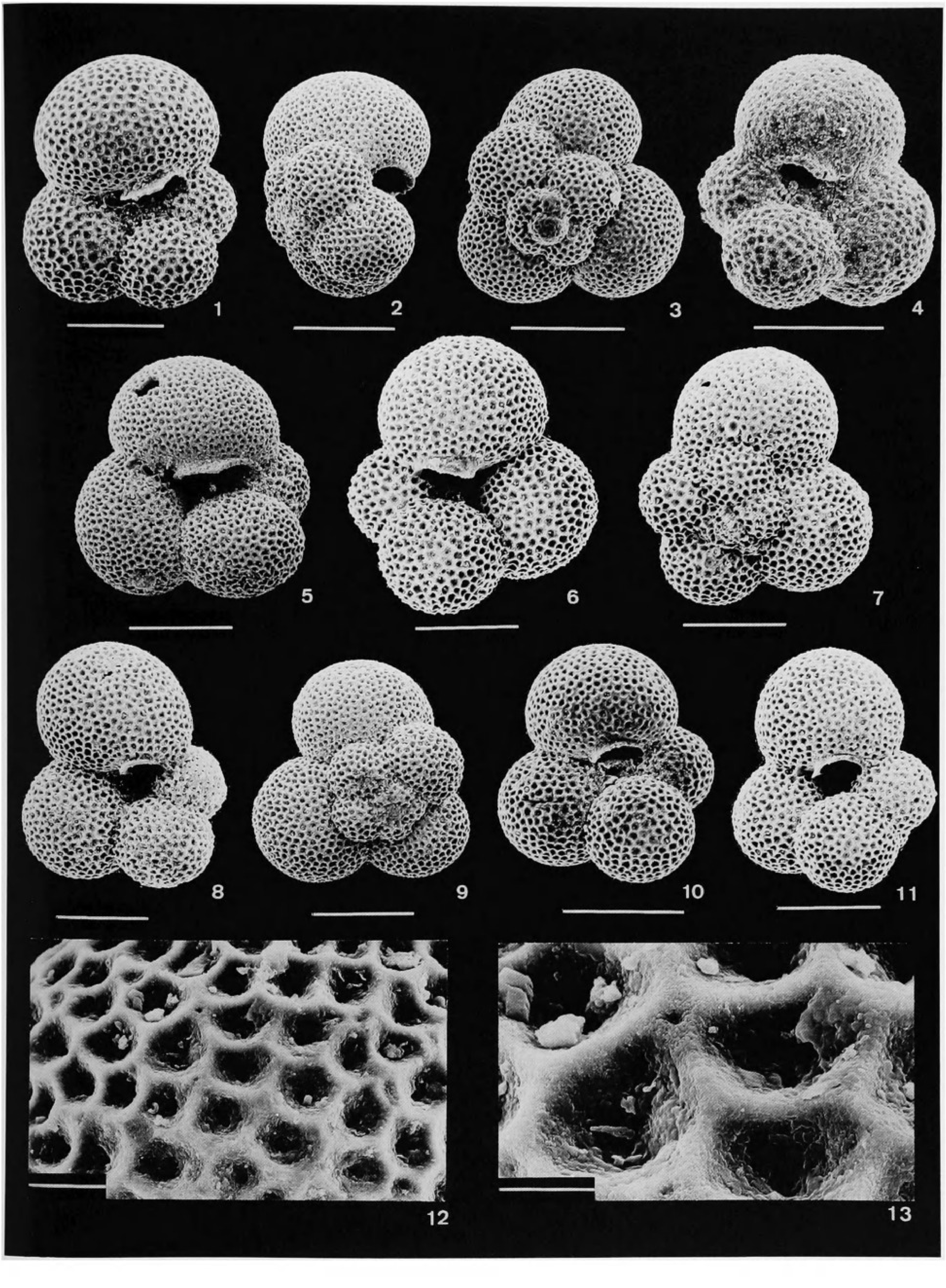

1
2
3
4
5
6
7
8
9
10
11
12
13

PLATE 29

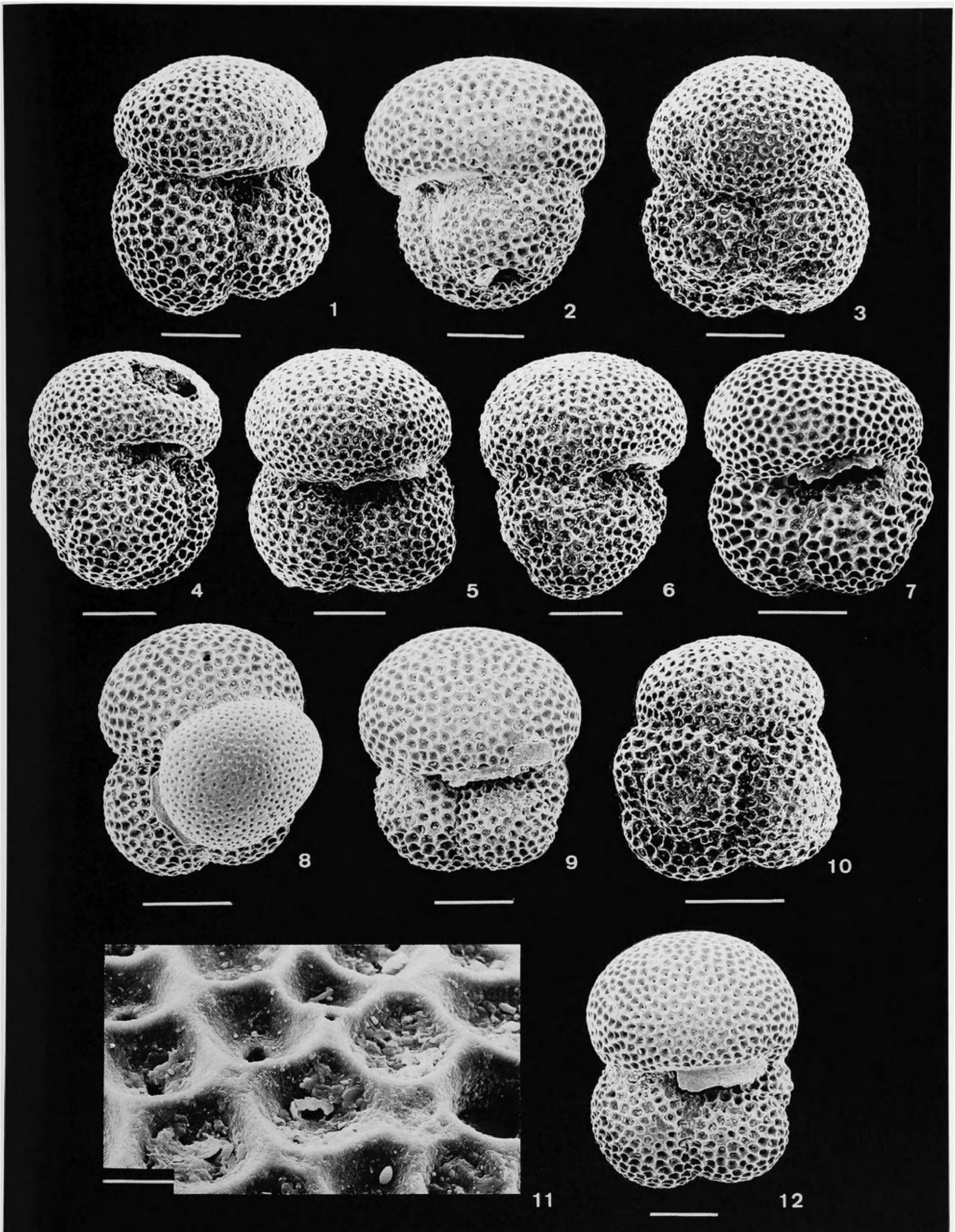
Subbotina velascoensis (Cushman, 1925)

(Figures 1–10, 12: bars = 100 μm; Figure 11: bar = 10 μm)

FIGURES 1, 3–6, 10.—Zone P4, Velasco Fm., Tamaulipas, Mexico.

FIGURES 2, 8, 9, 11, 12.—Zone P4, Glendola Well, New Jersey, sample 286–287 feet; Figure 11, view of wall of Figure 8 showing cancellate spinose wall texture.

FIGURE 7.—Zone P4, Nerinea Fm., Pondicherry, South India.


1
2
3
4
5
6
7
8
9
10
11
12