P2. *Praemurica uncinata–Morozovella angulata* Interval Zone (P2, defined in Berggren et al., 1995; emendation of, but biostratigraphically equivalent to, Zone P2 in Berggren and Miller, 1988).

Definition: Biostratigraphic interval between the FAD of *Praemurica uncinata* and the FAD of *Morozovella angulata.*

Magnetochronologic calibration: Chron C27n(o)–Chron C27n(y).

Estimated age: 61.2–61.0 mya; late early Paleocene (late Danian).

P3. *Morozovella angulata–Globanomalina pseudomenardii* Interval Zone (P3, defined in Berggren et al., 1995; emendation of Zone P3 in Berggren and Miller, 1988).

Definition: Biostratigraphic interval between the FAD of *Praemurica angulata* and the FAD of *Globanomalina pseudomenardii.*

Magnetochronologic calibration: Chron C27n(y)–Chron C26r (middle).

Estimated age: 61.0–59.2 mya; late Paleocene (Selandian).

P3a. *Morozovella angulata–Igorina albeari* Interval Subzone (P3a, defined in Berggren et al., 1995).

Definition: Biostratigraphic interval between FAD of *Morozovella angulata* and FAD of *Igorina albeari.*

Magnetochronologic calibration: Chron C27n(y)–Chron C26r (early).

Estimated age: 61.0–60.0 mya; early late Paleocene (Selandian).

P3b. *Igorina albeari–Globanomalina pseudomenardii* Interval Subzone (P3b, defined in Berggren et al., 1995).

Definition: Biostratigraphic interval between FAD of *Igorina albeari* and the FAD of *Globanomalina pseudomenardii.*

Magnetochronologic calibration: Chron C26r (early)–Chron C26r (middle).

Estimated age: 60.0–59.2 mya; late Paleocene (Selandian).

P4. *Globanomalina pseudomenardii* Total Range Zone (P4, Bolli, 1957a).

Definition: Biostratigraphic interval characterized by the total range of the nominate taxon, *Globanomalina pseudomenardii.*

Magnetochronologic calibration: Chron C26r (middle)–Chron C25n(y).

Estimated age: 59.2–55.9 mya; middle part of late Paleocene (late Selandian–Thanetian).

P4a. *Globanomalina pseudomenardii/Acarinina subsphaerica* Concurrent Range Subzone (P4a, defined in Berggren et al., 1995).

Definition: Biostratigraphic interval characterized by the concurrent range of the nominate taxa between the FAD of *Globanomalina pseudomenardii* and the LAD of *Acarinina subsphaerica.*

Magnetochronologic calibration: Chron C26r (middle)–Chron C25r (early).

Estimated age: 59.2–57.1 mya; late Paleocene (latest Selandian–early Thanetian).

P4b. *Acarinina subsphaerica–Acarinina soldadoensis* Interval Subzone (P4b, herein defined).

Definition: Biostratigraphic interval between the LAD of *Acarinina subsphaerica* and the FAD of *Acarinina soldadoensis.*

Magnetochronologic calibration: Chron C25r (early)–Chron C25r (late).

Estimated age: 57.1–56.5 mya; late Paleocene (Thanetian).

P4c. *Acarinina soldadoensis/Globanomalina pseudomenardii* Concurrent Range Subzone (P4c, defined in Berggren et al., 1995).

Definition: Biostratigraphic interval characterized by the concurrent range of the nominate taxa between the FAD of *Acarinina soldadoensis* and the LAD of *Globanomalina pseudomenardii.*

Magnetochronologic calibration: Chron C25r (late)–Chron C25n(y).

Estimated age: 56.5–55.9 mya; late Paleocene (late Thanetian).

P5. *Morozovella velascoensis* Interval Zone (P5, Bolli, 1957a; P5 and P6a of Berggren and Miller, 1988).

Definition: Biostratigraphic interval between the LAD of *Globanomalina pseudomenardii* and the LAD of *Morozovella velascoensis.*

Magnetochronologic calibration: Chron C25n(y)–Chron C24r (middle).

Estimated age: 55.9–54.7 mya; latest Paleocene–earliest Eocene (latest Thanetian–earliest Ypresian).

Wall Texture, Classification, and Phylogeny

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

The recovery of early Paleocene planktonic foraminifera following the end of the Cretaceous mass extinctions led to fundamental changes in the wall structure of the test, changes linked to the way in which the earliest Paleocene species adapted to the water-mass environment. These changes in wall structure, consequently, reflect biological activity. Five species are known to have survived into the Paleocene. We believe that the planktonic foraminiferal species that came to occupy the Paleocene oceans were derived from three survivors, which rapidly gave rise to distinct lineages. The structural differences in the test wall allow basic groups to be recognized. Two groups are separated by pore size, one being microperforate (pore diameter < 1 μm) and the other normal perforate (pore diameter 2–7 μm). The microperforate species, which evolved from the survivor-species *Guembelitria cretacea,* have been dealt with in various studies (D'Hondt, 1991; Liu and Olsson, 1992). In the earliest Paleocene (Danian), trochospiral and biserial microperforate taxa evolved from a triserial taxon. Although there are fundamental changes that occurred in the shape of the test, the wall structural changes are moderate (a thin wall pierced by micropores, and pustule growth in rounded mounds or short, sharp protuberances).

Wall structure changes in normal perforate planktonic foraminifera were often quite dramatic. Most notable is the development of a cancellate wall that is a distinctive and diagnostic feature of the Cenozoic. This feature, which developed in two groups, one with spines and the other without spines, indicates that the biological activities of planktonic species that possessed this structure were significantly different from the biological activities in Cretaceous species where this structure is absent. Another dramatic wall structural change was the development of the "pseudospinose" (Benjamini and Reiss, 1979) or "muricate" wall (Blow, 1979), identified by a heavy pustulose growth. All the taxa in this group can be separated phylogenetically on the basis of their distinctive pustulose wall texture. Perhaps the most dramatic change in wall structure was the development of spines, which was accompanied by growth of a cancellate wall. Wall growth in species using spines is different from wall growth in nonspinose pustule bearing species. Pustules are layered structures, which form during ontogeny as part of the wall, in contrast to spines, which are elongated single crystals planted in the shell wall (Hemleben, 1969; Hemleben, et al., 1991). Pustulose growth is rare in spinose species. Due to the development of these distinctive wall structures Paleocene normal perforate planktonic foraminifera can be classified and organized in phylogenetic lineages.

A classification based on functional morphology is somewhat more complex than one based on simple test morphology as it presumes that one can correctly interpret the function of a structure in an extinct species. In the Paleocene this is made easier because direct comparison can be made to living planktonic species in which there is much data on the function of test morphology and biological activity (Hemleben et al., 1977, 1985, 1989, 1991). The basic underlying bilamellar wall concept of Reiss (1957) can be applied to all known Paleocene planktonic foraminiferal species. The introduction of spines in the earliest Danian allowed planktonic foraminifera to develop a different habit of food gathering and to invade different habitats. It is possible that some species may have collected symbionts as is suggested by the carbon isotopic studies of D'Hondt and Zachos (1993) on *Eoglobigerina eobulloides.* Thus, photosymbiosis may have developed along with the evolution of some of the first spinose planktonic species of the Cenozoic. Species having symbionts would have been bound to the photic zone.

The nonspinose planktonic foraminifera are distinguished by two basic types of wall texture, smooth-walled and cancellate-walled. In the smooth-walled type, pustules may be absent, sparsely developed, or heavily developed as is observed in modern *Globorotalia.* Heavy pustule development in the Paleocene led to the "muricate structure," which characterizes the genera *Acarinina* and *Morozovella.* The cancellate texture develops by lateral growth of small pustules into smooth ridges upon which additional pustules may grow. This texture is observed in the modern *Neogloboquadrina dutertrei.*

It would appear, then, that some adaptations that evolved in Paleocene species of planktonic foraminifera are similar, if not identical in some cases, to the adaptations that are shown by living species of planktonic foraminifera. Because wall texture reflects the adaptive strategies exhibited in the biological activity of living species, it may be an important guide to phylogenetic study. We regard this relationship as a unifying concept in the classification and phylogenetic study of Cenozoic planktonic foraminifera. Although more work needs to be done on wall texture and morphologic change in the evolution of Paleogene planktonic species, it seems clear from the results of the Paleogene Planktonic Foraminifera Working Group that wall texture provides a guide to understanding the evolution and phylogeny of Paleocene planktonic foraminiferal species and for their classification (Plates 1–6).

GLOBOROTALIID WALL TEXTURE

The globorotaliid type, which includes the juvenile up to the neanic stage (Brummer et al., 1986), is characterized by a smooth nonspinose wall with more or less scattered pustules. Pustules increase in number during ontogeny, serving as anchor points for rhizopods (Plate 1: Figures 1, 2, 5, 6; Plate 3). During continued growth, more pustules form on the center of the spiral side, around the aperture, and, if a keel is present, on the keel. The last growth stage may be characterized by a coarse crystal growth or the pustules may coalesce to form a coarse crystalline outer layer (Plate 3: Figures 10, 11, 14). The abundance of pustules varies from species to species. The interpustule area is usually smooth with no or very low relief. Some typical living representatives of this type are *Globorotalia hirsuta, G. menardii, G. truncatulinoides* and others (Hemleben et al., 1977, 1985, 1991), and their ancestors. The Paleocene genus *Globanomalina* has this type of wall texture (Plate 4: Figures 4–13, 16). The smooth-walled genus *Globanomalina* was derived from the late Maastrichtian hedbergellid, *Hedbergella holmdelensis,* with the first species being *G. archeocompressa* (Plate 4: Figures 4, 5). In this transition, the morphologic characters of the descendant species (compressed test with an imperforate peripheral band and with an extraumbilical aperture bordered by a narrow lip) are derived from the ancestral species. The wall of *H. holmdelensis* is smooth with scattered small pustules on the chamber walls (Plate 4: Figures 1–3). In *G. archeocompressa* the pustules become confined to the umbilical area rather than being scattered over the entire test. A change to somewhat more angular-shaped chambers accompanies the transition. Although the change in overall morphology is small, the wall becomes distinctly smooth, a character that identifies species of *Globanomalina* and its possible descendant, *Pseudohastigerina.*

MURICATE WALL TEXTURES

In the Paleocene, a heavily pustulose wall texture occurs in the genera *Acarinina* and *Morozovella* (Plates 39–55). The test wall is characterized by large very coarse pustules that may cover the entire test, be concentrated on the umbilical shoulders, or be confined to the periphery of the test and forming a keel (Plate 4: Figures 14, 15; Plate 5: Figures 1–4). The pustules grow on a smooth globorotaliid surface. In the first species of *Acarinina, A. strabocella,* the early ontogenetic stage has a rather smooth wall resembling that of modern globorotaliid species, but later in ontogeny (or chamber calcification) the typical pustule pattern appears, which is similar to that in modern *Globorotalia inflata* (Plate 3: Figures 3, 4, 7). The pustules are spread over the entire test; however, they are arranged in lines leading towards the aperture and are especially large and thick in front of the aperture (see Plate 43: Figure 4). This development is a short step to the more typical heavily pustulose acarininids in which the pustules become broad and elongate (Plates 39–42, 44). The wall texture develops by the growth of conical to blade-like pustules at triple points between the pores. As these pustules grow larger they coalesce into larger structures, which give the muricate wall a somewhat cancellate appearance. Pustule enlargement is greatest around the umbilicus and often completely closes off the pores.

In the evolution of *Morozovella* two groups of species are separated by different types of muricate wall texture. The muricate wall texture in the *Morozovella aequa* line of species develops by growth of conical pustules of various sizes at triple points between pores on rather smooth chamber walls (Plates 47–49, 54). Heavier pustule growth occurs on the umbilical shoulders of the chambers and along the test periphery forming an imperforate muricate keel in some species. In the *Morozovella velascoensis* line of species the surface of the chambers are smooth (Plates 45, 46, 50–52, 55). Very heavy conical pustule growth occurs on the umbilical shoulders of the chambers and along the axial periphery of the test forming a strong, imperforate muricate keel. Scattered small pustules also may occur on the chamber surfaces. Extensions of the muricate keel occur on the spiral side of the test along the chamber sutures and the spiral suture. The genus *Morozovella* is further characterized by the development of conical-shaped chambers.

NEOGLOBOQUADRINID WALL TEXTURE (PRAEMURICATE)

This type of wall texture is seen in the living species *Neogloboquadrina dutertrei* (Plate 5: Figures 5–11). The growth pattern during ontogeny consists of the development of longer or shorter subparallel low ridges of plate-like crystals, often oriented towards the aperture (Plate 5: Figures 9, 10). They become more and more prominent as short ridges connecting the subparallel ones start to grow and, eventually, form a honeycomb cancellate wall structure (Hemleben et al., 1991). The short ridges are less developed and may extend only part way from one elongate ridge to the other (Plate 5: Figures 9, 10). It is a very common structure in Paleogene and Neogene planktonic foraminifera. This type of wall texture occurs in the Paleocene genera *Igorina* and *Praemurica* (Plates 56–62). A calcite crust (Plate 5: Figures 8, 11), which is a normal feature in *Neogloboquadrina,* has not yet been observed in Paleocene species. This is probably due to the warmer Paleocene surface waters as this crust is a feature usually developed in the cold waters of the modern ocean. In the modern *N. dutertrei,* however, as pustule growth becomes more and more prominent the test wall becomes thicker and encrusted, a feature that also is observed in *Igorina* (Plates 56–58). In Zone P0 the transition from the ancestral Maastrichtian *Hedbergella monmouthensis* to *Praemurica* involves the buildup of subparallel pustulose ridges and short connective ridges, thus producing the cancellate texture (Plate 5: Figures 12, 18; Plate 6: Figures 1–4). In *Praemurica taurica* (Plate 61), the first *Praemurica* species, the test remains a very low trochospiral with an extraumbilical aperture, but selection is to a *H. monmouthensis* morphotype with a lower rate of chamber expansion in the ultimate whorl (six-chambered test). In order to avoid confusion with the term neogloboquadrinid we propose the use of praemuricate for Paleocene taxa with this wall texture.

SPINOSE WALL TEXTURE

The spinose habit indicates that a group of new planktonic foraminifera intruded into the carnivorous food niche. The food catching process is supported by long calcitic spines along which flows the rhizopodial cytoplasm. Actively swimming zooplankton are snared and held without losing control of a struggling zooplankton organism. The spines are separated from the wall and are planted like telephone poles (Plate 1: Figures 3, 4, 7–20). During the reproductive process (gametogenesis) the spines are dissolved, leaving a vacated spine hole as an indication of the spinose condition, and gametogenetic calcite is deposited along the interpore ridges (Plate 2: Figures 2–16). More fundamental changes in wall texture and test morphology took place in the transition from *Hedbergella monmouthensis* to the spinose genera *Eoglobigerina* and *Parasubbotina* (Plates 18–23). The fundamental morphologic characters (trochospiral test with an extraumbilical aperture bordered by a narrow lip) are maintained in the descendent species, but the evolution of wall texture involves the innovation of a cancellate spinose wall. In *H. monmouthensis* the wall is lightly pustulose throughout the test, and low depressions or primitive pore pits occur in the chamber walls especially surrounding the umbilicus (Plate 31). The test is a very low trochospiral with rapidly inflating chambers in the ultimate whorl, but as noted in Liu and Olsson (1994), there is a range of morphotypes that show (1) a reduced rate of chamber-size increase with generally six chambers in the ultimate whorl, and (2) a moderately elevated trochospiral test with five chambers in the ultimate whorl. In the transition to the first spinose species, *Eoglobigerina eobulloides,* the moderately elevated trochospiral test becomes weakly cancellate and spinose (Plate 19). The cancellate texture is enhanced by gametogenetic calcification. Due to the moderately elevated trochospiral test the aperture shifts to a more umbilical position and is only slightly extraumbilical. In the derivation of *Parasubbotina* (Plates 21, 22) the rate of chamber increase is much more rapid than in *Eoglobigerina,* which produces a very low trochospiral test with large globular chambers in the ultimate whorl. The wall becomes weakly cancellate and spinose. The aperture remains extraumbilical. *Subbotina* (Plate 2: Figures 3–6, 15, 16; Plates 24–29) evolves from *Eoglobigerina* by a reduction in the number of chambers in the final whorl, a shifting of the aperture towards an umbilical position, and the development of a stronger cancellate-wall texture.

PRESERVATION AND DIAGENESIS

Preservation of fossil planktonic foraminifera plays an important role in taxonomic and phylogenetic studies. The effect of the lysocline and the carbonate compensation depth controls the preservation or partial preservation of an assemblage of planktonic foraminifera. Absence of a species could be due to its greater susceptibility to dissolution than other species, thereby leading directly to loss of information. Preservation of planktonic foraminifera can be loosely measured by visual inspection under the light microscope and more recently by the SEM. It is especially important to assess the degree of preservation of foraminifera tests in isotopic analyses, but it is also important in various other studies utilizing planktonic foraminifera. For instance, in taxonomic and phylogenetic studies, the degree of preservation may appear to be excellent (pristine) preservation under the light microscope but may actually be rather poor when examined using the SEM under high magnification. In working out phylogenetic lineages it is important to be able to recognize the original wall texture in order to assess whether an ancestor–descendant relationship exists. Preservation is an important factor in census work where many individuals of a species have to be accurately identified for the data to be meaningful. Census work should not be attempted where the tests of foraminifera are heavily recrystallized and overgrown, thus making identification very subjective due to similar morphology of different species. Plate 7 illustrates common types of diagenetic alteration of a planktonic foraminiferal test.

Recrystallization can vary from slight to heavy (Plate 7: Figures 1, 2, 5–8, 10–15). If the degree of recrystallization is substantial, subhedral and euhedral calcite crystals form and obscure the original wall (Plate 7: Figure 12). Overgrowth of calcite (Plate 7: Figures 4, 8, 10) further obscures the original wall. Corrosion of a test removes the outer wall layers (Plate 7: Figures 3, 5, 6) thereby destroying the original wall texture. Dissolution (Plate 7: Figures 3, 9) may destroy parts of the test wall leaving holes or may strip away outer wall layers, altering the appearance of the specimen. Accurate identification is precluded under such circumstances. Plates 1–6 illustrate well-preserved original wall texture that can be used as a guide in assessing the effects of diagenesis on samples of fossil planktonic foraminifera.

PHYLOGENY

The phylogeny of the normal perforate Paleocene planktonic foraminifera is shown in Figure 5*a,b* and that of the microperforate Paleocene planktonic foraminifera is shown in Figure 6. Comments on the phylogeny of the microperforates are given under each species in the Taxonomy section (also see D'Hondt, 1991; Liu and Olsson, 1992). The lineages of the normal perforates based on the study of wall texture is given below along with comments on the major morphologic changes that occurred in the evolution of the species in each lineage.

Spinose Lineages

CANCELLATE LINEAGES

Eoglobigerina

(PLATES 18–20)

E. eobulloides–E. edita–E. spiralis lineage is characterized by
(1) a cancellate spinose test;
(2) development of a higher trochospiral test in *E. edita* and *E. spiralis*;
(3) a reduced rate of chamber expansion in *E. edita* compared to *E. eobulloides*;
(4) a more strongly developed cancellate wall that is enhanced by gametogenetic calcification in *E. edita* and *E. spiralis.*

E. eobulloides–Subbotina lineage is characterized in the transition to *Subbotina* by
(1) a more strongly developed spinose cancellate wall;
(2) a reduced number of chambers in the ultimate whorl;
(3) development of a tripartite test due to a more rapid rate of chamber-size increase;
(4) a more umbilically directed aperture in *Subbotina.*

NOTE.—In *E. eobulloides* the aperture has an umbilical to slightly extraumbilical position due to the moderately elevated trochospire. In *Subbotina* the increase in the rate of expansion of chambers causes the aperture to shift to a more umbilical position. This trend culminates in *S. triloculinoides* by producing a large ultimate chamber with an umbilically directed aperture. The lip maintains its position relative to the apertural opening. With a greater expansion rate of chambers, the initial moderately elevated coil is enveloped by the expanding chambers thus producing a test with an apparent low trochospire.

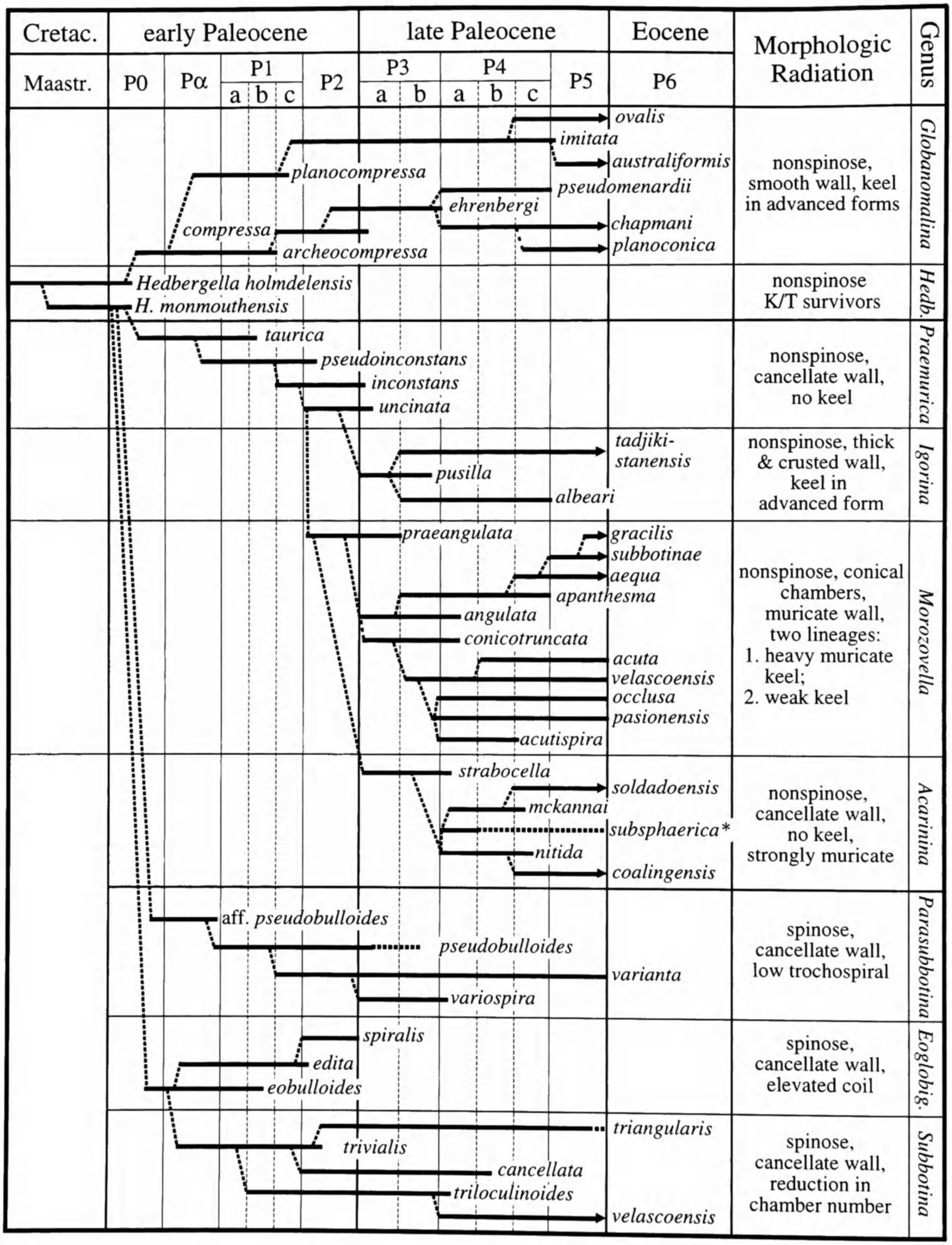

FIGURE 5*a*.—Phylogenetic reconstruction of normal perforate planktonic foraminifera showing the origin of *Morozovella* from *Praemurica uncinata* following the hypothesis of Bolli (1957a). See text for explanation. (* dashed line represents range extension at southern high latitude sites.)

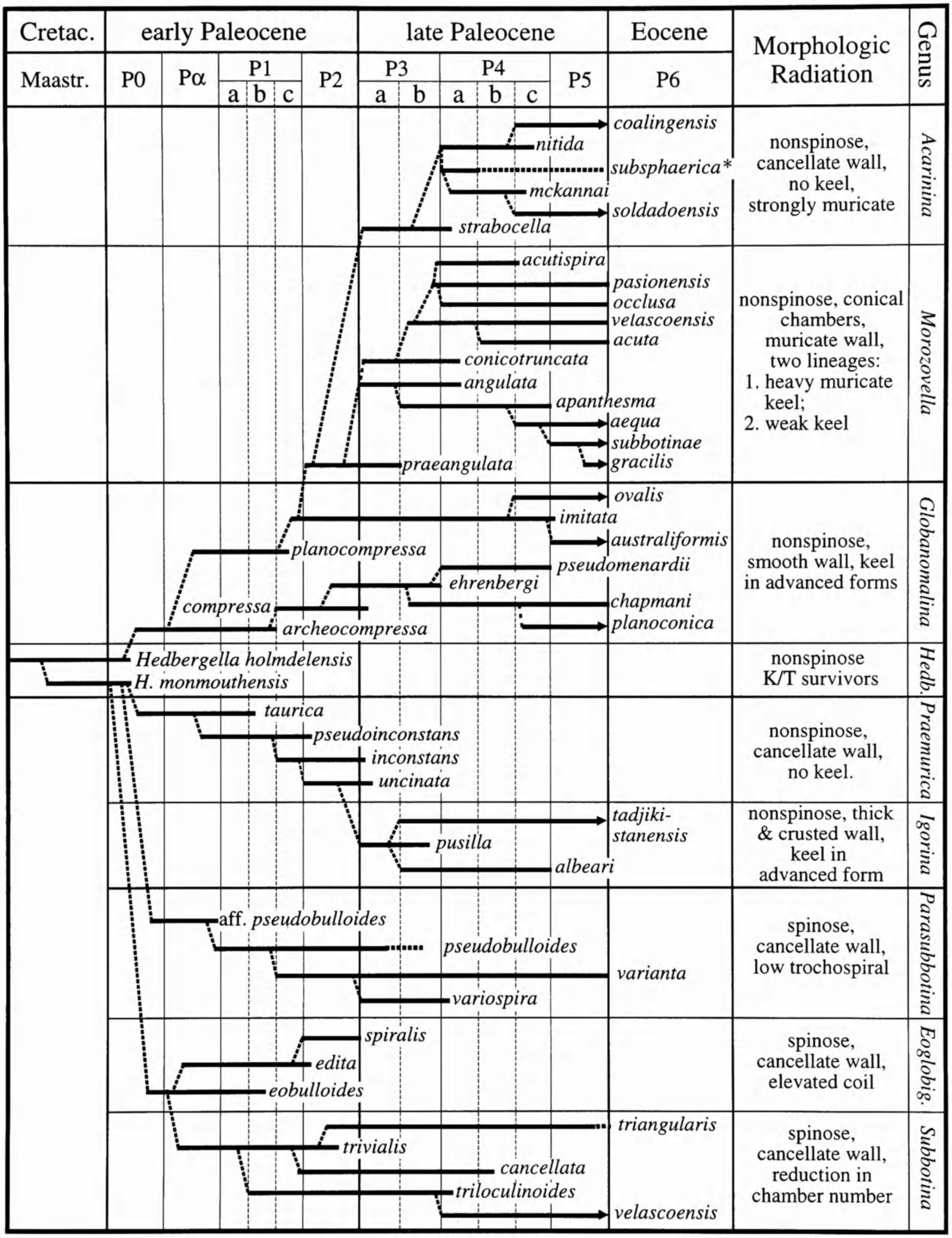

FIGURE 5*b*.—Phylogenetic reconstruction of normal perforate planktonic foraminifera showing the origin of *Morozovella* from *Globanomalina imitata* following the interpretation of Olsson and Hemleben (1996). See text for explanation. (* dashed line represents range extension at southern high latitude sites.)

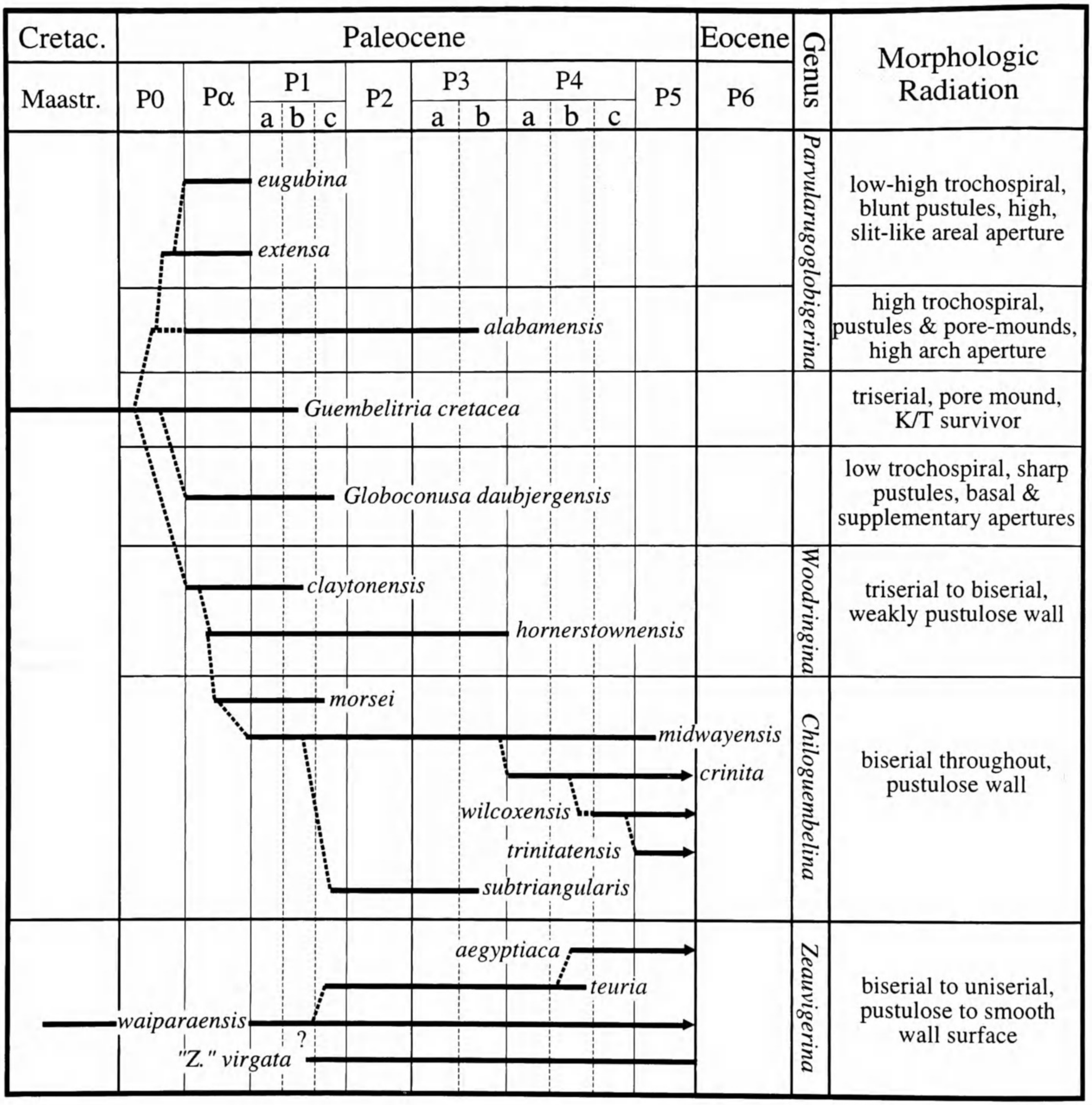

FIGURE 6.—Phylogenetic reconstruction of microperforate planktonic foraminifera and *Zeauvigerina*.

Parasubbotina

(PLATES 21–23)

P. aff. *pseudobulloides*–*P. pseudobulloides*–*P. varianta* lineage is characterized by
(1) a weakly developed cancellate spinose wall in *P.* aff. *pseudobulloides*;
(2) development of a pronounced cancellate spinose wall that is enhanced by gametogenetic calcification in *P. pseudobulloides*;
(3) an increase in test size in *P. pseudobulloides*;
(4) a decreased number of chambers in the ultimate whorl in *P. varianta*;

P. varianta–*P. variospira* lineage is characterized by
(1) an increased expansion of the chamber coil and a shift to a moderately elevated trochospire in *P. variospira*;
(2) a decreased rate of expansion of chambers in *P. variospira*;
(3) a test-size increase in *P. variospira*;
(4) development of tooth-like apertural lips in *P. variospira*.

NOTE.—*Parasubbotina* is distinguished from *Subbotina* by its very low trochospire, the greater number of chambers in the ultimate whorl, and high-arched umbilical–extraumbilical aperture.

Subbotina

(PLATES 24–29)

S. trivialis–*S.* aff. *cancellata*–*S. cancellata*–*S. velascoensis* lineage is characterized by
(1) development of a coarsely cancellate spinose wall in *S. cancellata;*
(2) a more rapid rate of chamber-size increase that ultimately closes the umbilicus in *S. velascoensis*;
(3) a test-size increase in the lineage;
(4) development of flattened, oval-shaped chambers in *S. velascoensis.*

S. trivialis–*S. triloculinoides* lineage is characterized by
(1) a more strongly developed cancellate spinose wall in *S. triloculinoides*;
(2) a more rapid rate of chamber-size increase that ultimately closes the umbilicus in *S. triloculinoides*;
(3) a test-size increase in *S. triloculinoides.*

S. trivialis–*S. triangularis* lineage is characterized by
(1) development of an asymmetric cancellate spinose pore pattern with well-developed coalescing spine collars in *S. triangularis*;
(2) development of wider than high oval-shaped chambers in *S. triangularis*;
(3) increased test size in *S. triangularis.*

NOTE.—The widening of the chambers in *S. triangularis* causes the umbilicus to open more than in *S. trivialis* and also lengthens the lip so that it becomes long and narrow.

Nonspinose Lineages

PRAEMURICATE LINEAGES

Praemurica

(PLATES 59–62)

P. taurica–*P. pseudoinconstans*–*P. inconstans*–*P. uncinata* lineage is characterized by
(1) development of a praemuricate cancellate nonspinose wall texture in *P. taurica* in the transition from *Hedbergella monmouthensis*;
(2) increased number of chambers in the final whorl in *P. taurica*;
(3) development of subconical-shaped chambers in the transition from *P. inconstans* to *P. uncinata.*

Igorina

(PLATES 56–58)

Praemurica uncinata–*Igorina* lineage is characterized by
(1) development of a thick, encrusted pustule layering over the praemuricate wall in the transition from *Praemurica* to *Igorina*;
(2) development of slightly conical to elongate oval-shaped chambers in *Igorina*;
(3) development of a somewhat elevated trochospire in *Igorina.*

I. pusilla–*I. albeari* lineage is characterized by
(1) low conical chambers in the lineage;
(2) development of a peripheral keel in *I. albeari.*

I. pusilla–*I. tadjikistanensis* lineage is characterized by
(1) development of inflated ovoid-conical chambers in *I. tadjikistanensis.*

SMOOTH-WALLED LINEAGE

Globanomalina

(PLATES 32–38)

G. archeocompressa–*G. compressa*–*G. ehrenbergi*–*G. pseudomenardii* lineage is characterized by
(1) a compressed test with an imperforate peripheral margin that becomes keeled in *G. pseudomenardii*;
(2) increased size and rate of expansion of chambers in the lineage;
(3) a change in chamber shape from compressed ovoid in *G. archeocompressa*–*G. ehrenbergi* to low conical in *G. pseudomenardii.*

G. compressa–G. chapmani–G. planoconica lineage is characterized by
(1) a compressed, nearly planispiral test with an imperforate peripheral margin that becomes thickened into a blunt keel in *G. planoconica*;
(2) increased size and rate of expansion of chambers in *G. chapmani*;
(3) decreased rate of expansion of chambers, increased number of chambers in the ultimate whorl, and reduced test size in *G. planoconica*.

G. archeocompressa–G. planocompressa–G. imitata–G. ovalis lineage is characterized by
(1) a low trochospiral, nearly planispiral test with rapidly inflating globular chambers in *G. planocompressa–G. imitata*;
(2) a largely perforate peripheral margin in the lineage;
(3) a large extraumbilical aperture that extends slightly onto the spiral side in *G. ovalis*.

G. imitata–G. australiformis lineage is characterized by
(1) development of low conical chambers in *G. australiformis*;
(2) development of fine pustules covering the test walls;
(3) increased test size in *G. australiformis*.

MURICATE LINEAGES

Acarinina

(PLATES 39–44)

A subtle but significant coiling change, which is first observed in the ancestral species *Acarinina strabocella,* occurs in the development of *Acarinina*. In *A. strabocella,* the coil becomes slightly elevated, thereby shifting the aperture from an extraumbilical to a more umbilical position (Plate 43). This evolved character is maintained in all subsequent species of *Acarinina*.

Morozovella praeangulata–Acarinina strabocella lineage is characterized by
(1) development of a muricate wall texture in *M. praeangulata*;
(2) development of oval-elongate chambers in *A. strabocella*;
(3) development of a slightly elevated trochospire in *A. strabocella*;
(4) a more umbilically directed aperture in *A. strabocella*.

NOTE.—The muricate wall is developed by growth of pustules on a smooth surface at triple points between the pores; moderate to strong pustule growth occurs on the umbilical shoulders surrounding the aperture. The elevated trochospire in *A. strabocella* causes the aperture to take a more umbilical position and tends to close off the umbilicus.

A. strabocella–A. nitida lineage is characterized by
(1) development of muricate wall texture;
(2) development of a more elongate chamber shape than in *A. strabocella*.

A. nitida–A. subsphaerica lineage is characterized by
(1) development of a higher trochospire and a more tightly coiled test in *A. subsphaerica*.

A. subsphaerica–A. mckannai lineage is characterized by
(1) development of muricate wall texture;
(2) oval-elongate chambers that are derived from *A. strabocella*.

A. mckannai–A. soldadoensis lineage is characterized by
(1) a change in chamber shape to less elongate-oval in edge view in *A. soldadoensis*.

A. nitida–A. coalingensis lineage is characterized by
(1) a change to more elongate-oval chambers in spiral view and less elongate-oval chambers in edge view in *A. coalingensis*;
(2) increased rate of chamber-size leading to a more tightly coiled test in *A. coalingensis*.

Morozovella

(PLATES 45–55)

As noted in the introduction, two opposing hypotheses of the phylogeny of the morozovellid lineage remain unresolved. The traditional view, based on the original hypothesis of Bolli (1957a), was adopted by Blow (1979), Toumarkine and Luterbacher (1985), and others. It derives *Morozovella* through the enhancement of the anguloconical chambers in the ultimate and penultimate whorls of *Praemurica uncinata* and further peripheral compression of the test, along with the development of a muricate test in *Morozovella* (see Plates 53 and 62). Other morphological features shared by the two genera relate to the interpretation of pore shape, development of muricae, umbilical morphology, and apertural morphology. In addition to these criteria, carbon and oxygen isotopic data are interpreted as supporting this phylogenetic hypothesis (Norris, 1996; Berggren and Norris, 1997). The alternate view (Olsson and Hemleben, 1996) emphasizes the development of the characteristic heavy pustulose wall texture of *Morozovella* from a smooth-walled *Globanomalina* ancestor, i.e., *G. imitata*. It is based on the observation that the wall texture of *Morozovella* develops through the growth of pustules on a smooth wall surface, thus linking this genus to *Globanomalina*. Anguloconical chambers and a lightly pustulose wall are observed in the inner whorl of *G. imitata* (see Plate 12: Figures 10–12; Plate 36). In contrast, the *Praemurica* wall texture develops as elongate subparallel ridges with short connective ridges, giving the wall a cancellate texture similar to the modern species

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 3½–6 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, 4–6½ 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].—

PLATE 1

Spinose and Nonspinose Wall Texture

FIGURE 1.—*Globorotalia hirsuta* (d'Orbigny), nonspinose smooth wall surface with scattered pustules, notice the size gradient of pustule distribution from the ultimate to the antiprepenultimate chambers (bar = 200 μm). Recent, plankton net catch, off Bermuda.

FIGURE 2.—*Globorotalia menardii* (Parker, Jones, and Brady), cross section of bilamellar wall, primary organic membrane (POM) spans across the pore cross section; during life the pore is closed by this organic layer in addition to organic pore fillings (bar = 10 μm). Recent, plankton net catch, Indian Ocean.

FIGURE 3.—*Globigerinoides ruber* (d'Orbigny), overall view of early adult stage showing spines implanted in test wall (bar = 100 μm). Recent, plankton net catch off Barbados, Caribbean Sea.

FIGURE 4.—*Globigerinoides sacculifer* (Brady), cross section showing POM and remanents of pore plate, organic pore lining, and terraced pore structure with plate-like crystals. Rather fine-grained crystals form the wall (bar = 2 μm). Recent, plankton net catch, Indian Ocean.

FIGURE 5.—*Globorotalia menardii* (Parker, Jones, and Brady), keel with small and medium-sized pustules growing on a very smooth surface (bar = 20 μm). Recent, Eltanin cruise 15 sample.

FIGURE 6.—*Globorotalia truncatulinoides* (d'Orbigny), tangential view and cross section of pustules showing layering indicating that pustules grow as part of the test wall (bar = 5 μm). Recent, DSDP Site 1/1/1: 1–4 cm.

FIGURE 7.—*Globigerinoides ruber* (d'Orbigny), cross section of wall showing broken spine that is separated from the wall. POM with part of the pore plate, inner organic lining (IOL), and organic pore lining (bar = 5 μm). Recent, plankton net catch, South Pacific Ocean.

FIGURE 8.—*Globigerina praebulloides* Blow, cross section of spine hole containing mold of a spine (bar = 2 μm). Upper Eocene, DSDP Hole 362A/7/5: 24–26 cm; Walvis Ridge, eastern South Atlantic Ocean.

FIGURE 9.—*Globigerinoides sacculifer* (Brady), overall view of surface of test showing regular cancellate structure with spines and spine holes (bar = 100 μm). Recent, plankton net catch off Barbados, Caribbean Sea.

FIGURE 10.—*Subbotina linaperta* (Finlay), overall view of surface of test showing same cancellate surface texture as above with spine holes (bar = 100 μm). Upper Eocene, DSDP Hole 362A/7/5: 24–26 cm; Walvis Ridge, eastern South Atlantic Ocean.

FIGURE 11.—*Globigerinoides ruber* (d'Orbigny), showing a less regular cancellate surface texture than *G. sacculifer* or *S. linaperta*. Note spine holes (bar = 100 μm). Recent, plankton net catch off Barbados, Caribbean Sea.

FIGURE 12.—*Globigerina bulloides* d'Orbigny, showing a more pitted surface due to rather isolated spine bases. Note spine holes in spine bases (bar = 100 μm). Recent, sediment trap off Bermuda, North Atlantic.

FIGURE 13.—*Globigerina praebulloides* Blow, same as Figure 8, above, but showing a rather thick wall (bar = 100 μm). Upper Eocene, DSDP Hole 362A/7/5: 24–26 cm; Walvis Ridge, eastern South Atlantic Ocean.

FIGURE 14.—*Globigerinoides sacculifer* (Brady), enlarged view of test wall showing spine holes left by the resorption of spines during gametogenesis (bar = 10 μm). Recent, plankton net catch off Barbados, Caribbean Sea.

FIGURE 15.—*Globigerinoides ruber* (d'Orbigny), enlarged view of test wall showing spine holes and some gametogenic calcification (bar = 10 μm). Recent, plankton net catch off Barbados, Caribbean Sea.

FIGURE 16.—*Globigerina bulloides* d'Orbigny, enlarged view of test wall showing spine holes (bar = 40 μm). Recent, plankton net catch, middle North Atlantic Ocean.

FIGURE 17.—*Globigerinoides sacculifer* (Brady), juvenile specimen showing a globorotaliid test with a smooth wall and a few spines (bar = 20 μm). Live specimen, Barbados.

FIGURE 18.—*Globigerinoides sacculifer* (Brady), showing crystal growth in surface view (bar = 20 μm). Live specimen, Barbados.

FIGURE 19.—*Globigerinoides sacculifer* (Brady), enlargement of Figure 18 showing the pore resorption (bar = 5 μm).

FIGURE 20.—*Globigerinoides sacculifer* (Brady), detail of cancellate structure of the pore funnel with plate-like crystal growth and spines (bar = 10 μm). Recent, Eltanin cruise 15 sample.

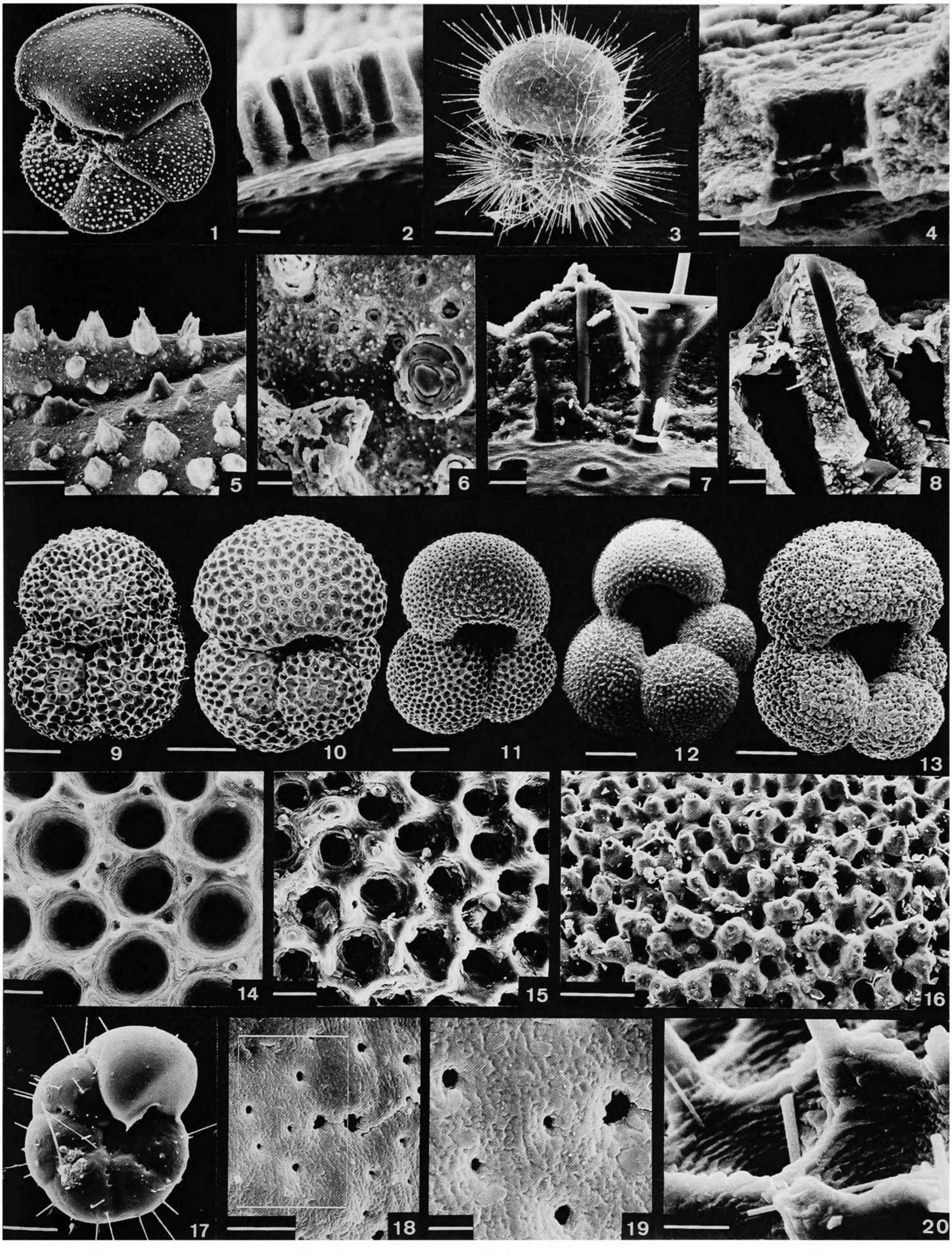
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PLATE 2

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.

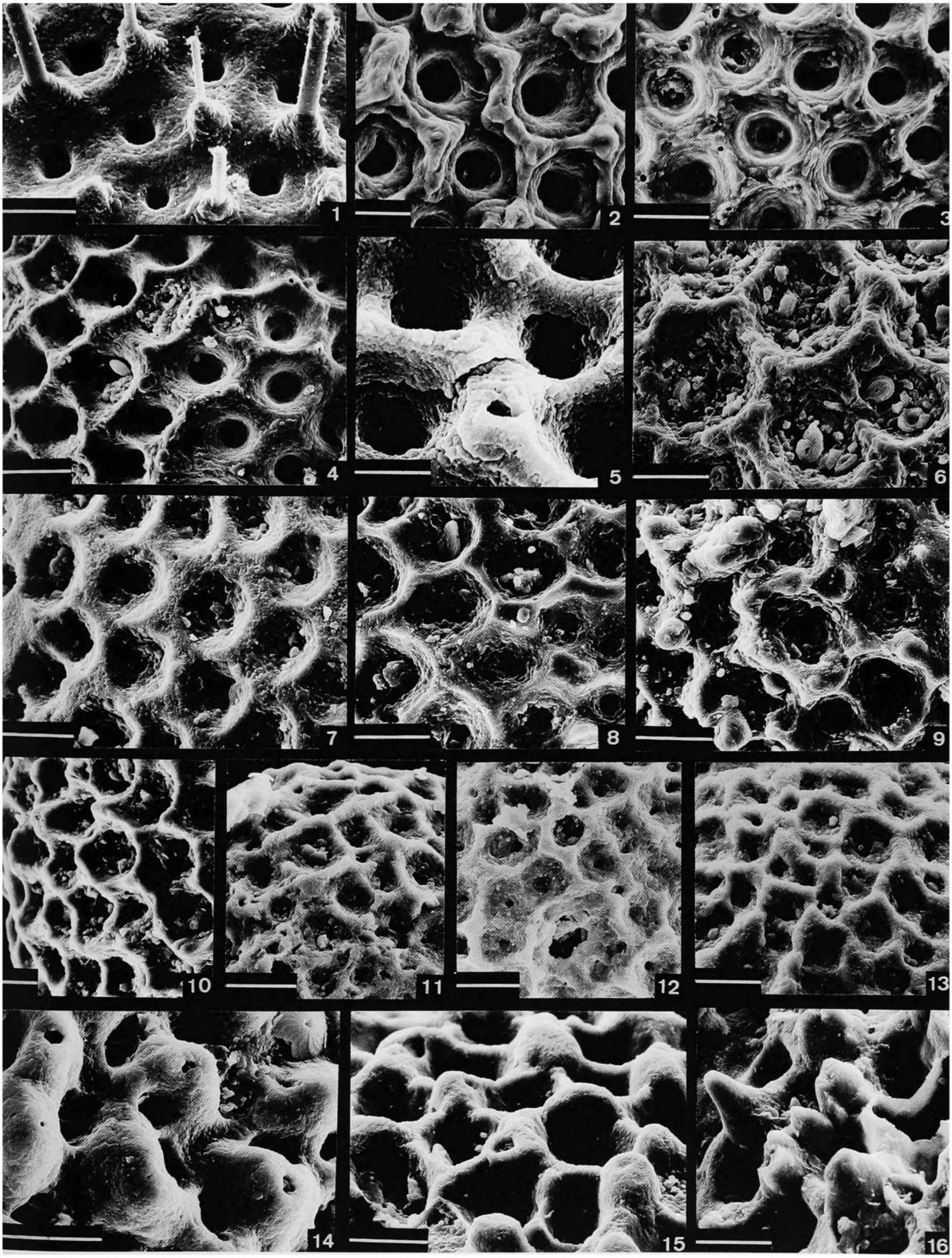
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PLATE 3

Nonspinose (Globorotaliid) Wall Texture

FIGURE 1.—*Globorotalia scitula* (Brady), overall view of a thin-walled test showing smooth surface and scattered pustules in umbilical area (bar = 100 µm). Recent, sediment trap, off Barbados.

FIGURE 2.—*Globorotalia truncatulinoides* (d'Orbigny), overall view of a medium thick-walled test showing heavier pustule growth on the older chambers (bar = 200 µm). Recent, sediment trap, off Bermuda.

FIGURE 3.—*Globorotalia inflata* (d'Orbigny), overall view of a medium thick-walled test showing pustules of various ages on all chambers (bar = 100 µm). Recent, plankton net catch, western South Atlantic Ocean.

FIGURE 4.—*Globorotalia inflata* (d'Orbigny), overall view of test showing a final layer of thick pustule growth (bar = 100 µm). Recent, plankton net catch, off Bermuda.

FIGURE 5.—*Globorotalia truncatulinoides* (d'Orbigny), enlarged view of chamber surface with young small pustules (bar = 10 µm). Recent, North Atlantic Ocean.

FIGURE 6.—*Globorotalia inflata* (d'Orbigny), enlarged view of tangential section of a thin-layered wall covering a previously formed wall, indicating superposition of various calcification events (bar = 4 µm). Recent, plankton net catch, off Bermuda.

FIGURE 7.—*Globorotalia inflata* (d'Orbigny), enlarged view of tangential section of test wall showing consecutive pustule growth that leads to a bumpy layered wall (bar = 20 µm). Recent, plankton net catch, *Chain* 35, Station 89.

FIGURE 8.—*Globorotalia scitula* (Brady), enlarged view of 3rd and 4th chambers of Figure 1 showing distribution of pustules and covering of pores by growth of pustules (bar = 20 µm). Recent, sediment trap, off Barbados.

FIGURE 9.—*Globorotalia truncatulinoides* (d'Orbigny), enlarged view of test wall showing several generations of pustule growth and an increase in wall thickness by pustule growth (bar = 40 µm). Recent, plankton net catch, South Atlantic Ocean.

FIGURES 10, 11.—*Globorotalia inflata* (d'Orbigny): 10, enlarged view of test wall showing outermost pustules and the beginning of calcite crust growth (bar = 20 µm); 11, additional calcification on top of pustules (bar = 4 µm). Recent, plankton net catch, off Bermuda.

FIGURE 12.—*Globorotalia truncatulinoides* (d'Orbigny), cross section of test wall showing the normal wall and a layered pustule (bar = 20 µm). Recent, DSDP Site 2/4/2: 149–151 cm; Gulf of Mexico.

FIGURE 13.—*Globorotalia truncatulinoides* (d'Orbigny), branching pustules (bar = 40 µm). Recent, DSDP Site 2/4/2: 149–151 cm; Gulf of Mexico.

FIGURES 14–16.—*Globorotalia menardii* (Parker, Jones, and Brady): 14, cross section of test wall showing the normal wall and the beginning of the calcite crust (elongated crystals); 15, early stage of keel development showing the doubling of the wall; at this stage the keel contains a few pores that do not function (bar = 10 µm). Recent, DSDP Site 2/4/2: 149–151 cm; Gulf of Mexico. 16, medium stage of keel development showing the layering of the keel (bar = 10 µm). Recent, DSDP Site 1/1/1: 1–4 cm; Gulf of Mexico.

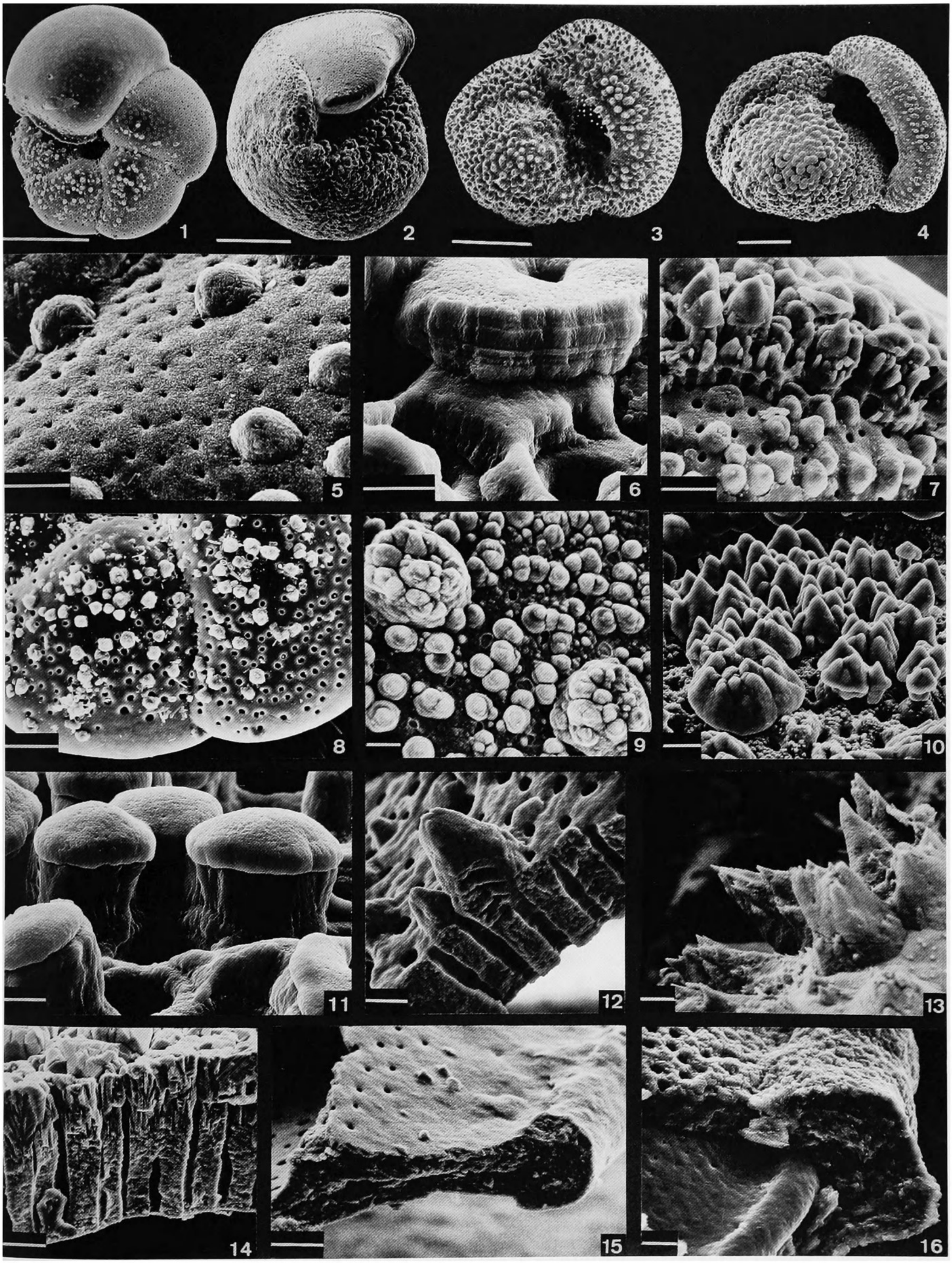
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PLATE 4

Nonspinose (Globorotaliid) Wall Texture, Cretaceous and Paleocene

FIGURES 1–3.—*Hedbergella holmdelensis* Olsson: 1, overall view of test showing a smooth wall with pustule distribution resembling *Globorotalia scitula* (Brady) (bar = 50 μm); 2, enlarged view of 3rd chamber showing overgrowth of pores by pustules (bar = 5μm); 3, pustule growth covering wall surface on 5th chamber (bar = 5 μm). Topotype, upper Maastrichtian, Navesink Formation, New Jersey.

FIGURES 4, 5.—*Globanomalina archeocompressa* (Blow): 4, overall view of test showing a smooth surface with a pustule distribution similar to *G. scitula* (Brady) and *H. holmdelensis* Olsson (bar = 20 μm); 5, enlarged view of wall showing a smooth surface and some small pustules in front of the aperture (bar = 10 μm). Paleocene, Zone P1a, DSDP Site 356/29/1: 70–72 cm; São Paulo Plateau, South Atlantic Ocean.

FIGURES 6, 7.—*Globanomalina planocompressa* (Shutskaya): 6, overall view of test showing a very smooth surface and no pustules (bar = 50 μm); 7, closeup view of 3rd chamber (bar = 10 μm). Paleocene, Zone P1c, Mexia Clay, Texas.

FIGURE 8.—*Globanomalina chapmani* (Parr), enlarged view of test wall showing smooth surface and some pores in the imperforate peripheral band (bar = 10 μm). Paleocene, Zone P4, Glendola Well, New Jersey, sample 286–287 feet.

FIGURES 9, 10.—*Globanomalina pseudomenardii* (Bolli): 9, cross section of test wall showing the layered wall and the trace of the POM (primary organic membrane) and pustule exhibiting the same morphology as in globorotaliid species (bar = 2 μm), Paleocene, Zone P4, Whitesville Well, New Jersey, sample 210–215 feet. 10, view of surface layer on top of keel and of pustules of various generations (bar = 10 μm), Paleocene, Zone P4, Glendola Well, New Jersey, sample 286–287 feet.

FIGURES 11–13, 16.—*Globanomalina imitata* (Subbotina): 11, enlarged view of test wall showing typical globorotaliid pustules (bar = 10 μm); 12, chambers of the inner whorl showing conical inner chambers with rounded and sharp-tipped pustules (bar = 20 μm); 13, enlarged view of inner chamber of Figure 12 showing pustules (bar = 10 μm); Paleocene, Zone P4, Whitesville Well, New Jersey, sample 210–215 feet. 16, enlarged view of inner chamber showing same pustule development as in Figure 12 (bar = 10 μm), Paleocene, Zone P4, DSDP Site 384/7/CC; southeast Newfoundland Ridge, North Atlantic Ocean.

FIGURE 14.—*Morozovella praeangulata* (Blow), enlarged view of test wall showing pustules growing on a smooth "globorotaliid" surface (bar = 20 μm). Paleocene, Zone P3b, DSDP Site 527/28/6: 30–32 cm; Walvis Ridge, eastern South Atlantic Ocean.

FIGURE 15.—*Morozovella velascoensis* (Cushman), enlarged view of test wall showing different sized pustules growing on a smooth "globorotaliid" surface (bar = 20 μm). Paleocene, Zone P5, DSDP Site 213/16/1: 104 cm; Wharton Basin, eastern Indian Ocean.

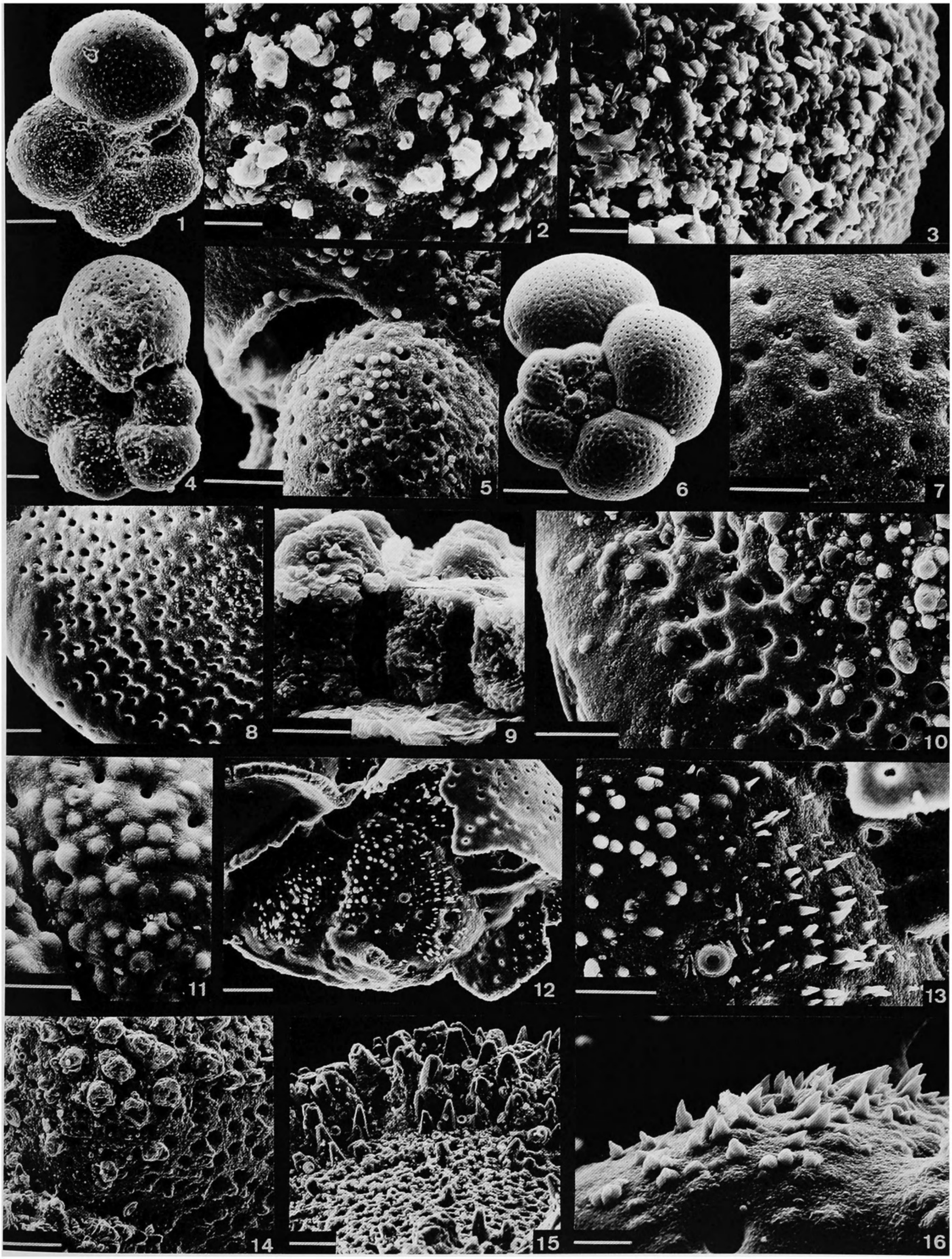
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PLATE 5

Acarinina and *Praemurica* Wall Texture

FIGURE 1.—*Acarinina strabocella* (Loeblich and Tappan), enlarged view of test wall showing a smooth (globorotaliid) surface with simple and coalescent pustules (bar = 10 μm). Paleocene, Zone P2, DSDP Site 356/25/5: 148–150 cm; São Paulo Plateau, South Atlantic Ocean.

FIGURE 2.—*Acarinina nitida* (Martin), enlarged view of test wall showing a smooth (globorotaliid) surface with simple and coalescent pustules, similar to Figure 1; wall texture, pustule morphology, and distribution is typical of extant globorotaliids (bar = 20 μm). Paleocene, Zone P4, DSDP Site 384/8/1: 136–138 cm; southeast Newfoundland Ridge, North Atlantic Ocean.

FIGURE 3.—*Acarinina mckannai* (White), enlarged view of test wall showing heavy, coalescing pustule growth on a smooth (globorotaliid) surface; wall texture, pustule morphology, and distribution is typical of extant globorotaliids (bar = 20 μm). Paleocene, Zone P4, DSDP Site 384/6/CC; southeast Newfoundland Ridge, North Atlantic Ocean.

FIGURE 4.—*Acarinina subsphaerica* (Subbotina), enlarged view of test wall showing heavy pustule growth; wall texture, pustule morphology, and distribution is typical of extant globorotaliids (bar = 20 μm). Paleocene, Zone P4, DSDP Site 465/5/1: 65–67 cm; Hess Rise, central Pacific Ocean.

FIGURES 5–8.—*Neogloboquadrina dutertrei* (d'Orbigny), overall view of thin (Figure 5), medium (Figures 6, 7), and thick (Figure 8) walled specimens showing development of globoquadrinid wall texture by growth and coalescing of pustules to form a cancellate wall texture. A calcite crust is formed in the final stage (Figure 8). (Figure 5: bar = 50 μm; Figures 6–8: bar = 100 μm.) Recent, plankton net catch, eastern North Atlantic.

FIGURES 9–11.—*Neogloboquadrina dutertrei* (d'Orbigny): 9, 10, enlarged views of test wall of same specimen showing pores separated by elongated, subparallel ridge-like structures, which are connected by short, less developed ridges, thereby forming the cancellate wall texture. (Figure 9: bar = 20 μm; Figure 10: bar = 10 μm.) Recent, sediment trap, off Barbados. 11, two enlarged views of test wall of single specimen showing gametogenetic calcification and early formation of a calcite crust. The wall thickens as the individual sinks to deeper water, e.g., deep chlorophyll maximum. (Bars = 20 μm and 5 μm, respectively.) Recent, plankton net catch, off Bermuda.

FIGURES 12–15.—*Hedbergella monmouthensis* (Olsson), views of test wall showing the development and distribution of pustules on a smooth surface: 12, overall view of specimen (bar = 40 μm); 13, enlarged view of ultimate chamber with small scattered pustules; 14, enlarged view of penultimate chamber showing growth and coalescing of pustules; 15, enlarged view of 4th chamber showing coalescing of pustules around pores, which is an initial step toward the development of a cancellate wall texture. (Figures 13–15: bars = 10 μm.) Topotype, upper Maastrichtian, Redbank Formation, New Jersey.

FIGURES 16–18.—*Praemurica taurica* (Morozova): 16, overall view of test showing the globoquadrinid-type (praemuricate) wall texture (bar = 40 μm); 17, enlarged view of test wall of another specimen showing the praemuricate cancellate wall (bar = 10 μm); 18, enlarged view of test wall of another specimen showing elongate, subparallel ridges connected by short, less developed ridges surrounding the pores (bar = 10 μm). Paleocene, Zone P1a, Millers Ferry, Alabama, core 225, Figures 16, 17, from sample 216 and Figure 18 from sample 194.

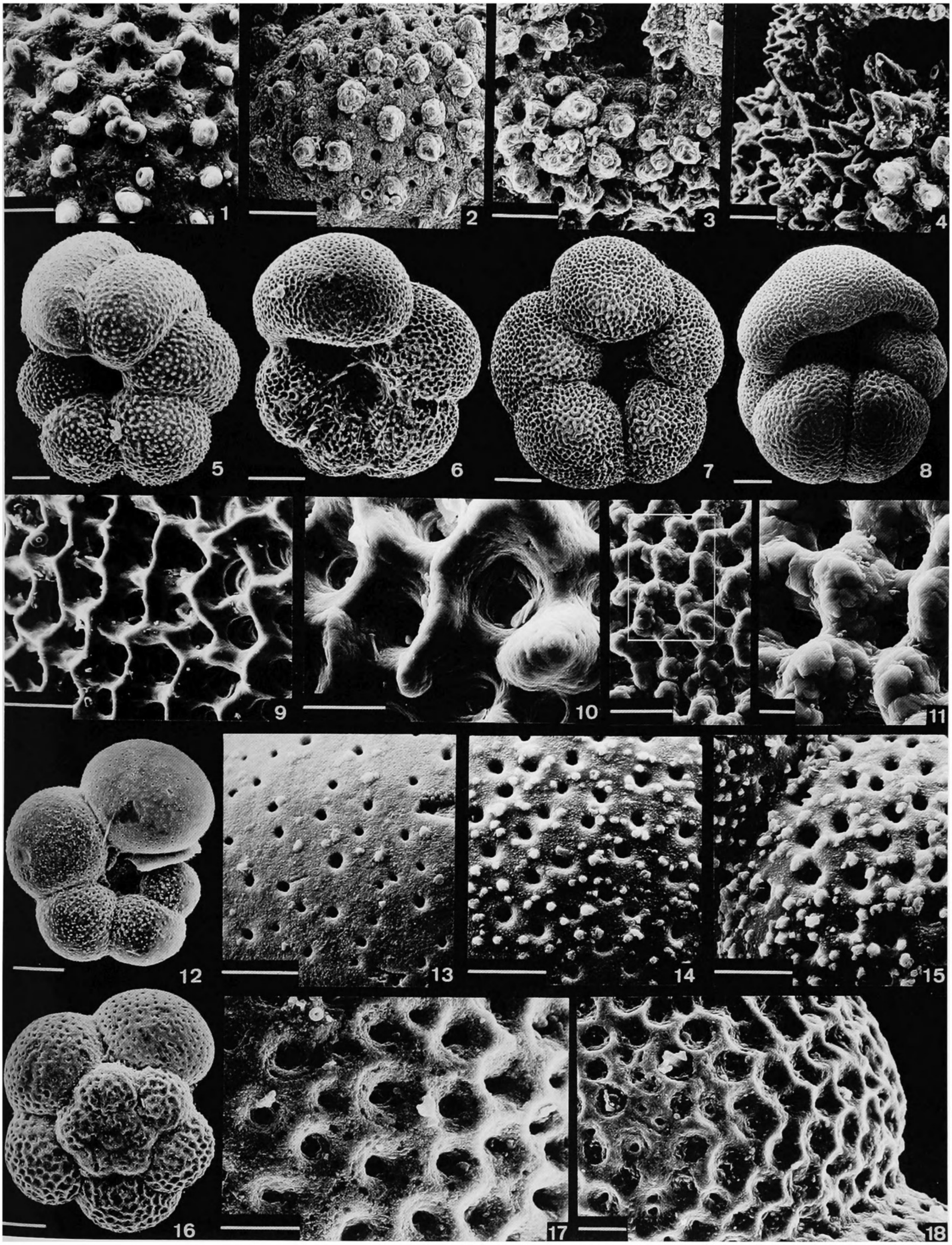
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PLATE 6

Praemurica and Microperforates

FIGURES 1-4.—*Praemurica pseudoinconstans* (Blow): 1, overall view of test showing the globoquadrinid-type (praemuricate) wall texture (bar = 40 µm); 2, 4, enlarged view of 6th and 3rd chambers, respectively, showing the typical praemuricate wall texture of elongate, subparallel ridges connected by shorter, less developed ridges surrounding the pores, and showing light gametogenetic calcification (bar = 10 µm); 3, enlarged view of another specimen showing the praemuricate wall texture (bar = 10 µm). Paleocene, Zone P1a, Millers Ferry, Alabama, core 225, sample 194.

FIGURE 5.—*Igorina pusilla* (Bolli), enlarged view of test wall showing the praemuricate wall texture (bar = 10 µm). Paleocene, Zone P4, Glendola Well, New Jersey, sample 286–287 feet.

FIGURE 6.—*Igorina albeari* (Cushman and Bermúdez), enlarged view of test wall showing the typical praemuricate wall texture of subparallel ridges connected by shorter, less developed ridges surrounding the pores (bar = 20 µm). Paleocene, Zone P3b, DSDP Site 356/24/2: 92–94 cm; São Paulo Plateau, South Atlantic Ocean.

FIGURES 7-10.—*Globigerinita glutinata* (Egger): 7, overall view of early adult form showing microperforate wall and scattered small pustules (bar = 100 µm); 8, mature adult form showing heavy pustulose wall texture and bulla with scattered small pustules (bar = 100 µm); 9, enlarged view of test wall of another specimen showing microperforate wall with multifaceted pustules covering pores (bar = 20 µm); 10, enlarged view of test wall of another specimen showing microperforate wall with small rounded pustules overgrowing pores (bar = 5 µm). Recent, plankton net sample, North Atlantic Ocean.

FIGURES 11, 12.—*Globoconusa daubjergensis* (Brönnimann): 11, overall view of test showing microperforate wall with scattered pustules (bar = 50 µm); 12, enlarged view of another specimen showing microperforate wall with sharp-pointed pustules (bar = 10 µm). Paleocene, Zone P1c, Brightseat Formation, Maryland.

FIGURES 13, 14.—*Chiloguembelina crinita* (Glaessner): 13, overall view of test showing microperforate wall covered with coarse rounded pustules (bar = 50 µm); 14, enlarged view of 3rd chamber showing microperforate wall and rounded pustules overgrowing pores (bar = 10 µm). Paleocene, Zone P4, Whitesville Well, New Jersey, sample 180–185 feet.

FIGURES 15-18.—*Chiloguembelina morsei* (Kline): 15–17, overall view and enlarged views of test wall showing microperforate texture with coarse multifaceted pustules overgrowing pores (compare to Figure 9) (Figure 15: bar = 40 µm; Figures 16, 17: bar = 10 µm). Paleocene, Zone P2, DSDP Site 356/24/2: 92–94 cm; São Paulo Plateau, South Atlantic Ocean. 18, enlarged view of test wall, partially recrystallized, showing multifaceted pustules (bar = 20 µm). Paleocene, ODP Hole 690B/16/5: 76–80 cm; Maud Rise, Southern Ocean.

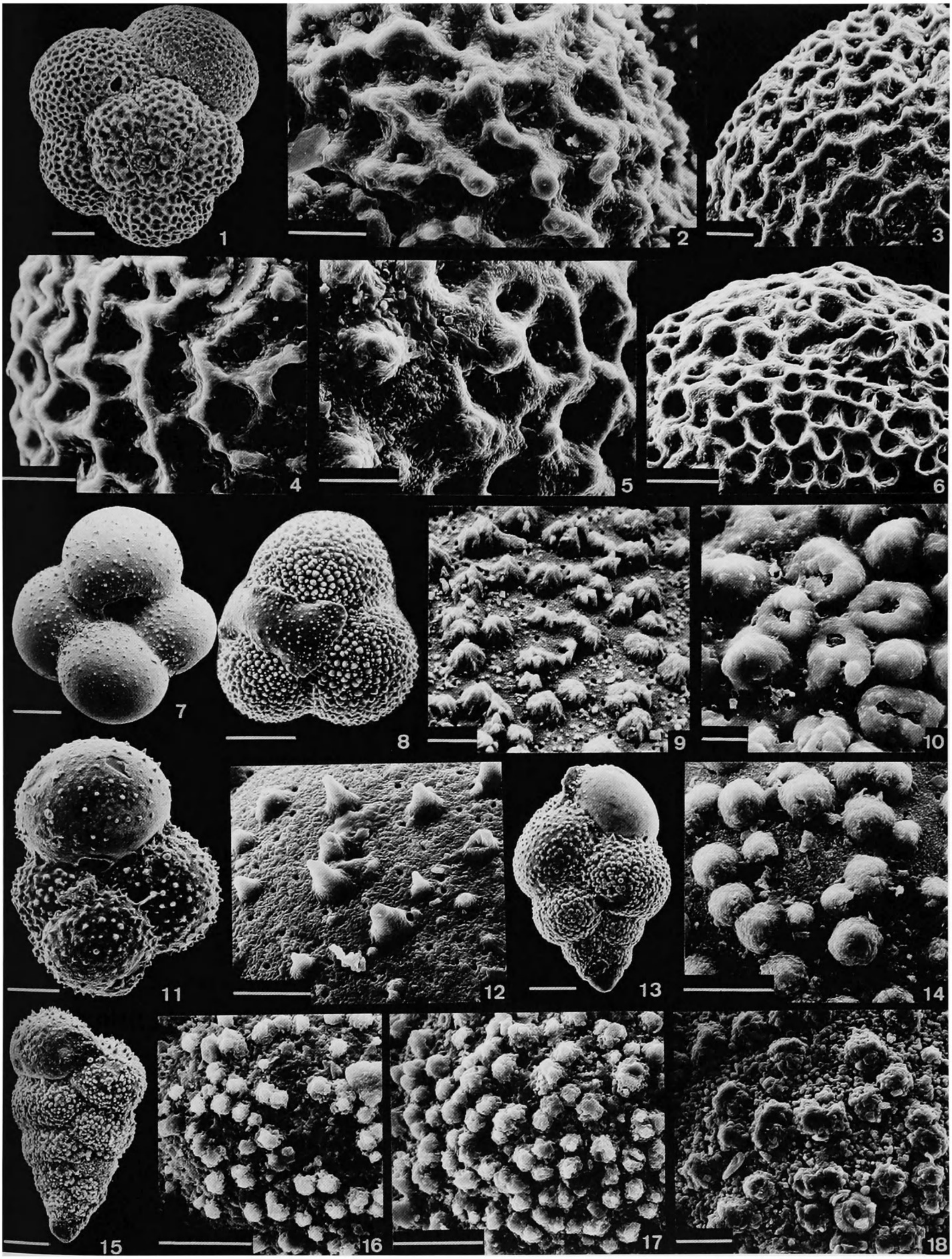
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PLATE 7

Diagenesis

FIGURES 1, 2.—*Subbotina cancellata* Blow, overall view and enlarged view of recrystallized and corroded specimen; diagenesis obscures original wall texture, although a spine hole is visible in center of picture (Figure 1: bar = 40 μm; Figure 2: bar = 10 μm). Paleocene, Zone P2, DSDP Hole 398D/39/4: 145–147 cm; western Iberian continental margin, eastern North Atlantic Ocean.

FIGURE 3.—*Eoglobigerina edita* (Subbotina), enlarged view of test wall showing corrosion and dissolution (bar = 4 μm). Paleocene, Zone Pα, Millers Ferry, Alabama, core 226, sample 8.

FIGURE 4.—*Subbotina trivialis* (Subbotina), enlarged view of heavily recrystallized and overgrown test wall showing euhedral calcite crystals closing off pores, although a spine hole is still visible in center of picture (bar = 20 μm). Paleocene, Zone P1, DSDP Hole 390A/11/4: 80–82 cm; Blake-Bahama Basin, North Atlantic Ocean.

FIGURES 5, 6.—*Parasubbotina pseudobulloides* (Plummer), enlarged views of corroded and recrystallized test wall; diagenesis has nearly obliterated original wall texture, but a few spine holes are preserved (Figure 5: bar = 10 μm; Figure 6: bar = 4 μm). Paleocene, Zone P1a, Millers Ferry, Alabama, core 226, sample 85.

FIGURE 7.—*Acarinina strabocella* (Loeblich and Tappan), enlarged view of recrystallized wall showing fine subhedral crystals; recrystallized pustules show euhedral crystal surfaces (bar = 10 μm). Paleocene, Zone P3, ODP Hole 750A/11/1: 149–150 cm; southern Kerguelen Plateau, Southern Ocean.

FIGURE 8.—*Praemurica inconstans* (Subbotina), enlarged view of recrystallized and overgrown test wall, showing closed off pores and obscured original wall texture (bar = 10 μm). Paleocene, Zone P1c, DSDP Site 577/12/1: 49–51 cm; Shatsky Rise, western Pacific Ocean.

FIGURE 9.—*Subbotina* cf. *triangularis* (White), enlarged view of partially dissolved wall showing calcitic pore linings that are visible due to dissolution (bar = 10 μm). Paleocene, Zone P5, DSDP Site 2/3/16; Wharton Basin, eastern Indian Ocean.

FIGURE 10.—*Subbotina* cf. *velascoensis* (Cushman), enlarged view of cross section showing recrystalled wall with overgrowth on inner wall, but POM is still visible (bar = 10 μm). Paleocene, Zone P2, DSDP Site 398D/39/4: 145–147 cm; western Iberian continental margin, eastern North Atlantic Ocean.

FIGURE 11.—*Subbotina* sp., enlarged view of heavily recrystallized wall (bar = 4 μm). Paleocene, Zone Pα, DSDP Site 577/12/5: 113–114 cm; Shatsky Rise, western Pacific Ocean.

FIGURE 12.—*Subbotina triangularis* (White), enlarged view of cross section showing heavily recrystallized wall completely obscuring the original wall texture (bar = 10 μm). Paleocene, Zone P4, DSDP Site 549/20/2: 69–71 cm; Goban Spur, eastern North Atlantic Ocean.

FIGURES 13, 14.—*Parvularugoglobigerina eugubina* (Luterbacher and Premoli Silva), overall view and enlarged view showing completely recrystallized test wall; original microperforate wall is obscured (Figure 13: bar = 40 μm; Figure 14: bar = 10 μm). Paleocene, Zone Pα, DSDP Site 577/12/5: 125–126 cm; Shatsky Rise, western Pacific Ocean.

FIGURE 15.—*Chiloguembelina wilcoxensis* (Cushman and Ponton), enlarged view of recrystallized wall showing recrystallized pustules; microperforate wall is obscured (bar = 10 μm). Paleocene, ODP Hole 690B/16/5: 76–80 cm; Maud Rise, Southern Ocean.

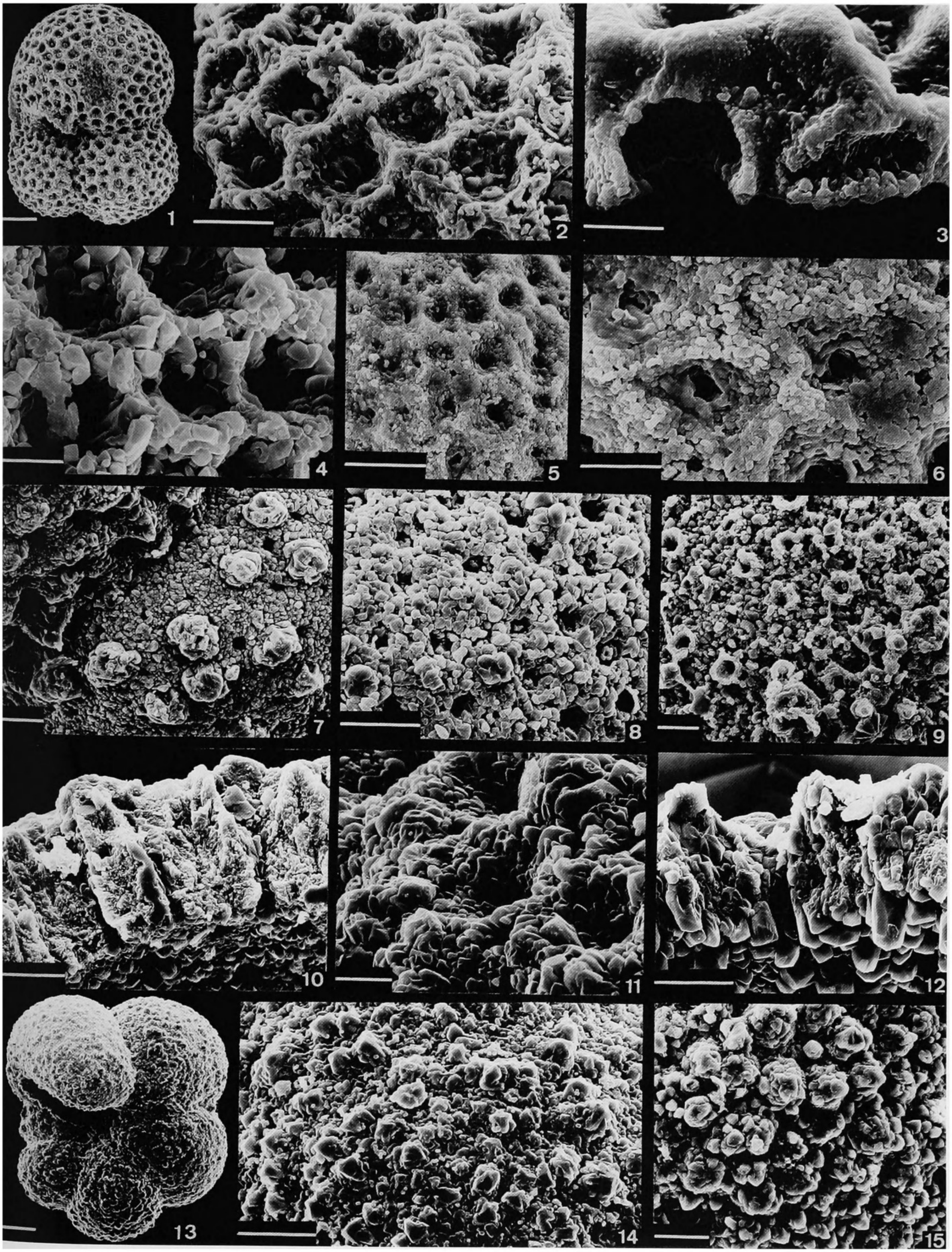
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PLATE 18

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.

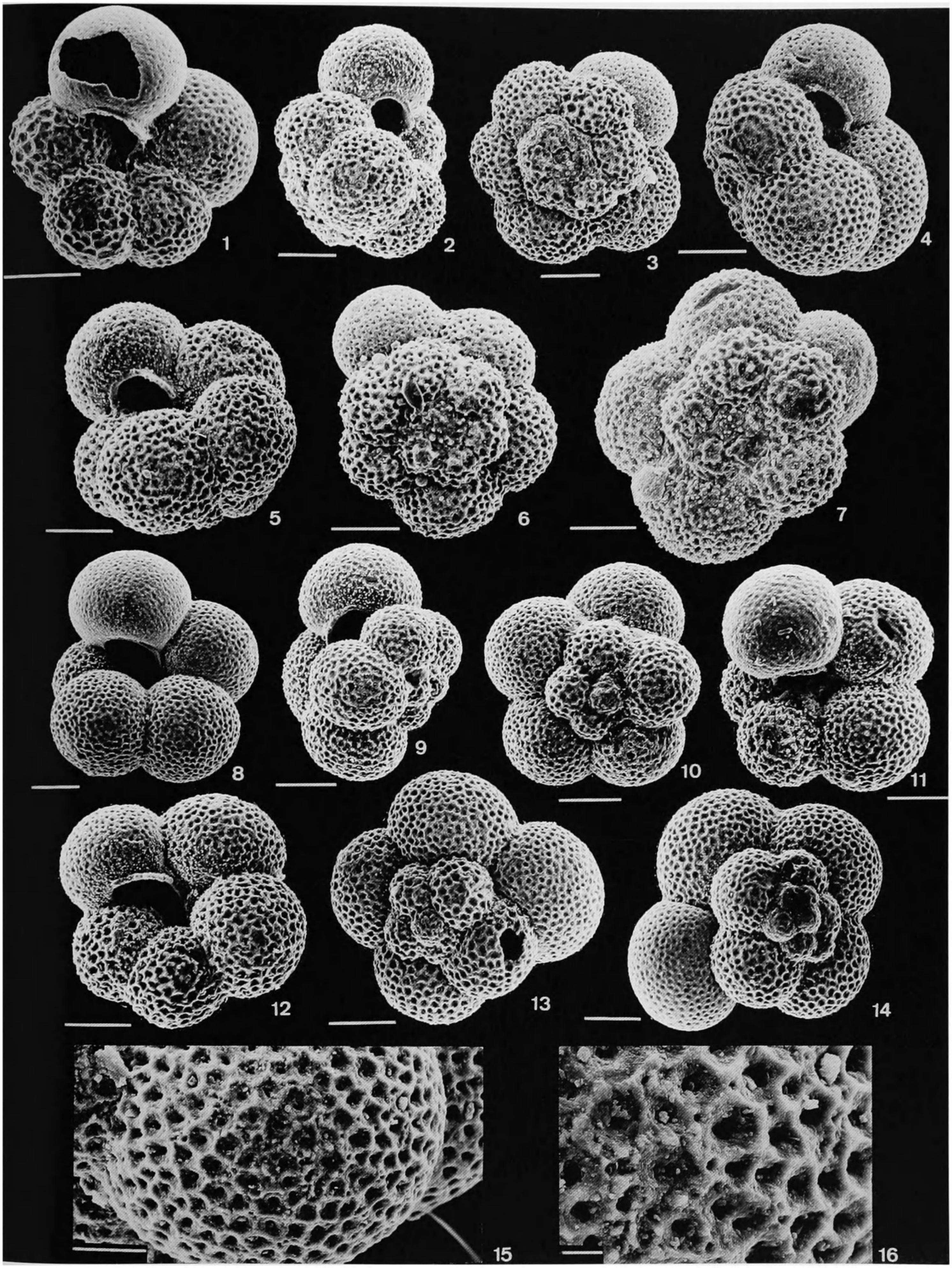
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PLATE 19

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.

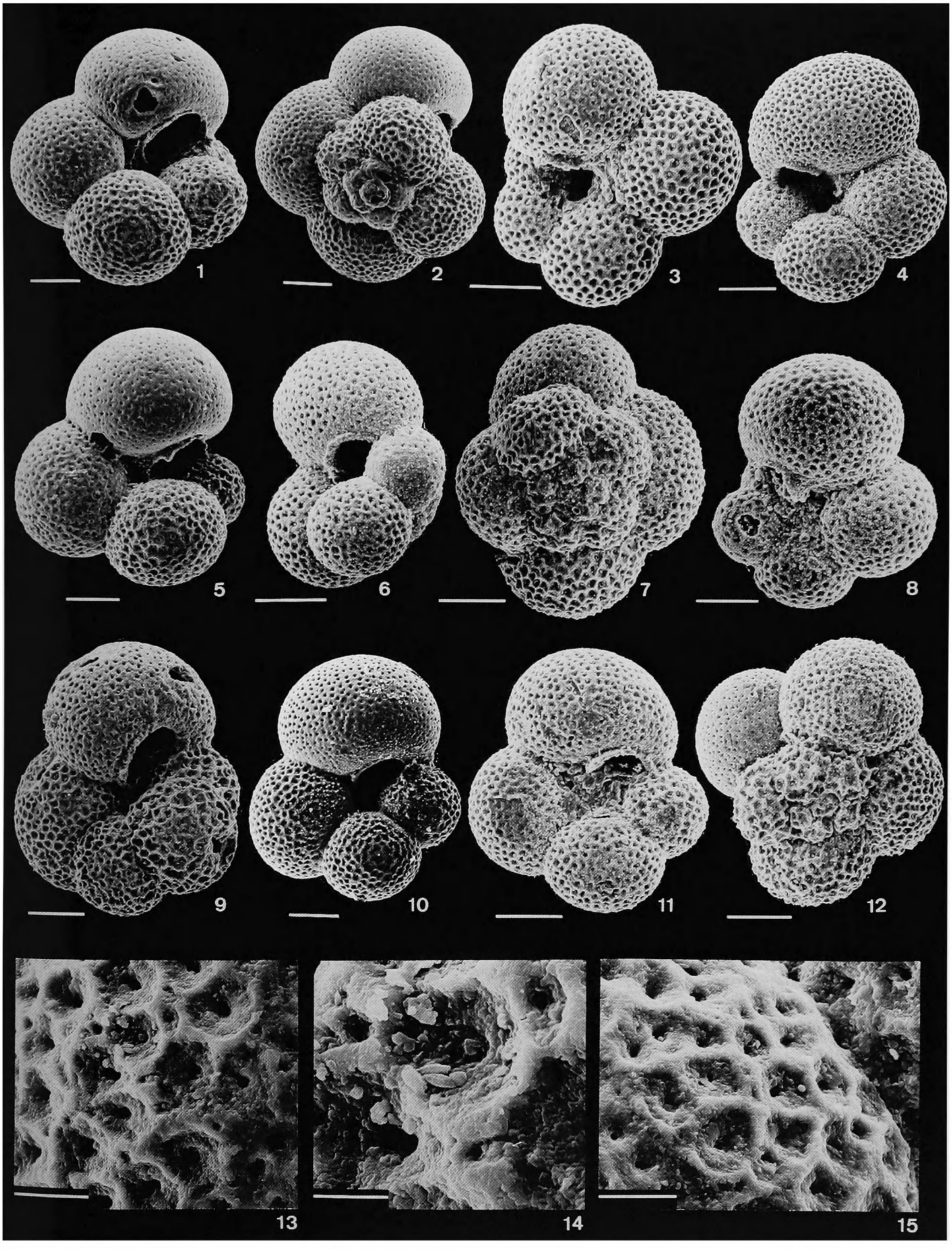
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PLATE 20

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.

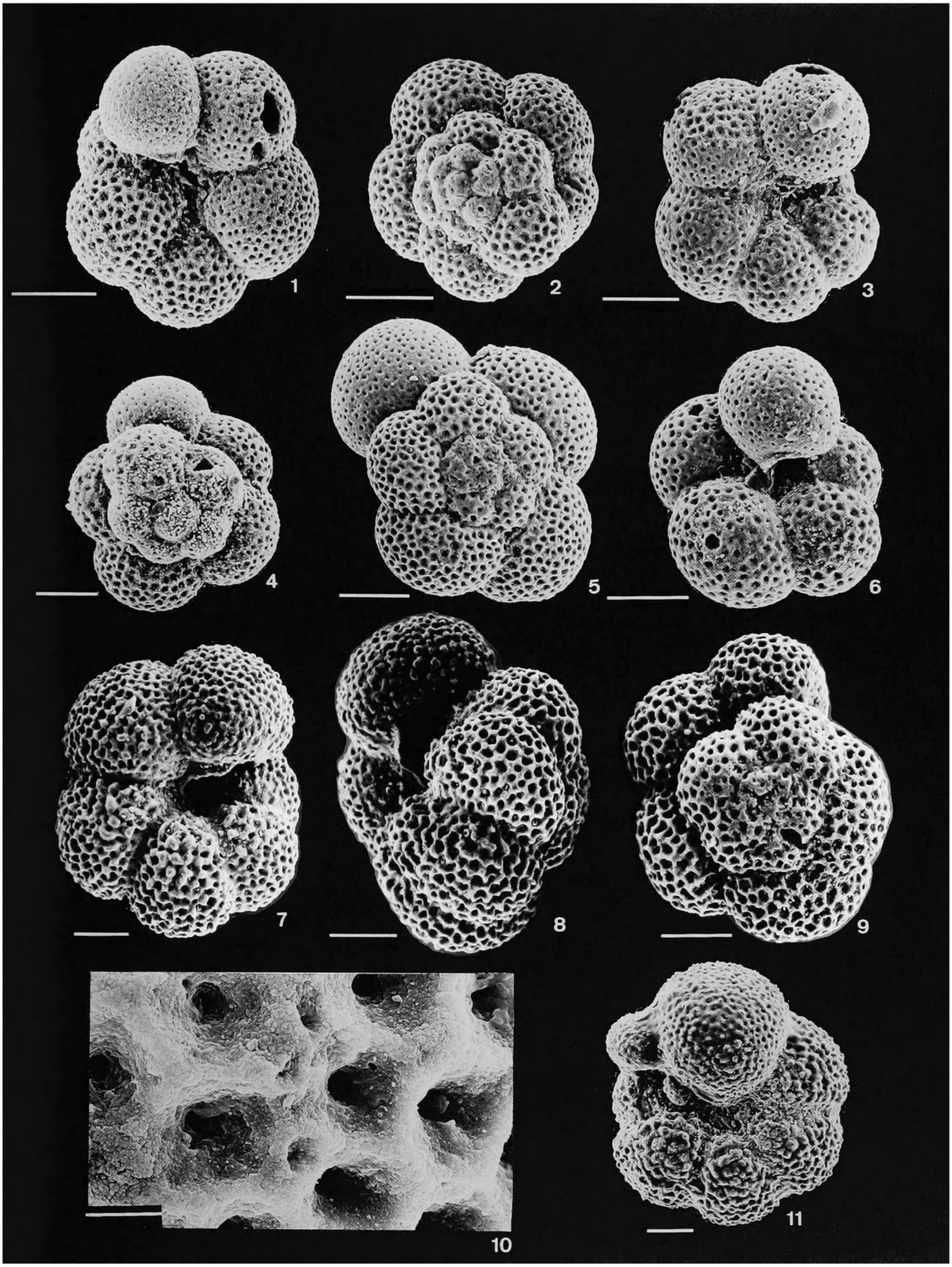
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PLATE 21

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.

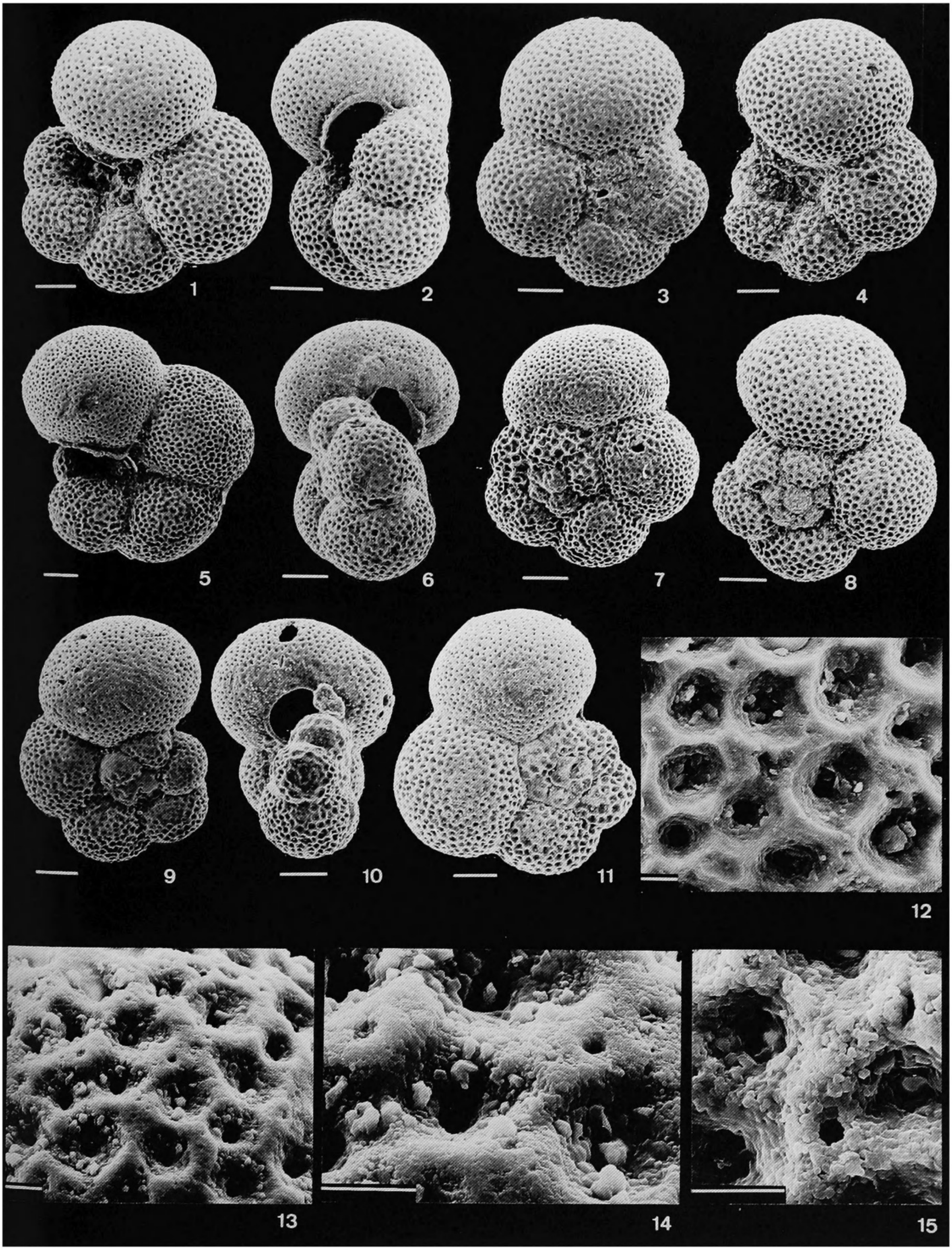

PLATE 22

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.

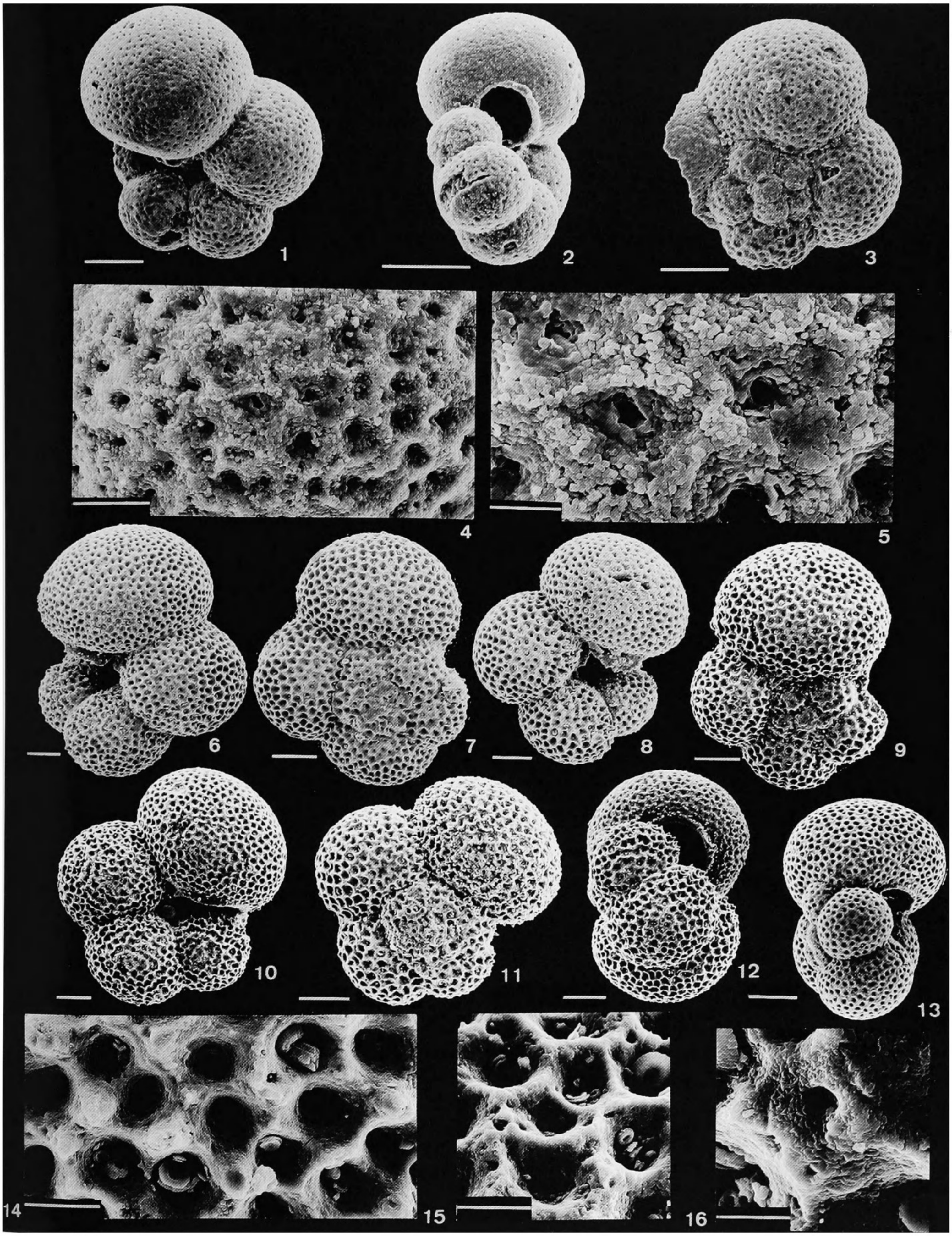
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PLATE 23

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.

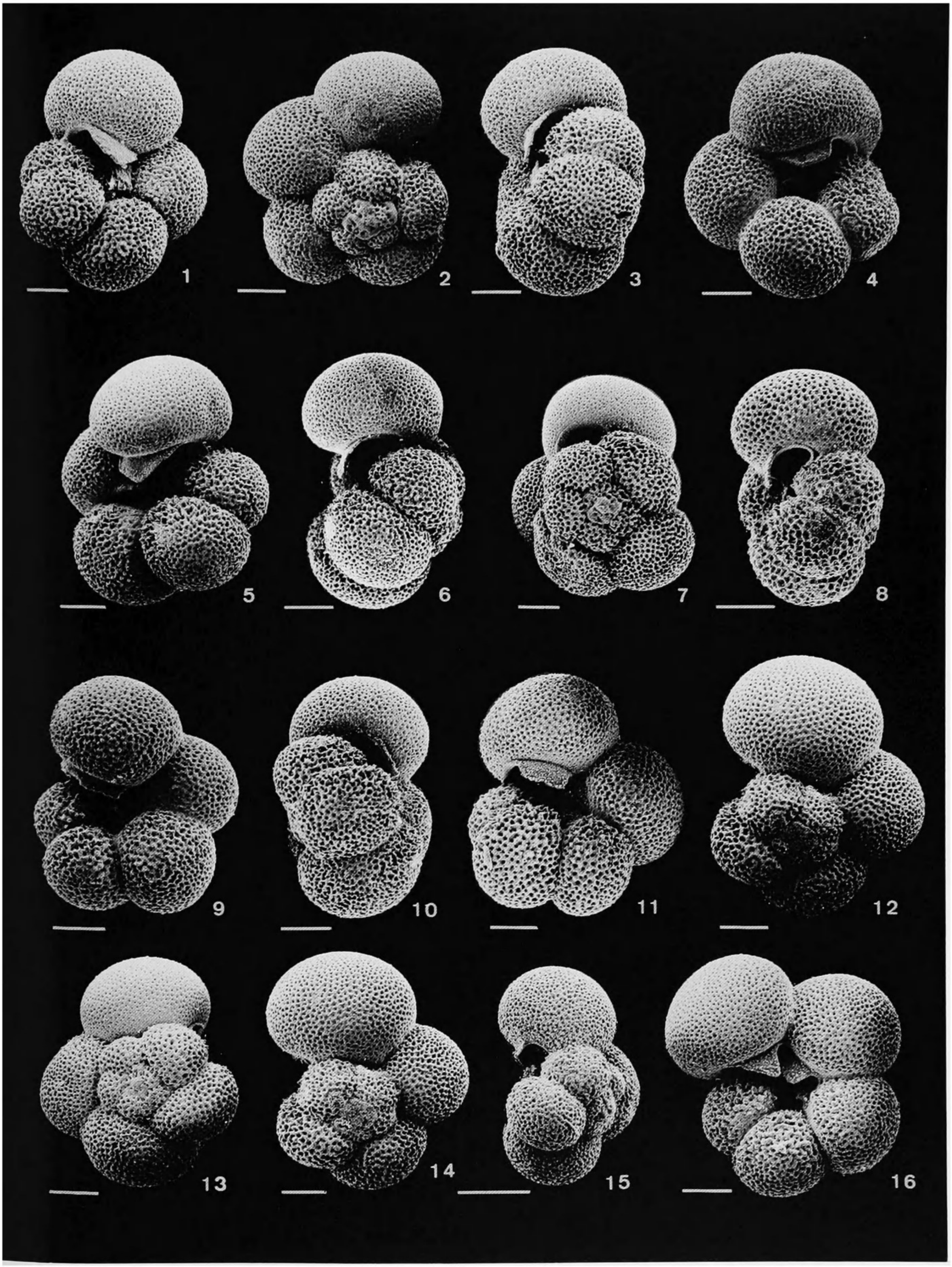
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PLATE 24

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.

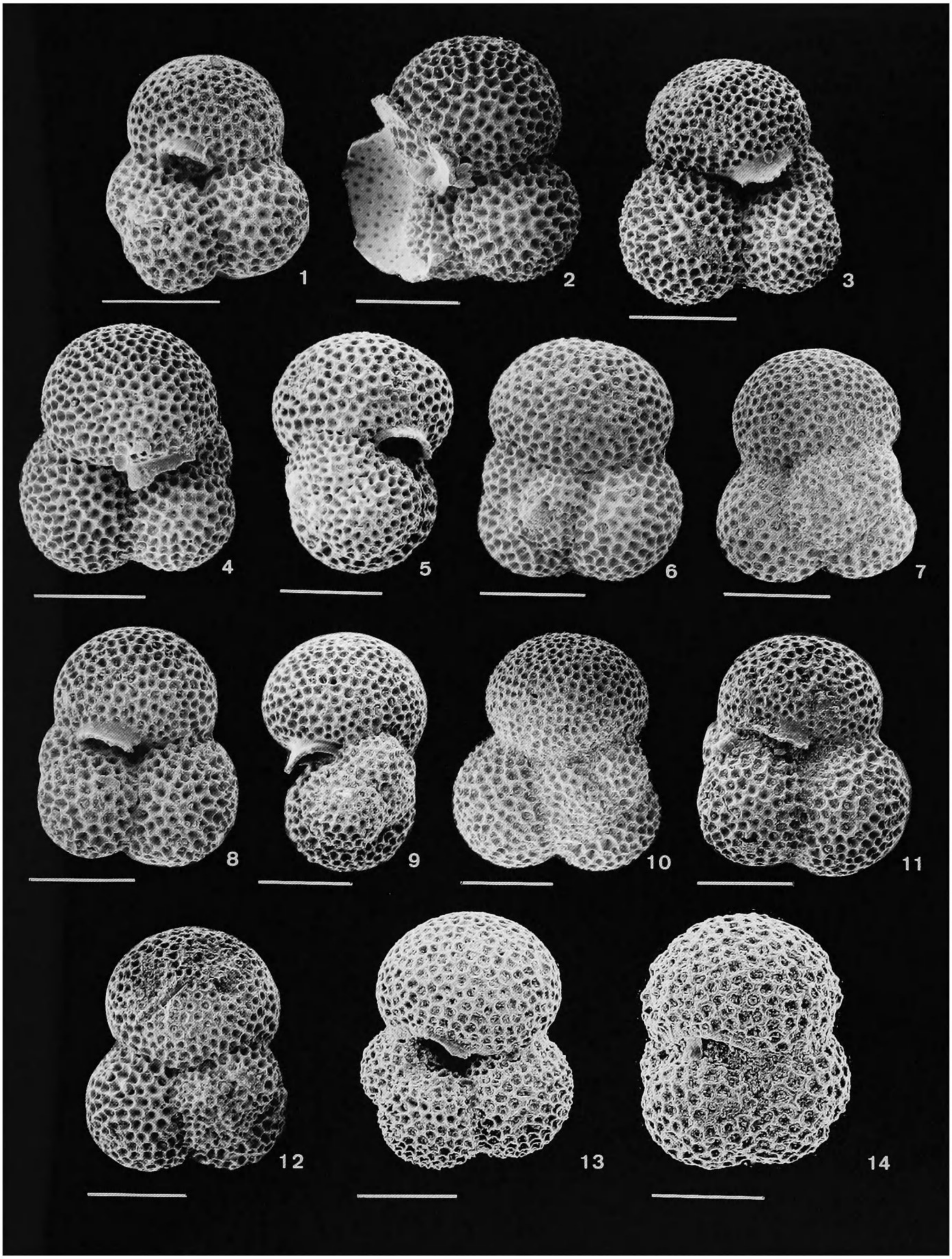
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PLATE 25

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.

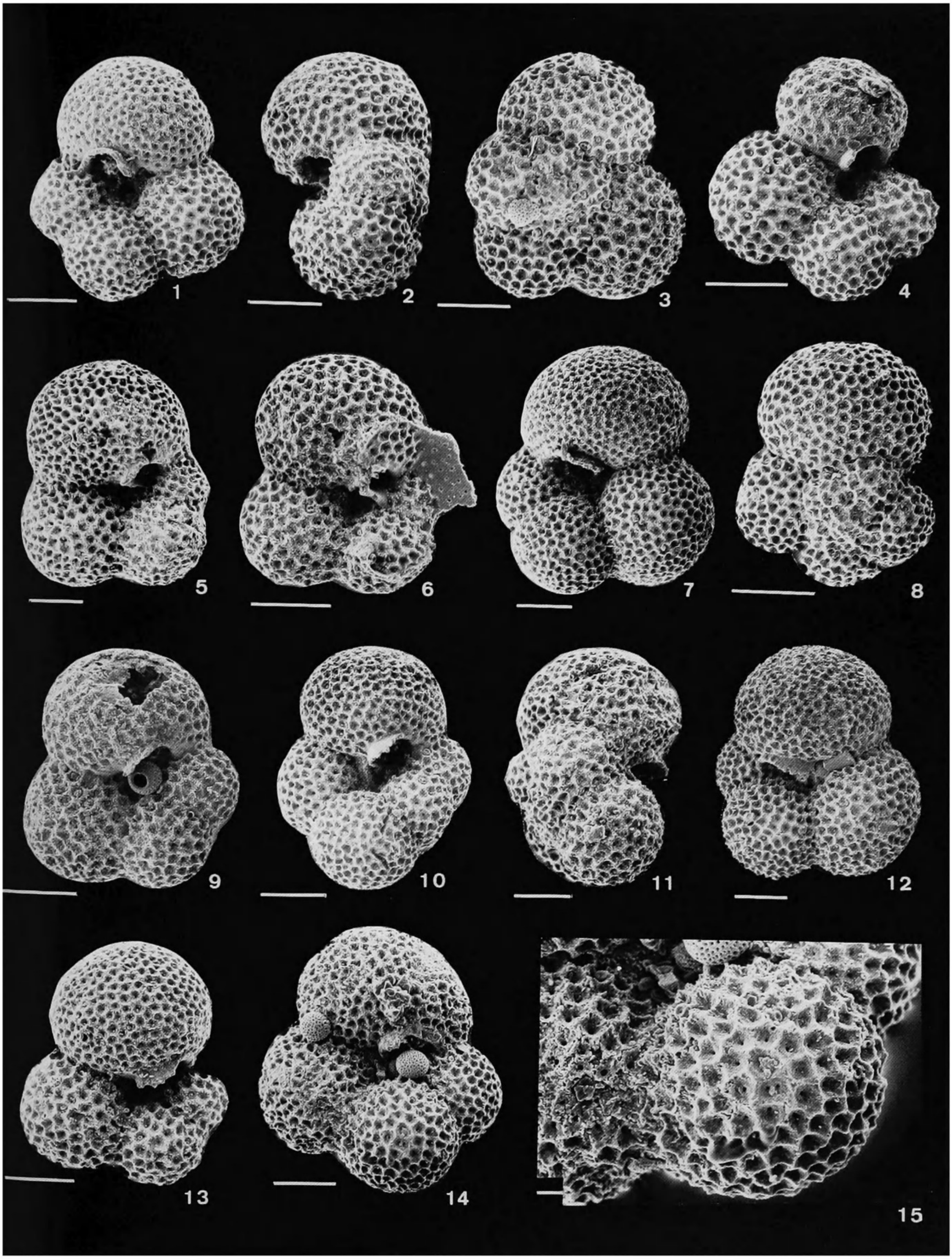
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PLATE 26

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.

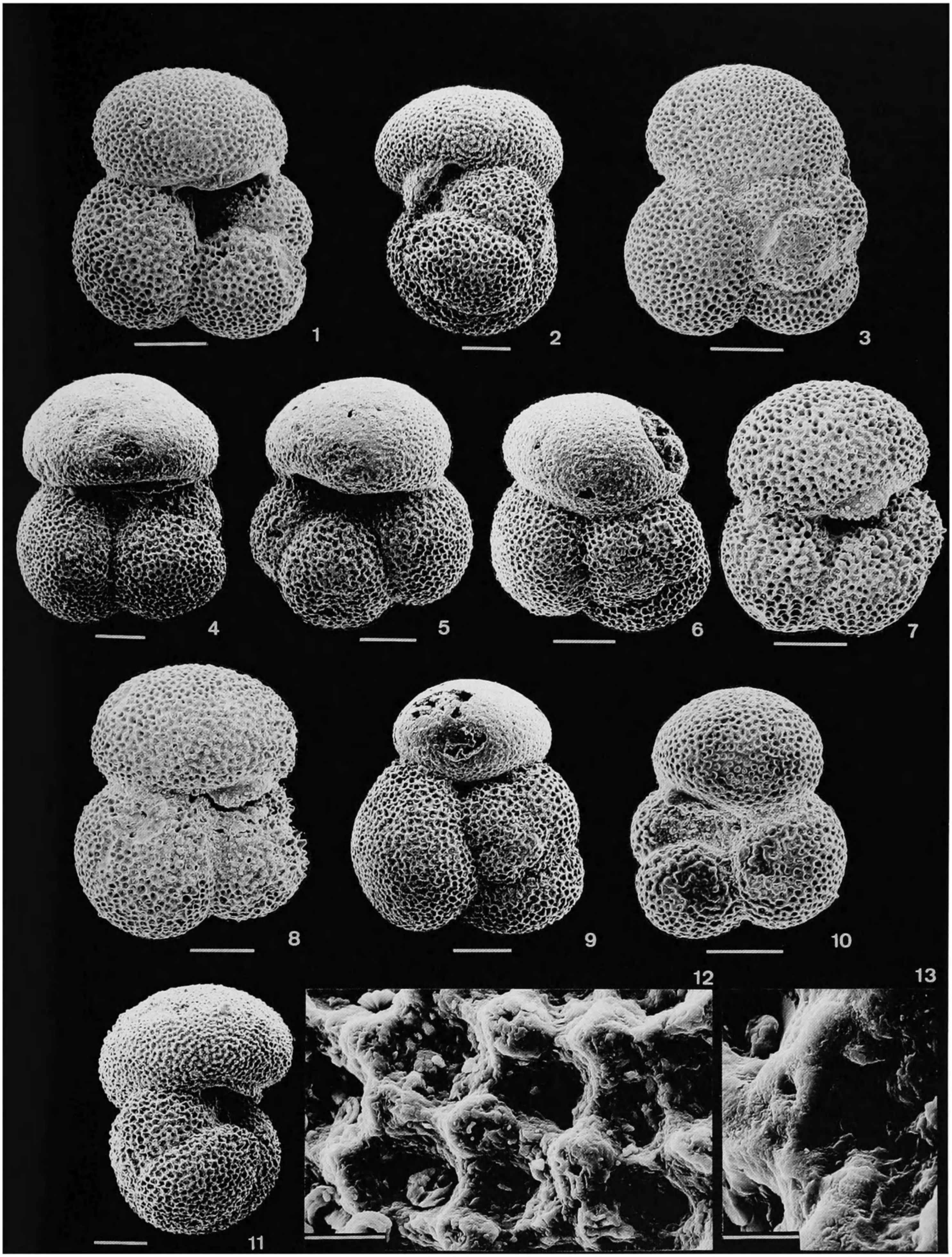
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PLATE 27

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.

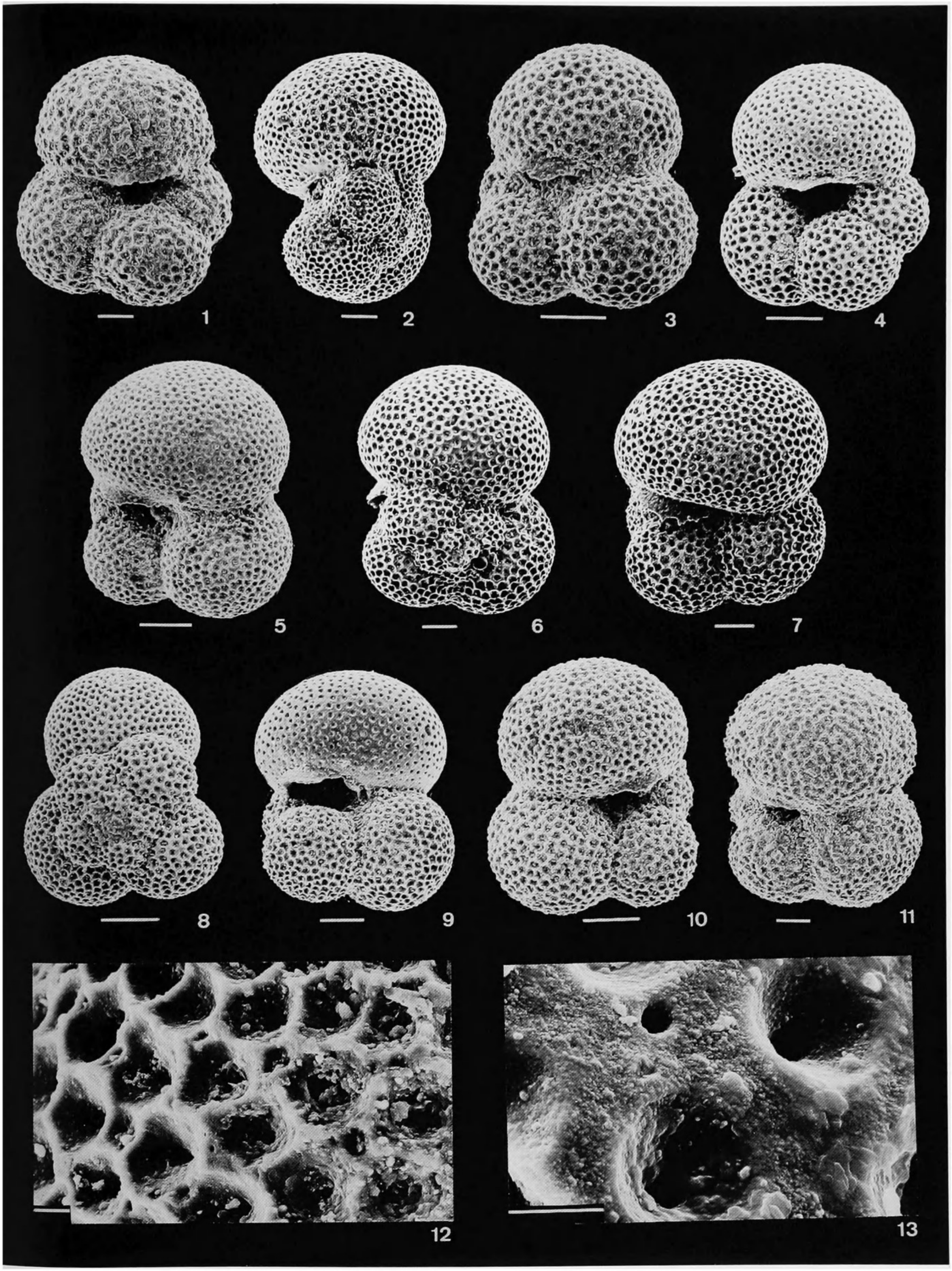
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PLATE 28

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.

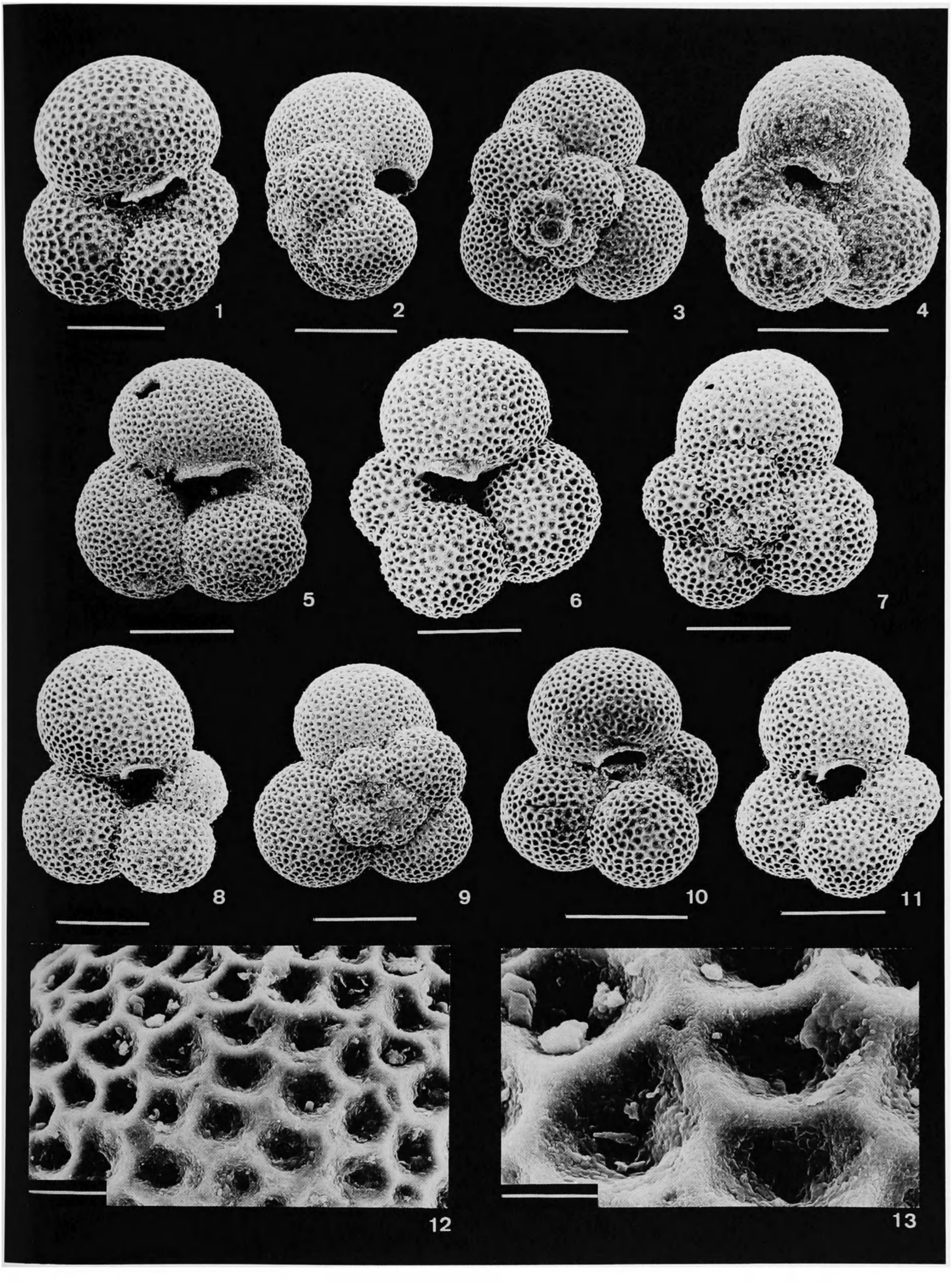
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PLATE 29

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.

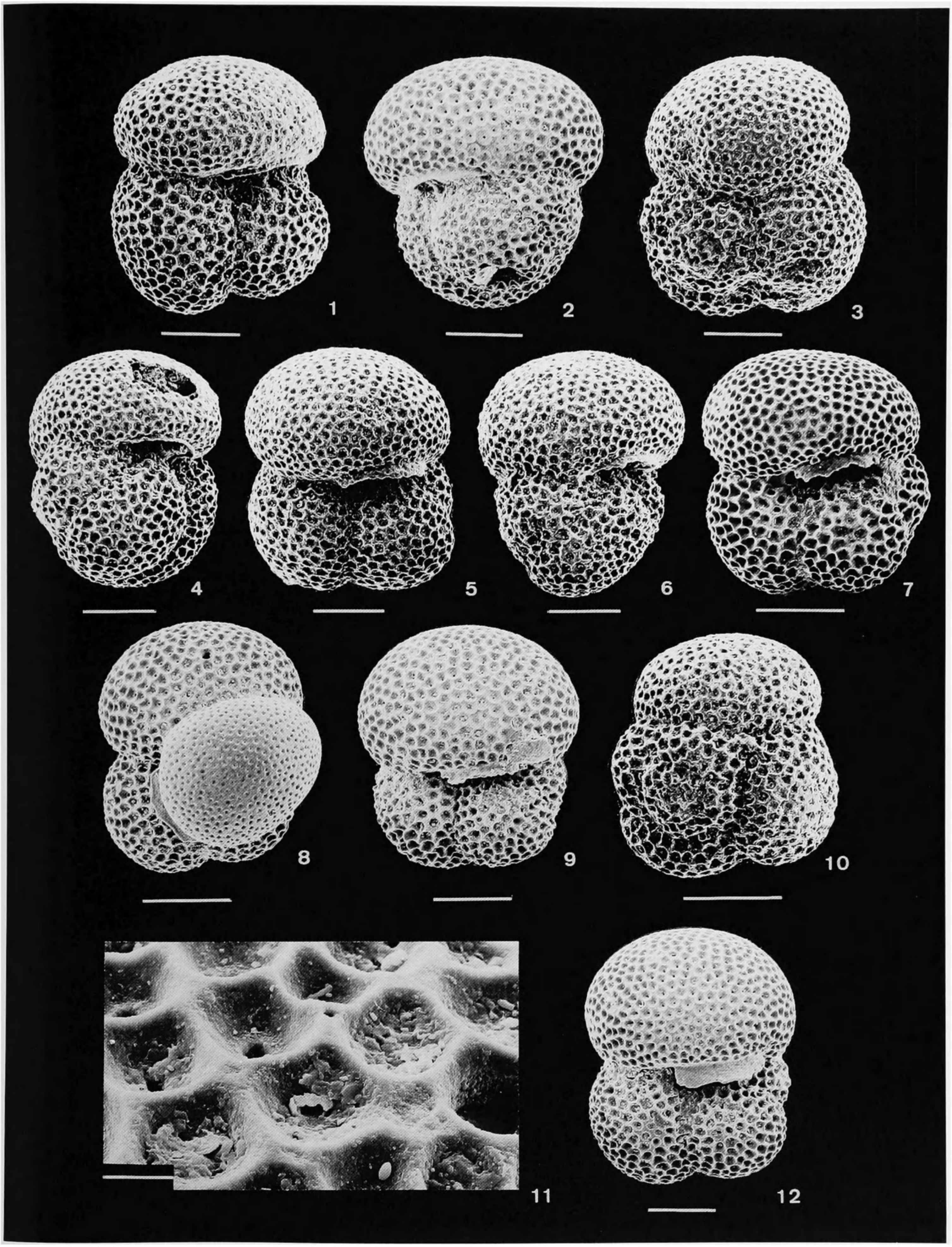
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PLATE 31

Hedbergella monmouthensis (Olsson, 1960)

(Figures 1–6, 8–13: bars = 50 μm; Figures 7, 14: bars = 10 μm; Figure 15: bar = 4 μm)

FIGURES 1–11.—Topotypes, upper Maastrichtian, Redbank Fm., New Jersey; Figure 7, enlarged view of apertural lips of Figure 1.

FIGURES 12–15.—Zone P0, Millers Ferry, Alabama, core 225, sample 346; Figures 14, 15, views of wall of Figure 13 showing development of primitive pore pits.

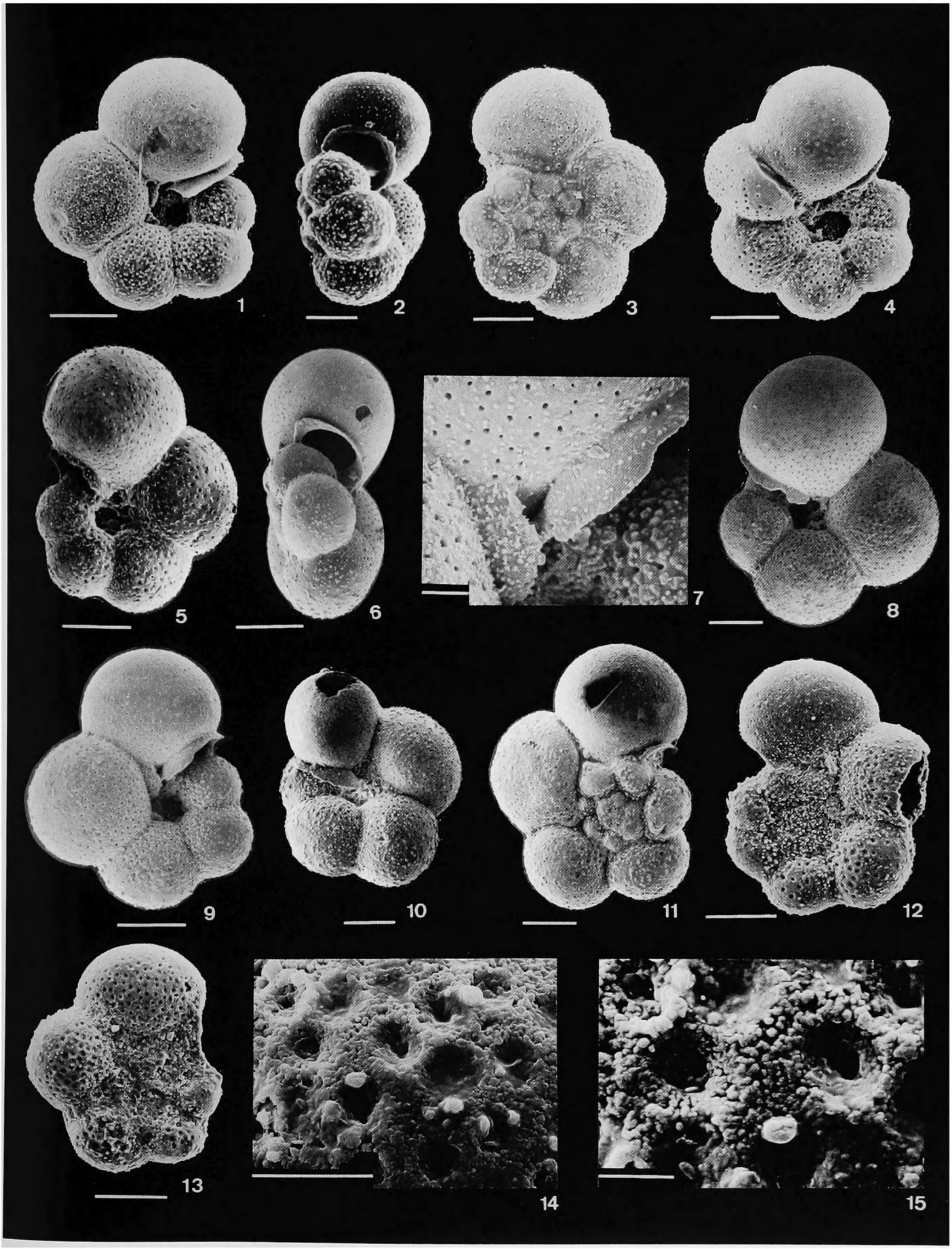
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PLATE 32

Globanomalina archeocompressa (Blow, 1979)

(bars = 10 μm)

FIGURES 1-9.—Zone P0, Millers Ferry, Alabama, core 225, sample 342.

FIGURE 10.—Zone P0, Millers Ferry, Alabama, core 225, sample 346.

Globanomalina compressa (Plummer, 1926)

(bars = 100 μm)

FIGURES 11-13, 15, 16.—Zone P1c, DSDP Site 356/26/3: 90-92 cm; São Paulo Plateau, South Atlantic Ocean.

FIGURE 14.—Zone P2, DSDP Hole 398D/39/4: 100-102 cm; western Iberian continental margin, eastern North Atlantic Ocean.

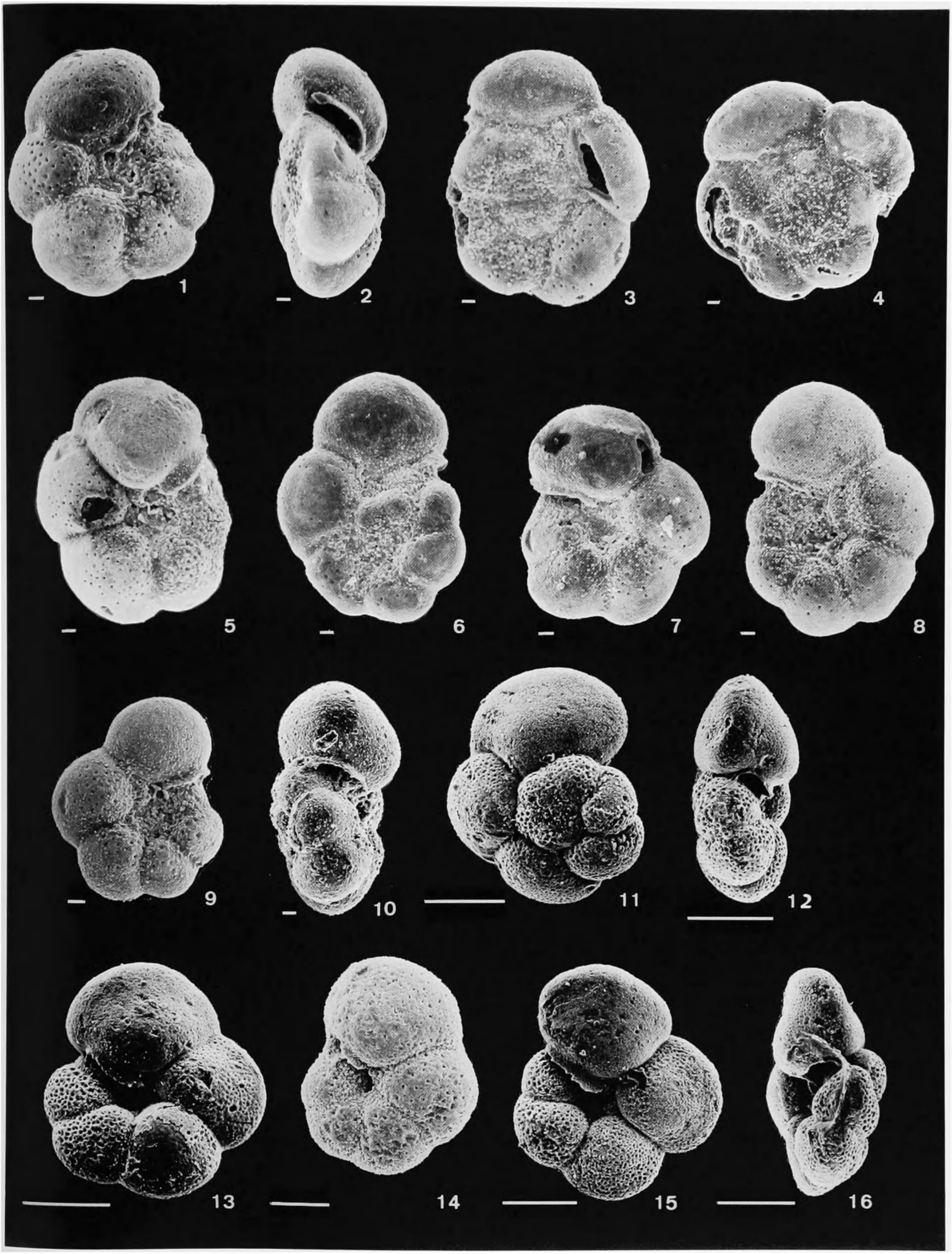
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PLATE 33

Globanomalina australiformis (Jenkins, 1965)

(Figures 7, 10, 11, 13: bars = 100 μm; Figures 1–4, 6: bars = 40 μm; Figures 8, 9: bars = 50 μm; Figures 5, 12: bars = 10 μm)

FIGURES 1–6.—Topotypes, *Subbotina triloculinoides* Zone, N141/910N.2, Waipara, New Zealand; Figure 5, view of 3rd chamber of Figure 3 showing wall texture.

FIGURES 8, 9.—Lower Paleocene, ODP Hole 738B/23X/CC; Kerguelen Plateau, southern Indian Ocean.

FIGURES 7, 10–13.—Zone P1c, ODP Hole 747C/2R/4: 90–92 cm; Kerguelen Plateau, southern Indian Ocean; Figure 12, view of 4th chamber of Figure 13 showing wall texture.

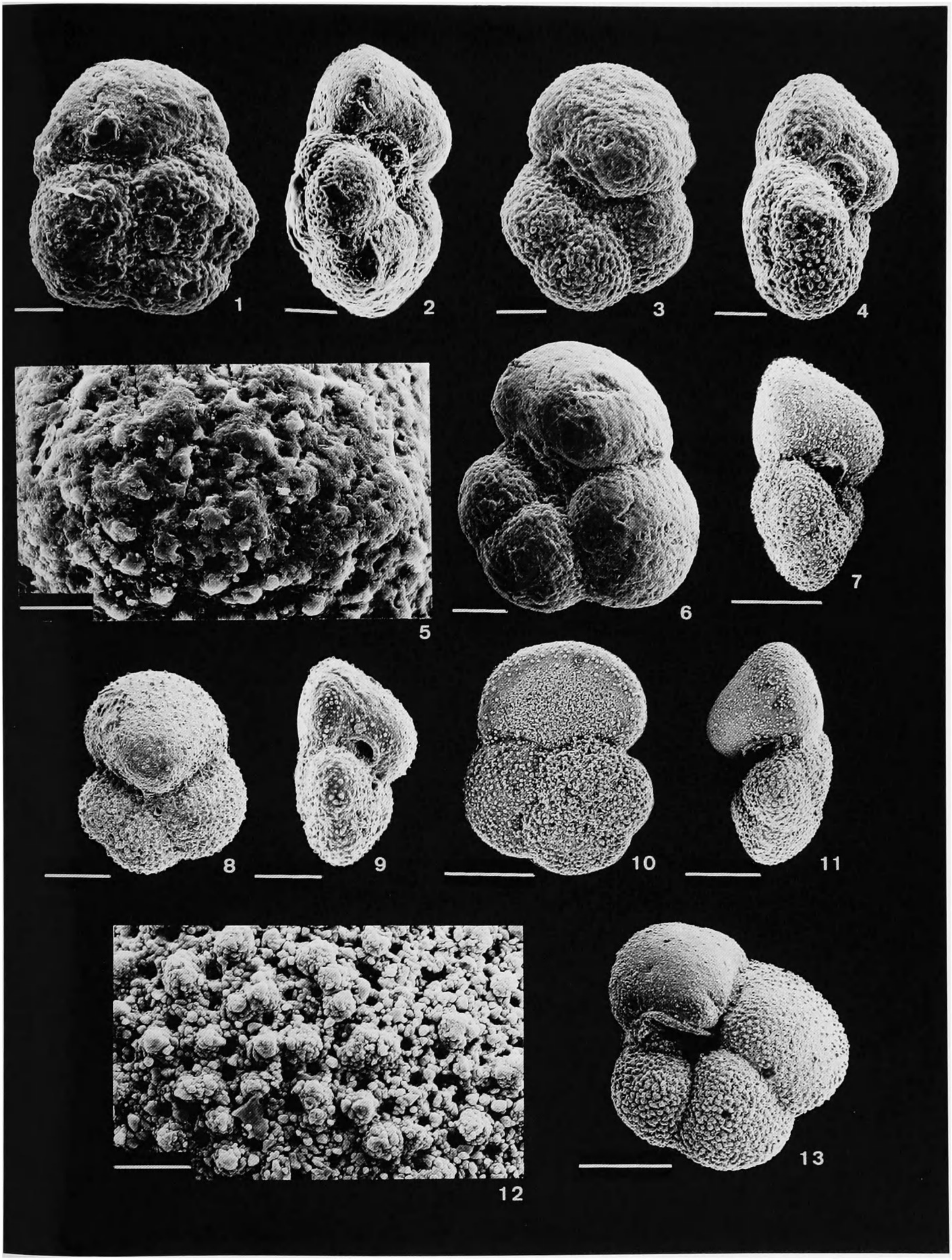
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PLATE 34

Globanomalina chapmani (Parr, 1938)

(bars = 50 μm)

FIGURES 1, 2, 5, 6.—Zone P4, Vincentown Fm., Glendola Well, New Jersey, sample 286–287 feet.

FIGURE 4.—Zone P4, Vincentown Fm., Whitesville Well, New Jersey, sample 215–220 feet.

FIGURES 3, 7.—Zone P4, Nerinea Fm., Pondicherry, South India, sample PT14.

Globanomalina planoconica (Subbotina, 1953)

(bars = 50 μm)

FIGURES 8–17.—Zone P4, Velasco Fm., Tamaulipas, Mexico, John Cruz Collection, sample 17.

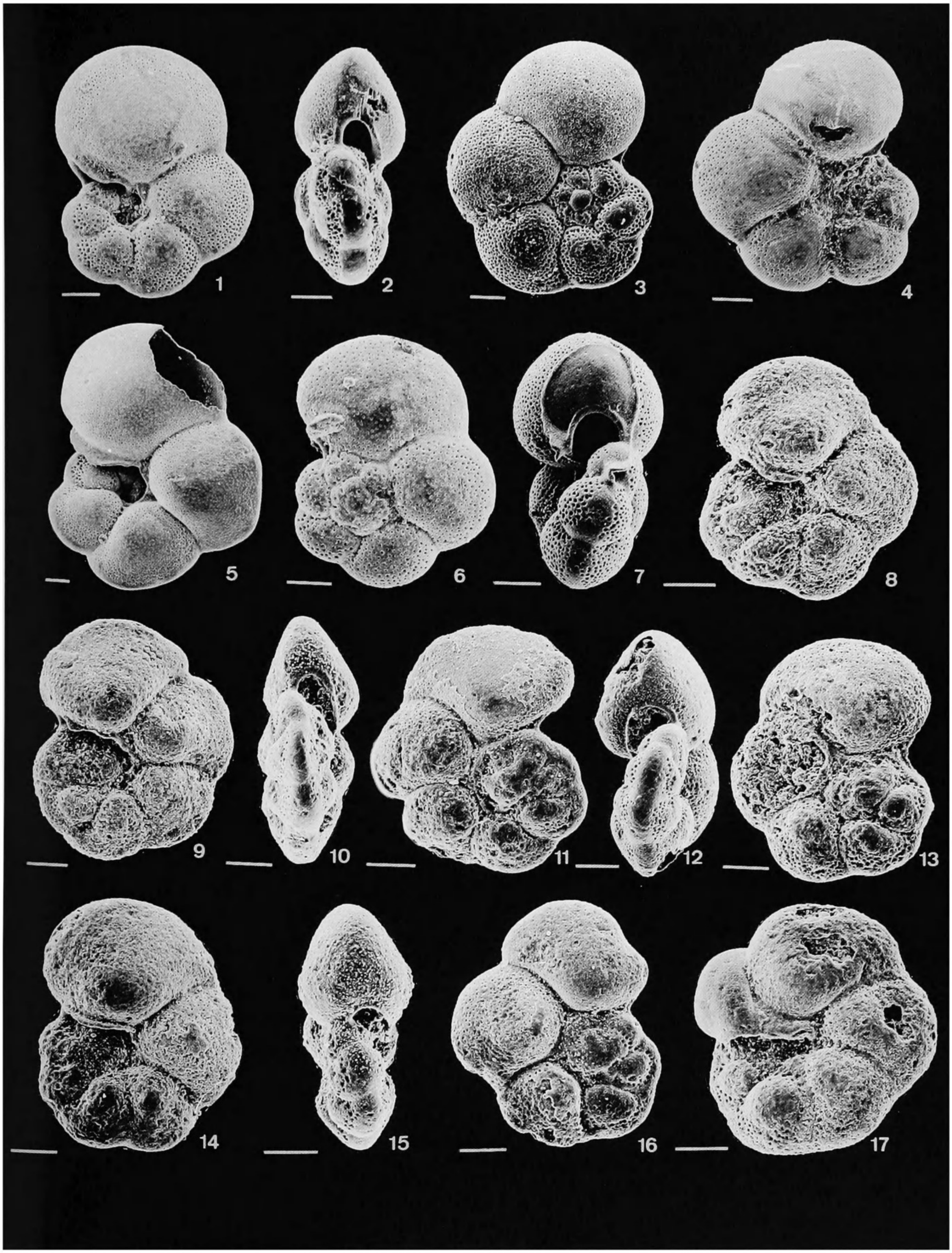
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PLATE 35

Globanomalina compressa (Plummer, 1926)

(Figures 1-3, 5-13, 17: bars = 100 μm; Figure 4: bar = 40 μm)

FIGURES 1, 3, 5, 7, 11.—Zone P1c, Mexia Clay Mbr., Midway Group, Texas.

FIGURE 4.—Zone P2, Wills Point Fm., Texas.

FIGURES 2, 6, 8-10.—Zone P1c, Brightseat Fm., Maryland.

FIGURES 12, 13, 17.—Zone P1c, DSDP Site 356/26/3: 90-92 cm; São Paulo Plateau, South Atlantic Ocean.

Globanomalina ehrenbergi (Bolli, 1957)

(bars = 100 μm)

FIGURES 14-16.—Zone P1c, Mexia Clay Mbr., Midway Group, Texas.

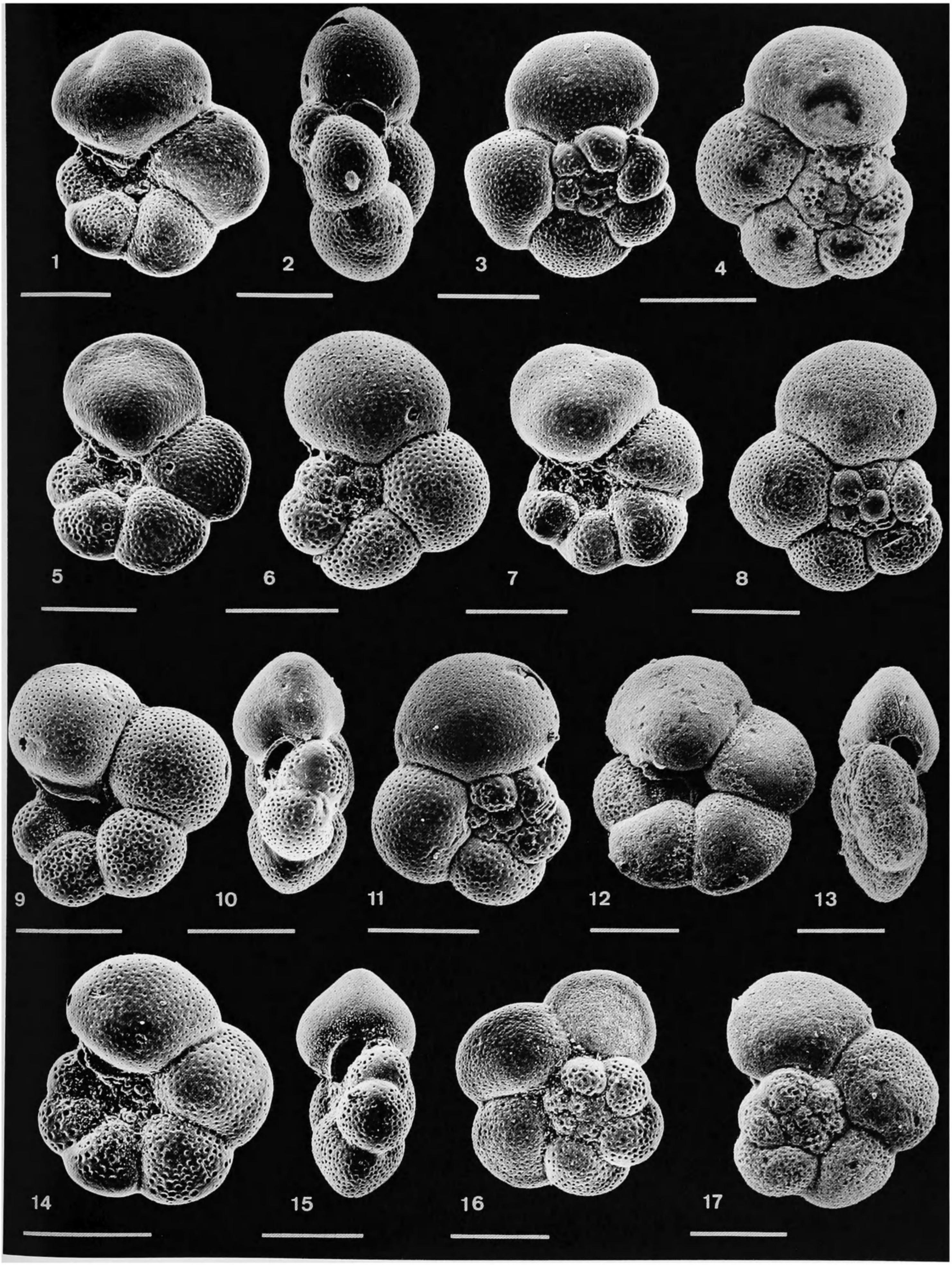
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PLATE 36

Globanomalina planocompressa (Shutskaya, 1965)

(Figures 1–4: bars = 40 μm; Figures 5, 6: bars = 100 μm)

FIGURE 1.—Zone P1a, Millers Ferry, Alabama, core 225, sample 194.

FIGURES 2, 3, 6.—Zone P1a, Millers Ferry, Alabama, surface sample 30 feet.

FIGURE 4.—Zone P1b, Eureka Core, Gulf of Mexico, sample 6817–6817.5 feet.

FIGURE 5.—Zone P1c, Brightseat Fm., Maryland.

Globanomalina imitata (Subbotina, 1953)

(Figures 8–13, 15, 16: bars = 40 μm; Figures 7, 14: bars = 100 μm)

FIGURES 7, 16.—Zone P1c, Mexia Clay Mbr., Midway Group, Texas.

FIGURES 8–12.—Zone P4, Vincentown Fm., Whitesville Well, New Jersey, sample 210–215 feet; Figure 12, view showing inner whorl of conical-shaped chambers with pustulose surface.

FIGURES 13–15.—*Globanomalina* aff. *imitata* transitional to *G. ovalis,* Zone P4, Nerinea Fm., Pondicherry, South India, sample PT14.

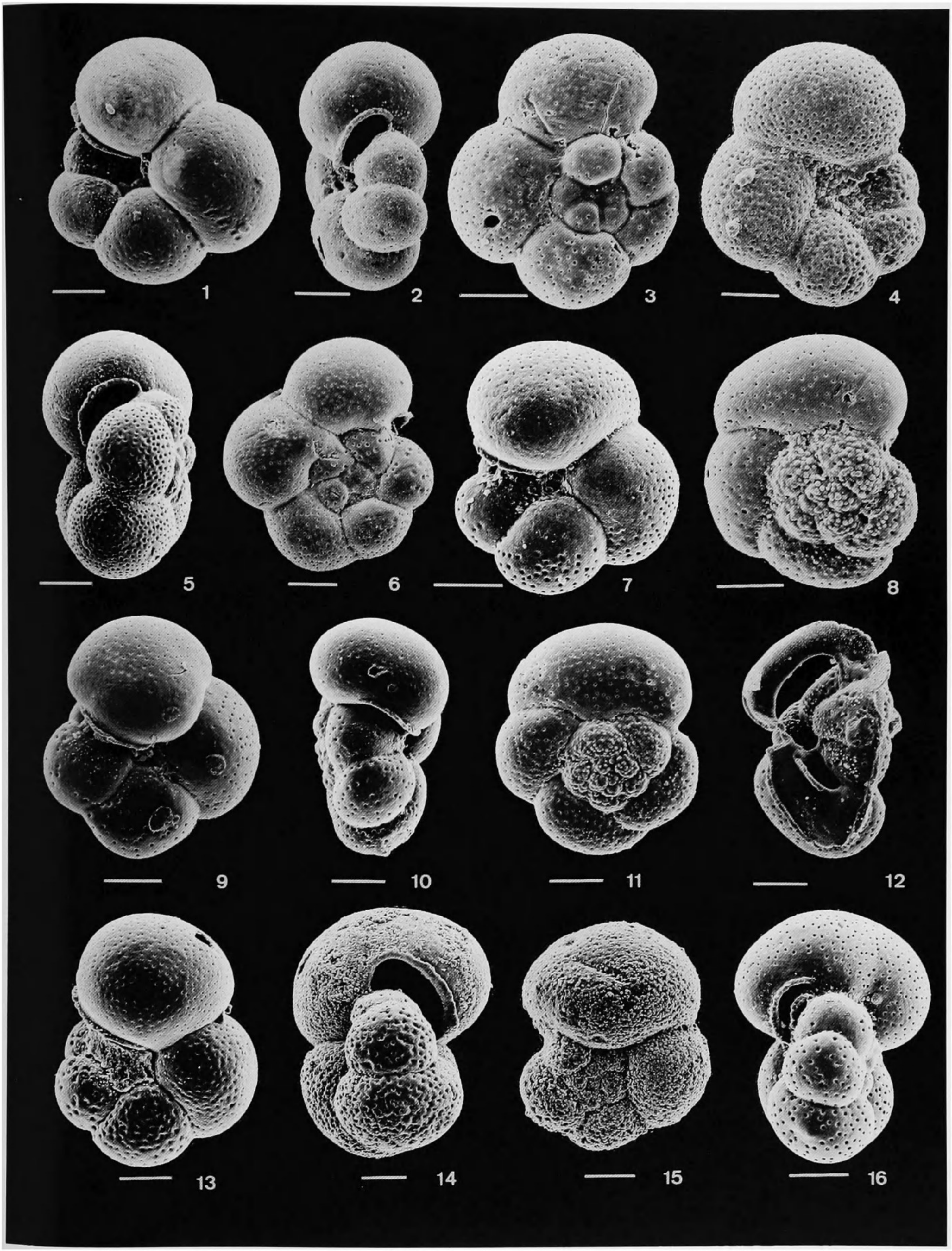
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PLATE 37

Globanomalina ovalis Haque, 1956

(bars = 50 μm)

FIGURES 1–15.—Zone P4, Nerinea Fm., Pondicherry, South India, sample PT14.

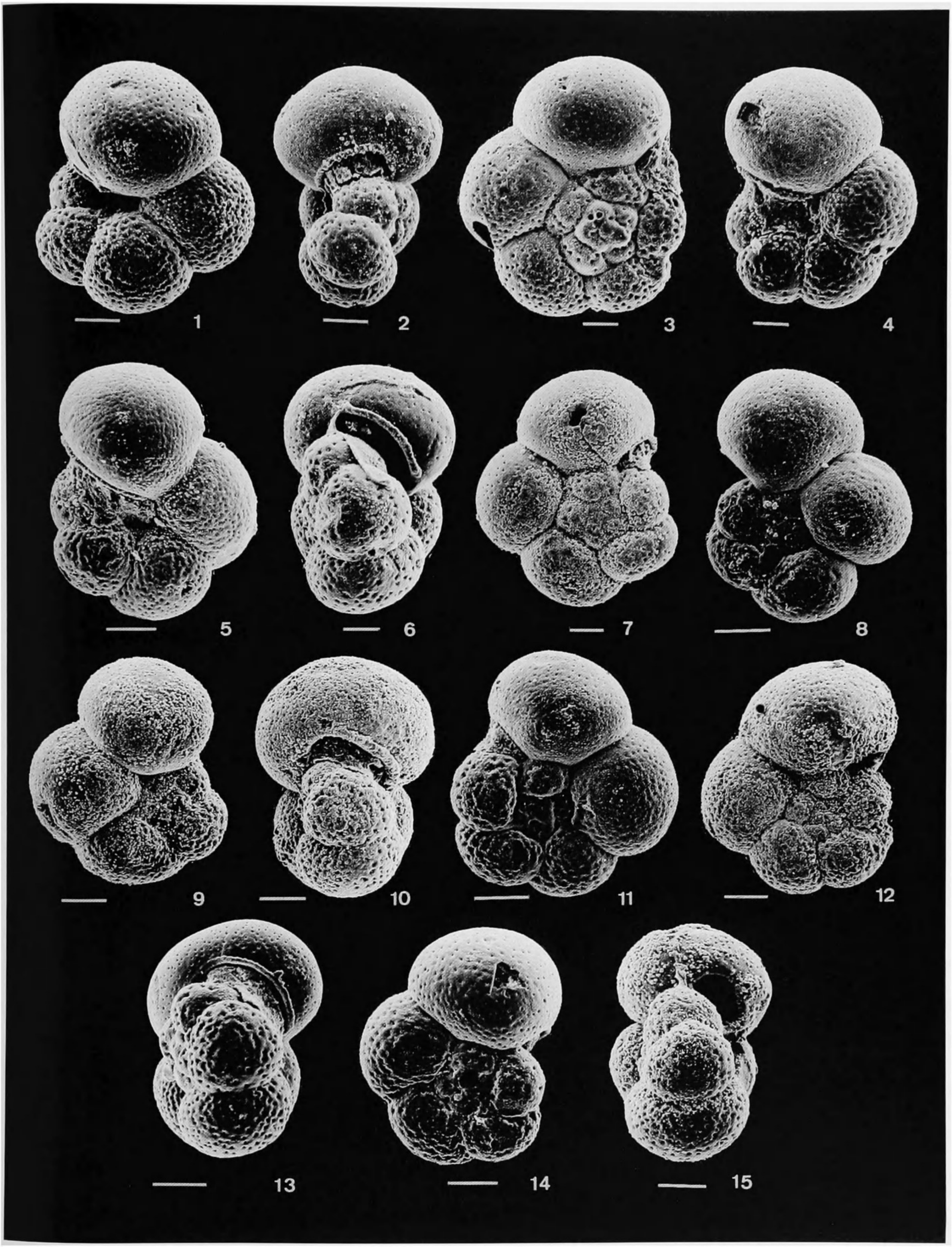
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PLATE 38

Globanomalina pseudomenardii (Bolli, 1957)

(bars = 50 μm)

FIGURES 1–7.—Zone P4, Velasco Fm., Tamaulipas, Mexico.

FIGURES 8, 10–16.—Zone P4, Vincentown Fm., Glendola Well, New Jersey, sample 286–287 feet.

FIGURE 9.—Zone P4, Nerinea Fm., Pondicherry, South India, sample PT14.

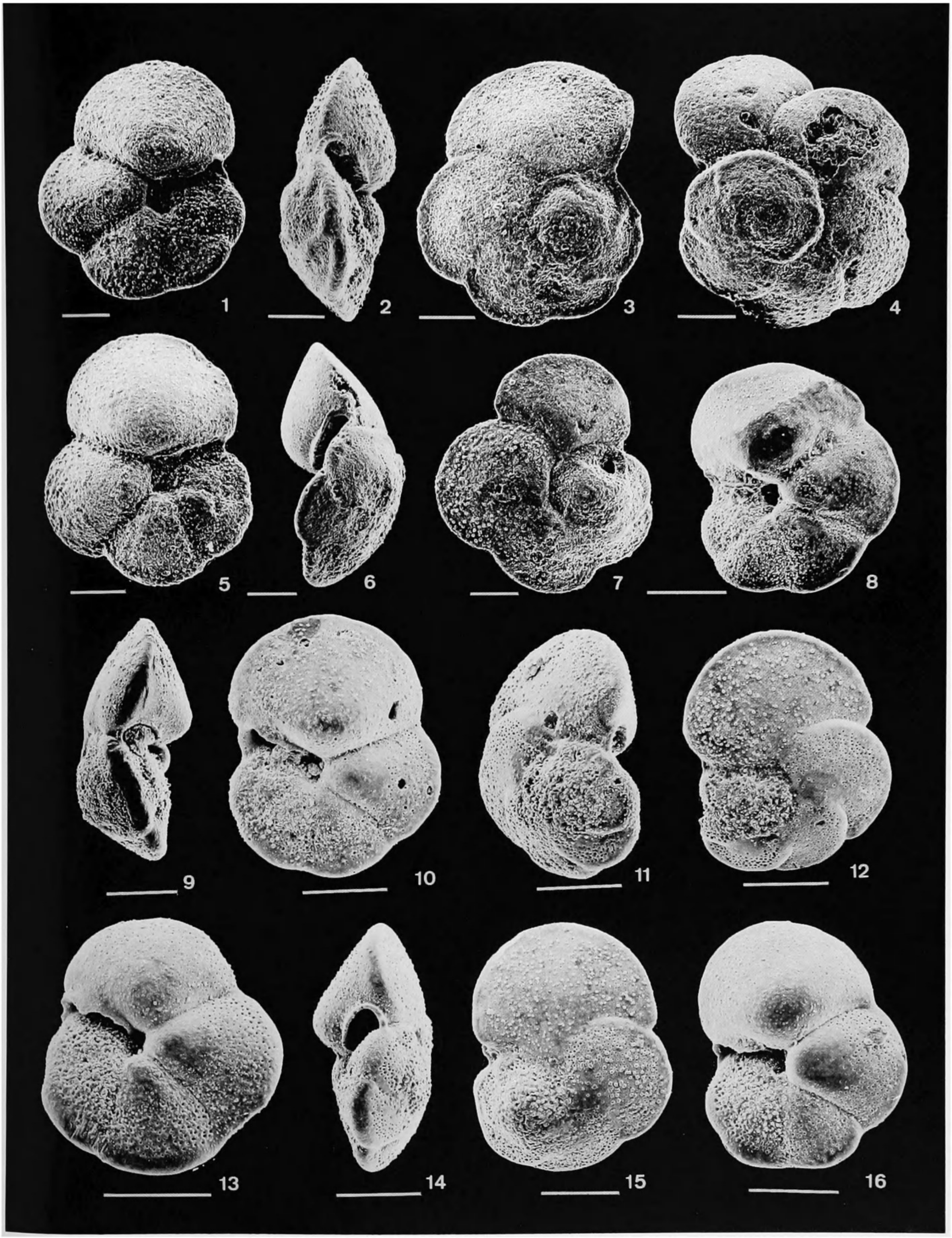
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PLATE 39

Acarinina coalingensis (Cushman and Hanna, 1927)

(bars = 100 μm)

FIGURES 1, 4, 13–15.—Zone P5, DSDP Site 465/3/1: 59–61 cm; Hess Rise, central North Pacific Ocean.

FIGURES 2, 3, 8, 12, 16.—Zone P5, DSDP Hole 20C/6/4: 17–19 cm; Brazil Basin, South Atlantic Ocean.

FIGURES 5–7, 9–11.—Zone P5, ODP Hole 758A/28/1: 50–52 cm; Ninetyeast Ridge, Indian Ocean.

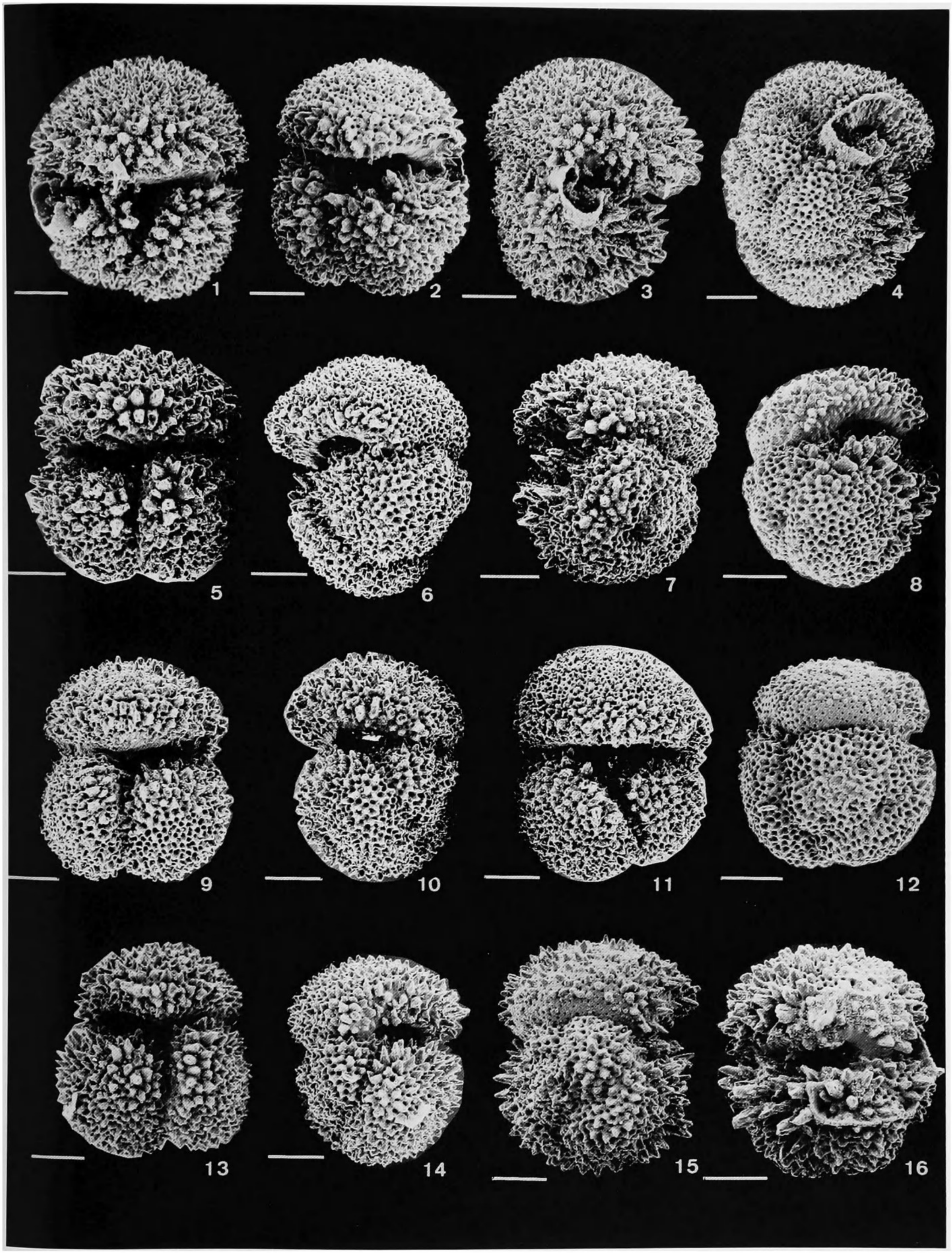
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PLATE 40

Acarinina mckannai (White, 1928)

(bars = 100 μm)

FIGURES 1–4.—Zone P4, DSDP Site 465/4/3: 62–64 cm; Hess Rise, central North Pacific Ocean.

FIGURES 5–7.—Zone P4, DSDP Site 384/6/CC; southeast Newfoundland Ridge, North Atlantic Ocean.

FIGURE 8.—Zone P4, DSDP Site 384/7/1: 60–62 cm; southeast Newfoundland Ridge, North Atlantic Ocean.

FIGURES 9–11.—Zone P4, DSDP Site 527/27/1: 30–32 cm; Walvis Ridge, South Atlantic Ocean.

FIGURES 12, 16.—Zone P4, ODP Hole 758A/28/5: 50–52 cm; Ninetyeast Ridge, Indian Ocean.

FIGURE 13.—Late Paleocene, ODP Hole 738C/16R/1: 55–60 cm; Kerguelen Plateau, southern Indian Ocean.

FIGURES 14, 15.—Zone P4, Vincentown Fm., Glendola Well, New Jersey, sample 219–221 feet.

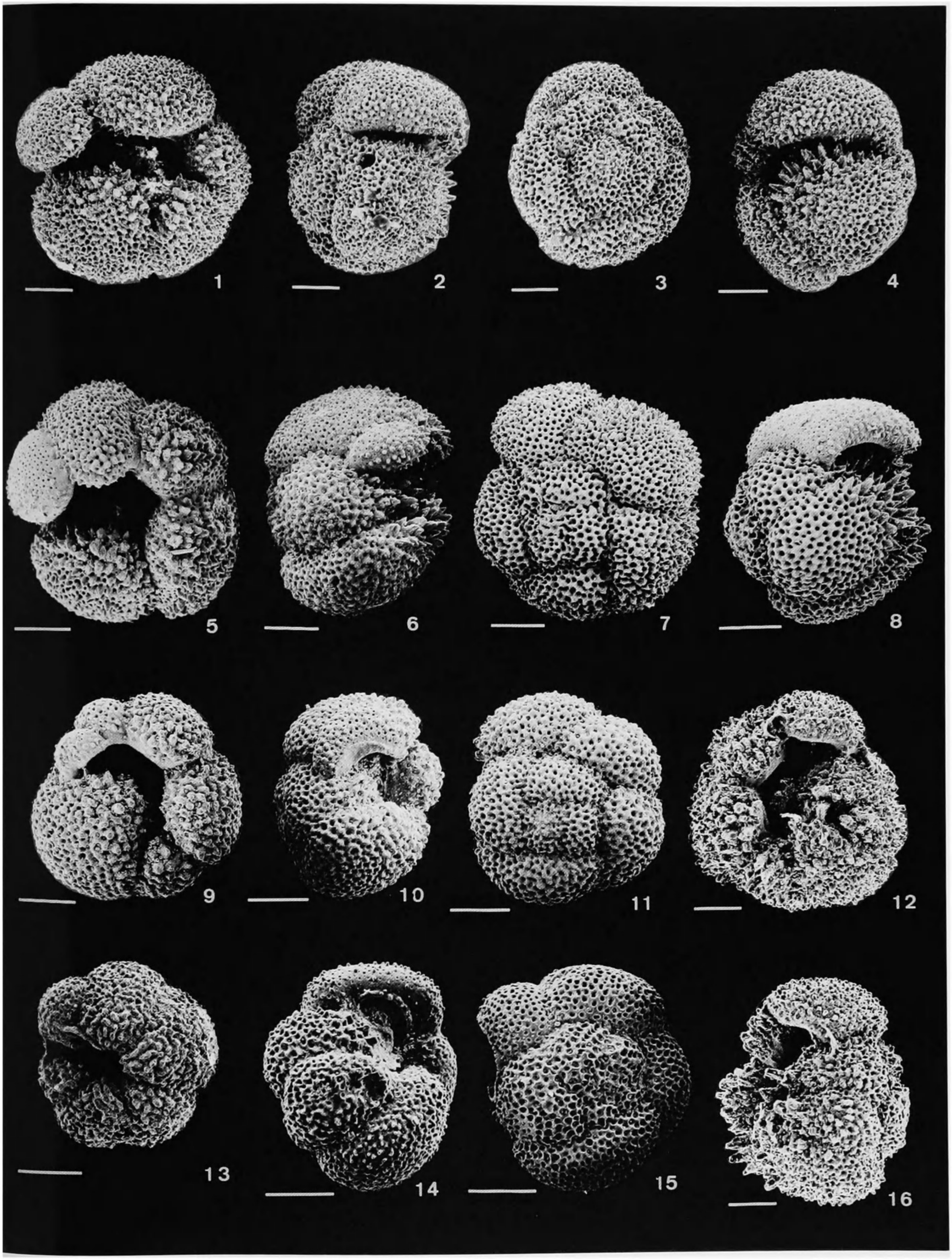
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PLATE 41

Acarinina nitida (Martin, 1943)

(Figures 1–4, 7, 10: bars = 40 μm; Figures 13–15: bars = 50 μm; Figures 5, 6, 8, 9, 11, 12, 16: bars = 100 μm)

FIGURES 1–3, 7.—Zone P4, DSDP Site 384/9/2: 136–138 cm.

FIGURES 4, 10.—Zone P4, DSDP Site 384/8/4: 136–138 cm; southeast Newfoundland Ridge, North Atlantic Ocean.

FIGURES 5, 8, 9, 11, 12.—Zone P4, Vincentown Fm., Glendola Well, New Jersey, sample 219–221 feet.

FIGURE 6.—Zone P5, ODP Hole 758A/28/3: 50–52 cm; Ninetyeast Ridge, Indian Ocean.

FIGURE 13.—Lower Eocene, ODP Hole 738C/10R: 277.78 mbsf.

FIGURES 14, 15.—Lower Eocene, ODP Hole 738C/10R/3: 98–102 cm; Kerguelen Plateau, southern Indian Ocean.

FIGURE 16.—Upper Paleocene, ODP Hole 690B/25/3: 90–92 cm; Maud Rise, Southern Ocean.

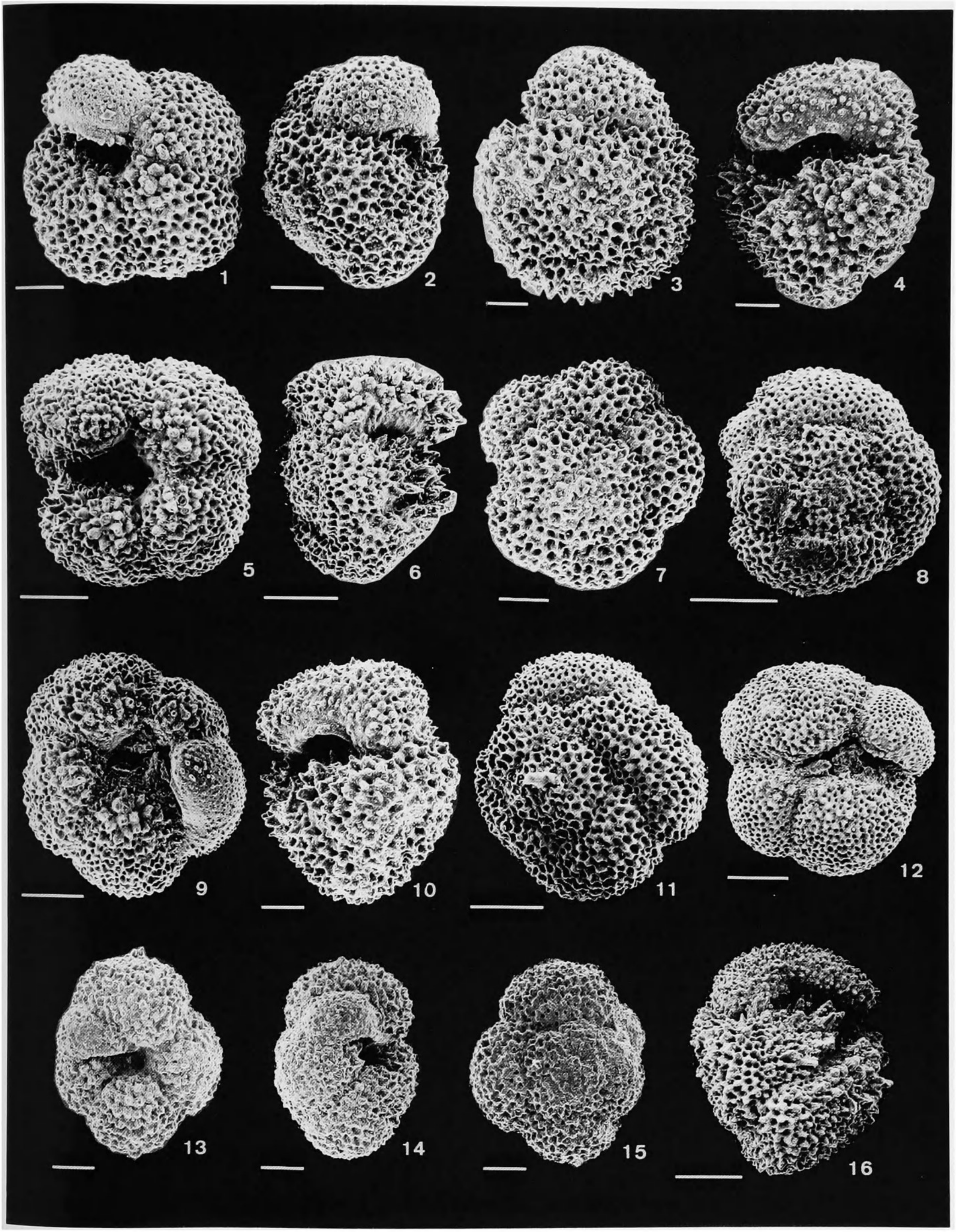
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PLATE 42

Acarinina soldadoensis (Brönnimann, 1952)

(bars = 100 μm)

FIGURES 1–3.—Zone P4, DSDP Site 465/4/4: 62–64 cm.

FIGURE 4.—Zone P5, ODP Hole 758A/28/3: 50–52 cm.

FIGURES 5–7.—Zone P6a, DSDP Hole 20C/3/1: 1–19 cm; Brazil Basin, South Atlantic Ocean.

FIGURES 8, 12–14.—Zone P5, DSDP Site 465/3/1: 59–61 cm; Hess Rise, central North Pacific Ocean.

FIGURES 9–11.—Zone P5, DSDP Site 213/16/1: 104–106 cm; eastern Indian Ocean.

FIGURES 15, 16.—Zone P4, ODP Hole 758A/28/5: 50–52 cm; Ninetyeast Ridge, Indian Ocean.

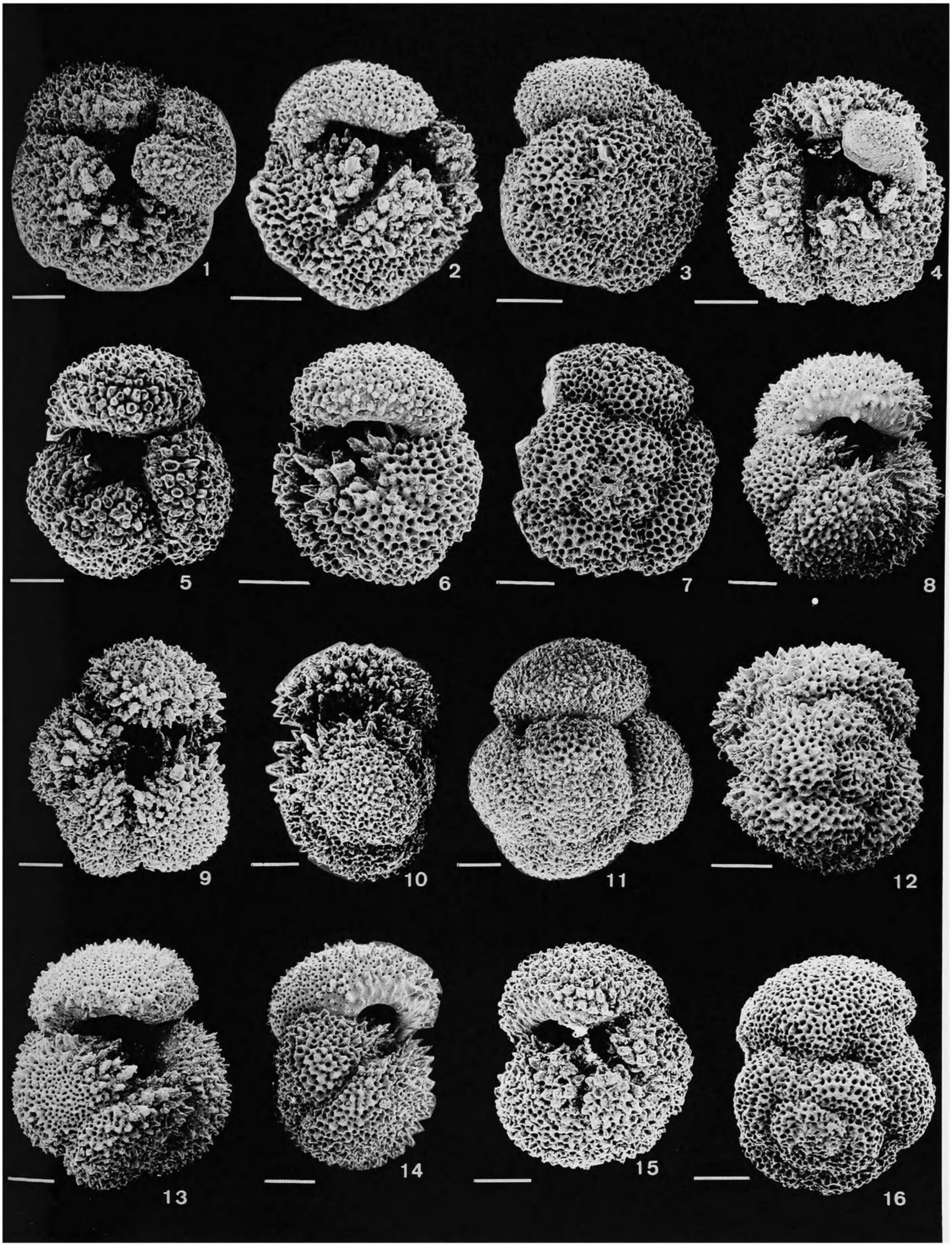
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PLATE 43

Acarinina strabocella (Loeblich and Tappan, 1957)

(Figures 1, 2, 5: bars = 40 μm; Figures 3, 4, 6–16: bars = 100 μm)

FIGURE 1.—Zone P3b, Hornerstown Fm., New Jersey, NJT 12-1A.

FIGURES 2, 3, 13.—Zone P2, DSDP Site 356/25/5: 148–150 cm; São Paulo Plateau, South Atlantic Ocean.

FIGURES 4, 7, 8, 10, 11, 14, 16.—Zone P2, ODP Hole 750A/11/2: 19–21 cm.

FIGURES 5, 6, 9, 12.—Zone P2/3, ODP Hole 750A/11/1: 149–150 cm; Kerguelen Plateau, southern Indian Ocean.

FIGURE 15.—Zone P3, DSDP Site 384/9/6: 136–138 cm; southeast Newfoundland Ridge, North Atlantic Ocean.

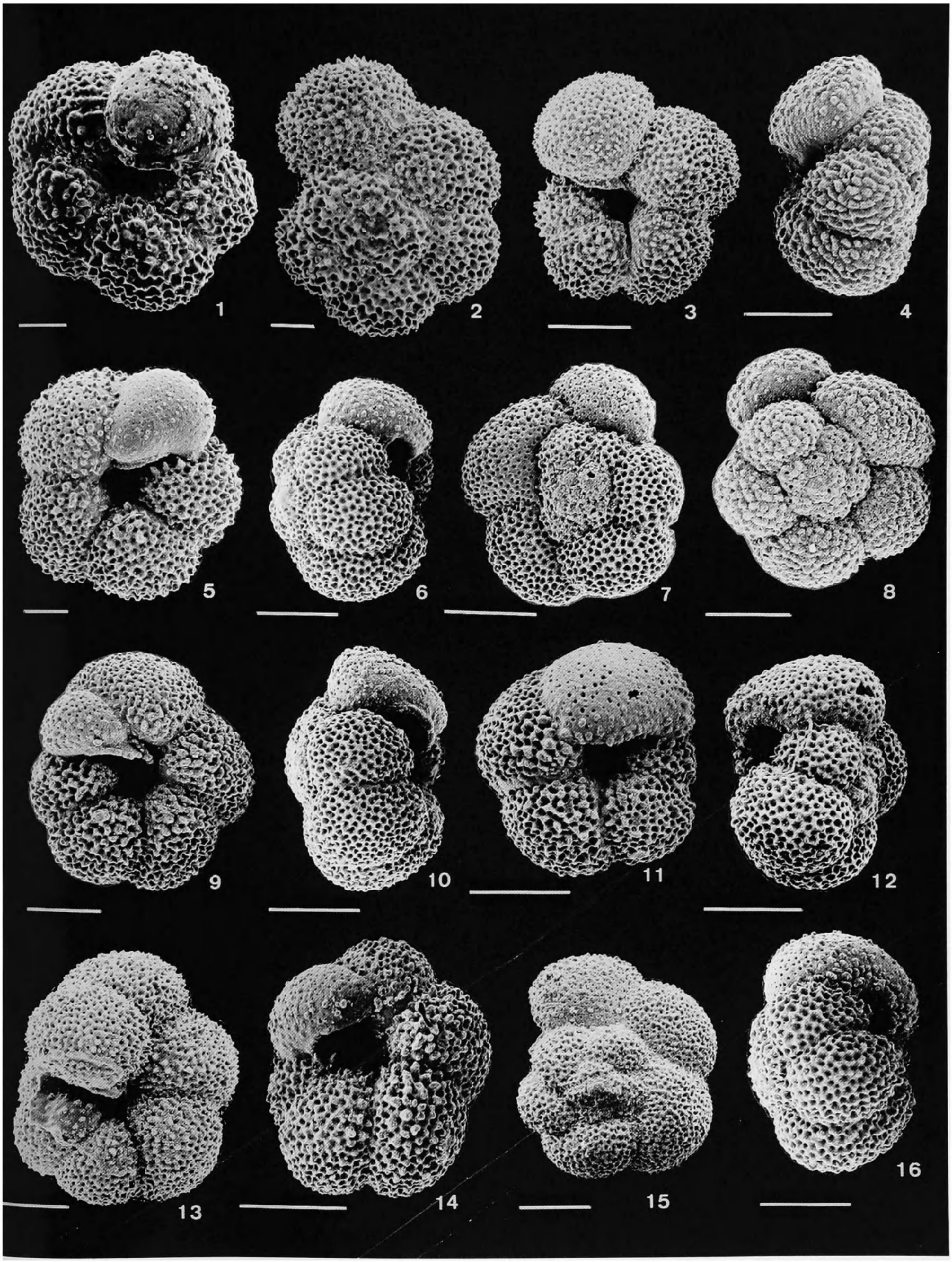
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PLATE 44

Acarinina subsphaerica (Subbotina, 1947)

(bars = 100 μm)

FIGURES 1, 5, 16.—Zone P4, DSDP Site 384/7/CC; southeast Newfoundland Ridge, North Atlantic Ocean.

FIGURES 2, 3, 8, 10, 13.—Zone P4, DSDP Site 465/5/1: 65-67 cm.

FIGURE 4.—Upper Paleocene, ODP Hole 738C/15R: 322.07 mbsf; southern Kerguelen Plateau, Southern Ocean.

FIGURES 6, 7.—Zone P4, DSDP Site 527/27/1: 30-32 cm; Walvis Ridge, South Atlantic Ocean.

FIGURES 9, 11.—Zone P5, ODP Hole 758A/28/3: 50-52 cm; Ninetyeast Ridge, Indian Ocean.

FIGURE 12.—Zone P4, ODP Hole 761B/17/6: 49-51 cm; Wombat Plateau, eastern Indian Ocean.

FIGURES 14, 15.—Zone P4, DSDP Site 465/4/4: 62-64 cm; Hess Rise, central North Pacific Ocean.

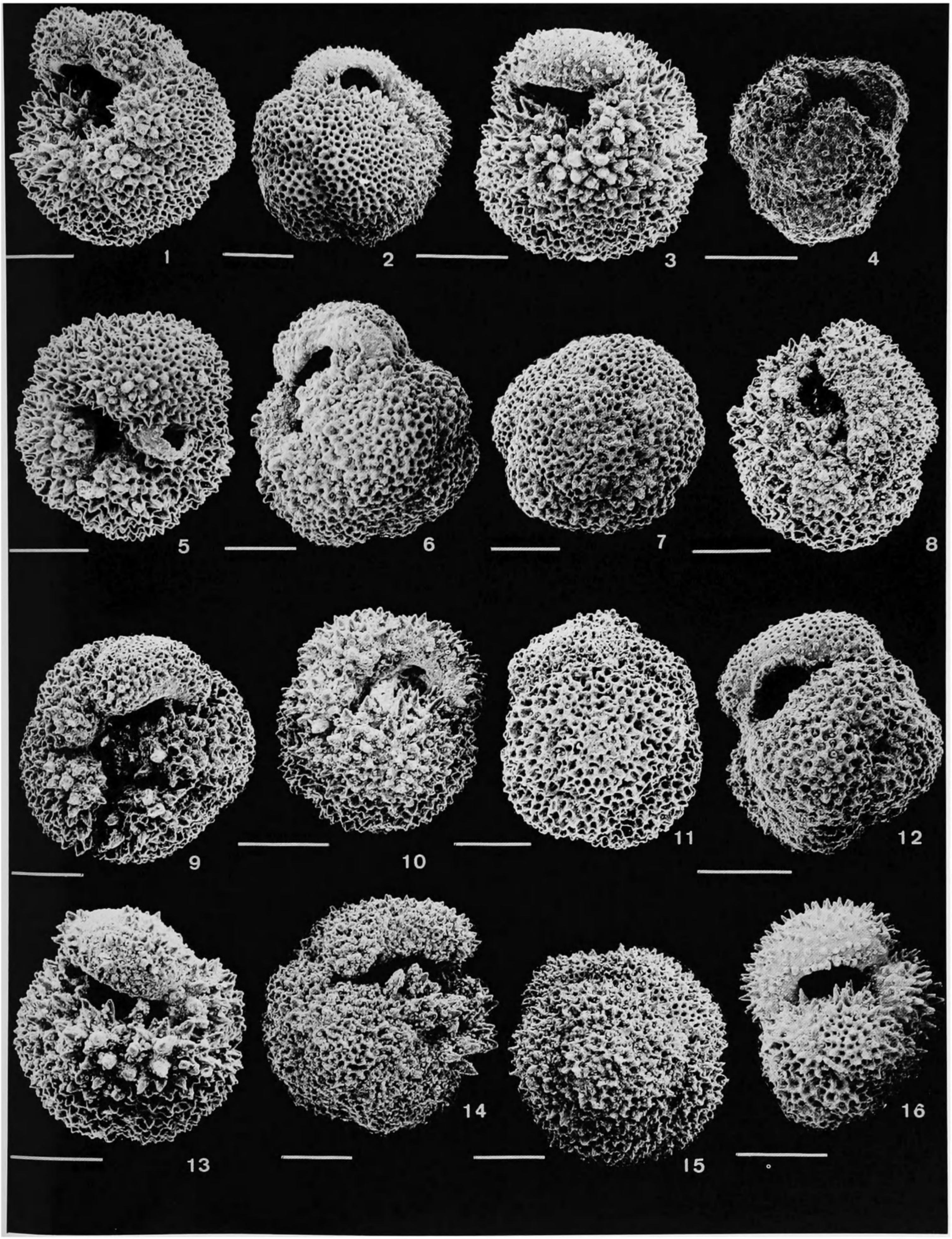
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PLATE 45

Morozovella acuta (Toulmin, 1941)

(bars = 100 μm)

FIGURES 1, 3, 5, 6, 9–11.—Zone P4, Velasco Fm., Tamaulipas, Mexico.

FIGURES 2, 12–14.—Zone P3, DSDP Site 465/5/4: 63–64 cm; Hess Rise, central North Pacific Ocean.

FIGURES 4, 7, 8.—Zone P4, Vincentown Fm., Glendola Well, New Jersey, sample 230–232 feet.

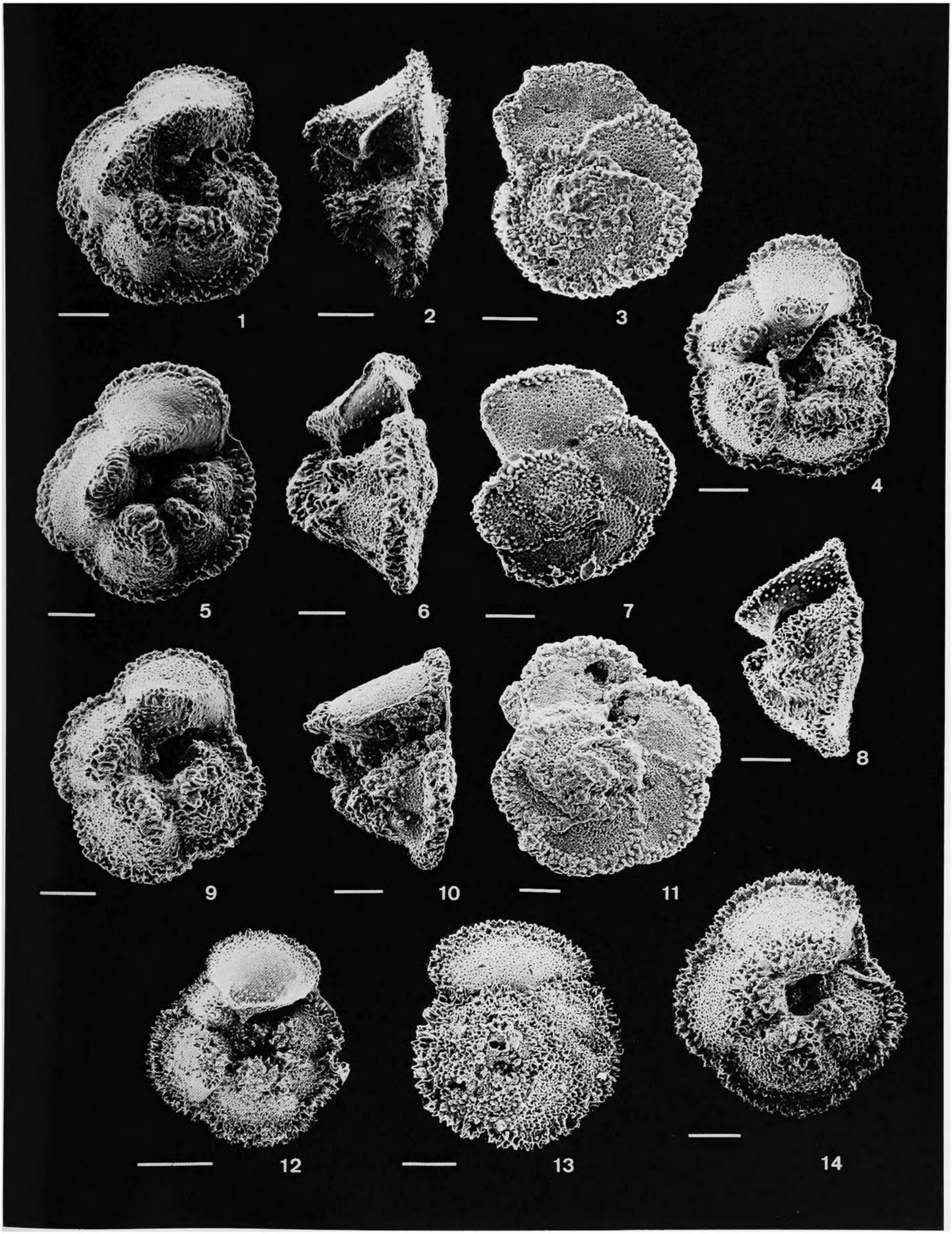
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PLATE 46

Morozovella acutispira (Bolli and Cita, 1960)

(bars = 100 μm)

FIGURES 1–6.—Zone P3b, DSDP Site 527/28/6: 30–32 cm; Walvis Ridge, South Atlantic Ocean.

FIGURES 7, 12.—Zone P4, Vincentown Fm., Whitesville Well, New Jersey, sample 212–220 feet.

FIGURES 8, 9.—Zone P4?, ODP Hole 864C/13/2: 73–75 cm; East Pacific Rise, eastern central Pacific Ocean.

FIGURES 10, 11.—Zone P4, DSDP Site 465/3/4: 62–64 cm; Hess Rise, central North Pacific Ocean.

FIGURES 13–15.—Topotypes, Zone P4, Paderno d'Adda, northern Italy.

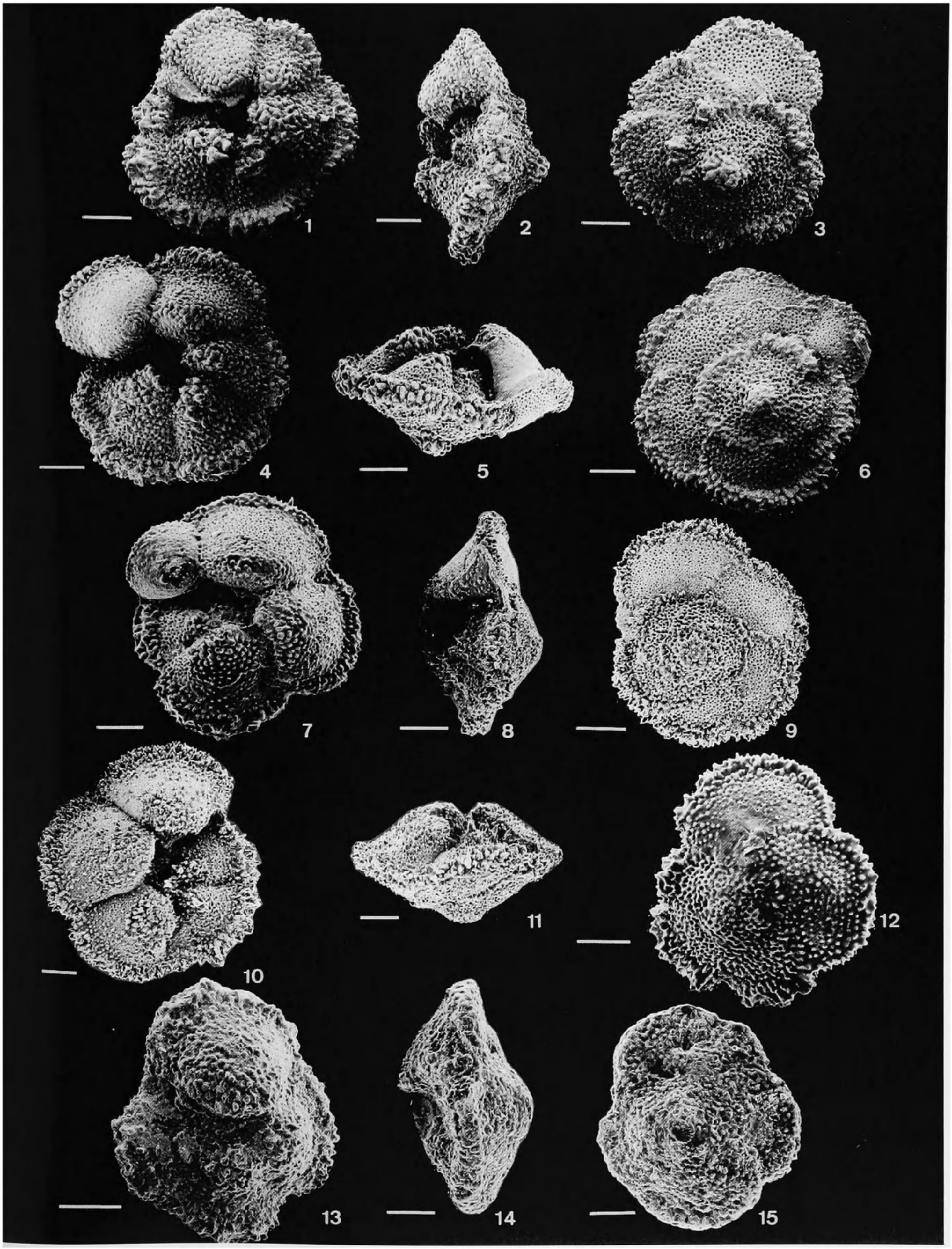
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PLATE 47

Morozovella aequa (Cushman and Renz, 1942)

(Figures 1–3, 7–10, 13–16: bars = 100 μm; Figures 4–6, 11, 12: bars = 200 μm)

FIGURES 1–3.—Zone P5, ODP Hole 758A/28/5: 50–52 cm.

FIGURES 4, 6, 7.—Zone P5, ODP Hole 758A/28/1: 50–52 cm, Ninetyeast Ridge, Indian Ocean.

FIGURES 5, 11, 12.—Zone P5, DSDP Site 465/3/1: 59–61 cm.

FIGURES 8–10.—Zone P4, DSDP Site 465/3/3: 98–100 cm; Hess Rise, central North Pacific Ocean.

FIGURES 13, 14, 16.—Zone P4, Vincentown Fm., Glendola Well, New Jersey, sample 230–232 feet.

FIGURE 15.—Zone P4, Velasco Fm., Tamaulipas, Mexico.

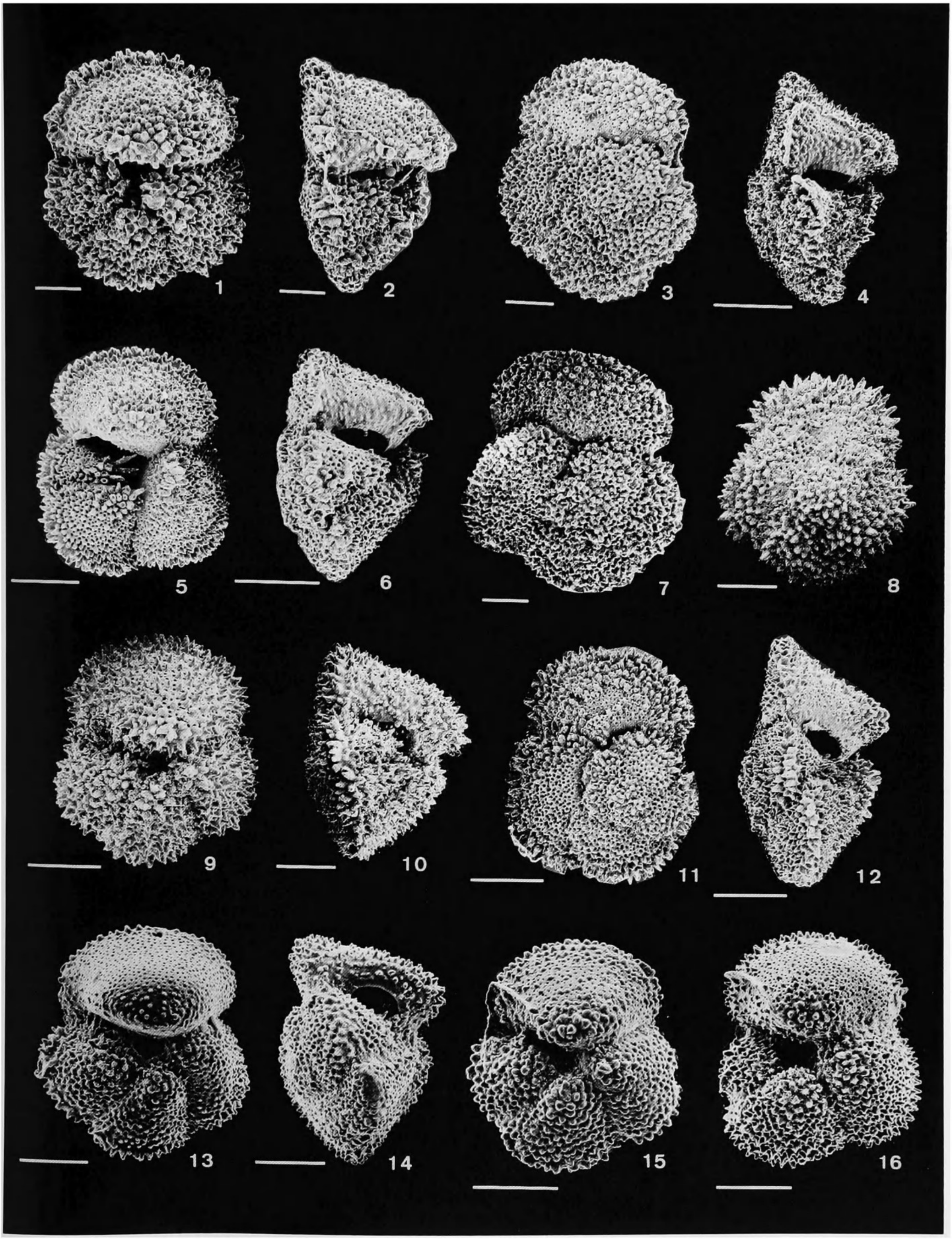
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PLATE 48

Morozovella angulata (White, 1928)

(bars = 100 μm)

FIGURES 1–3, 11.—Zone P3, DSDP Site 356/21/4: 110–112 cm; São Paulo Plateau, South Atlantic Ocean; Figures 1–3, *M.* aff. *M. angulata*.

FIGURES 4, 5, 7.—Zone P3, DSDP Site 465/6/5: 66–68 cm; Hess Rise, central North Pacific Ocean.

FIGURE 6.—Zone P2, DSDP Site 384/11/1: 86–88 cm.

FIGURES 8–10.—Zone P2, DSDP Site 527/30/1: 50–52 cm; Walvis Ridge, South Atlantic Ocean.

FIGURE 12.—Zone P2, DSDP Site 384/11/3: 30–32 cm.

FIGURES 13–16.—Zone P2, DSDP Site 384/10/CC; southeast Newfoundland Ridge, North Atlantic Ocean.

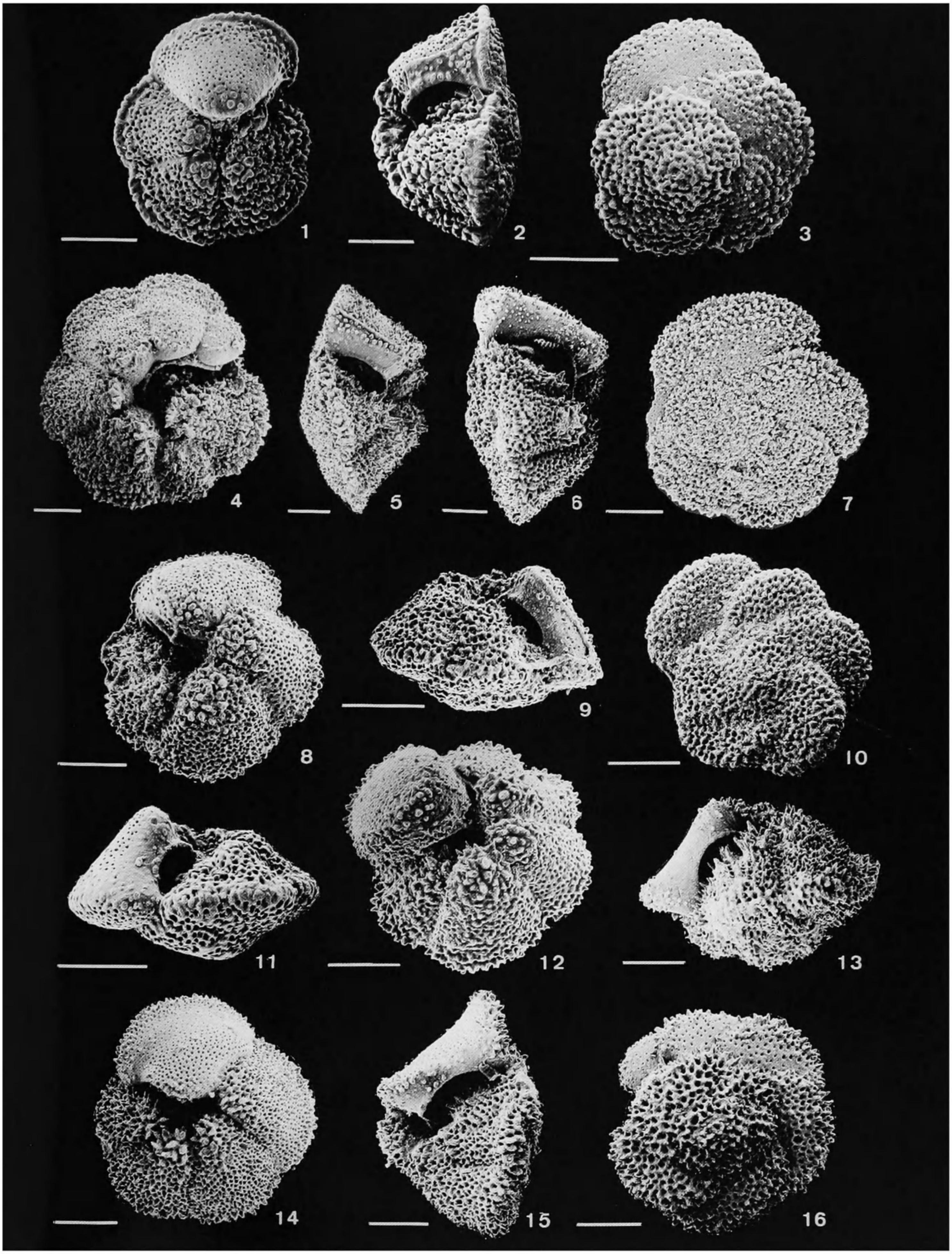
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PLATE 49

Morozovella apanthesma (Loeblich and Tappan, 1957)

(bars = 100 μm)

FIGURES 1–6.—Zone P4, DSDP Site 465/4/1: 62–64 cm.

FIGURES 7–9.—Zone P3, DSDP Site 465/6/5: 66–68 cm.

FIGURES 10, 11.—Zone P3, DSDP Site 384/10/5: 24–26 cm; southeast Newfoundland Ridge, North Atlantic Ocean.

FIGURES 12–15.—Zone P3a, DSDP Site 465/7/CC; Hess Rise, central North Pacific Ocean.

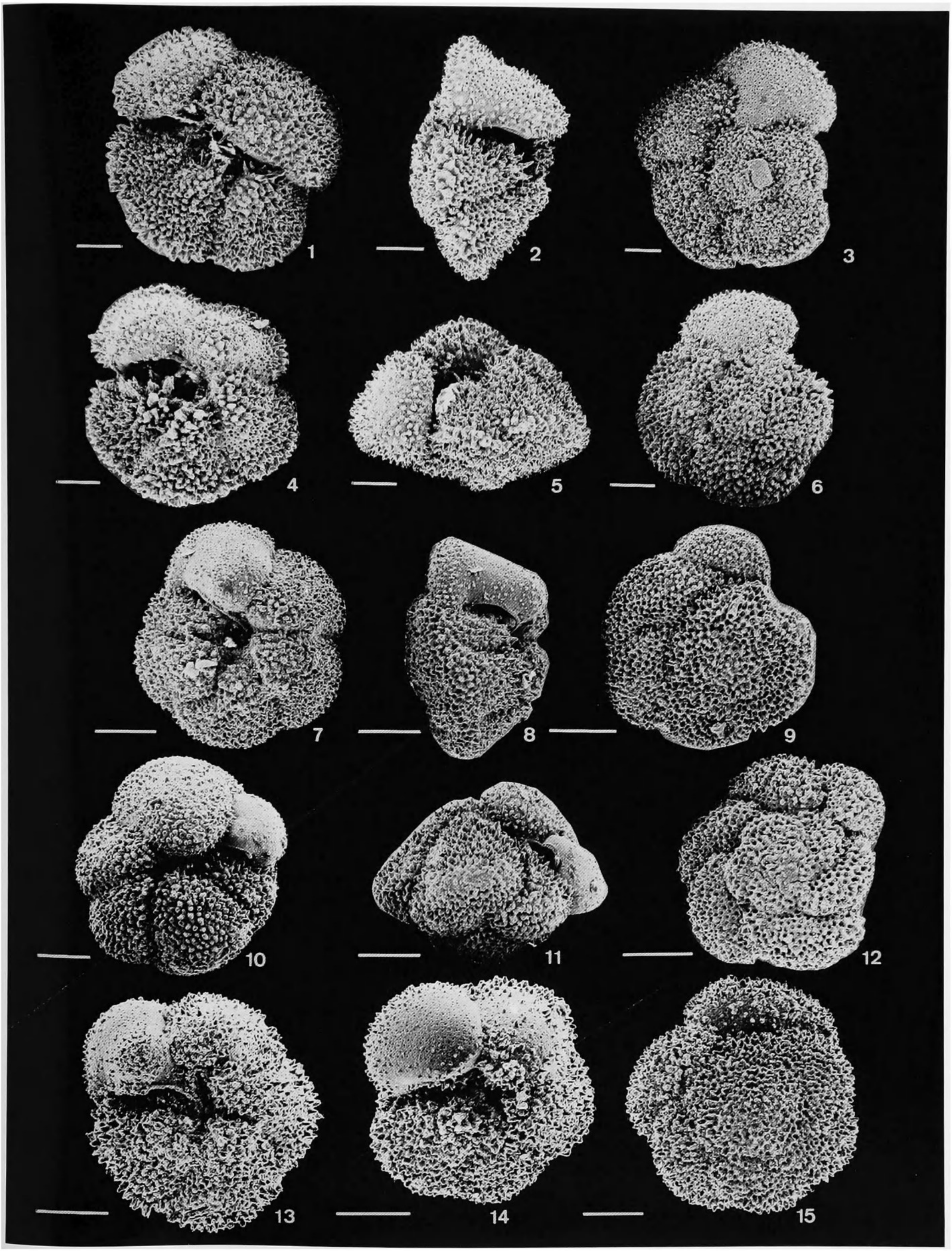
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PLATE 50

Morozovella conicotruncata (Subbotina, 1947)

(Figures 1, 5, 9–15: bars = 100 µm; Figures 2–4, 6–8: bars = 200 µm)

FIGURES 1–3.—Zone P3, DSDP Site 384/10/2: 136–138 cm.

FIGURES 4–6.—Zone P3, DSDP Site 465/6/5: 66–68 cm.

FIGURES 7–9.—Zone P3b, ODP Hole 758A/31/1: 50–52 cm; Ninetyeast Ridge, Indian Ocean.

FIGURES 10–12.—Zone P3, DSDP Site 465/6/3: 61–63 cm; Hess Rise, central North Pacific Ocean.

FIGURES 13–15.—Zone P3, DSDP Site 384/10/3: 10–12 cm; southeast Newfoundland Ridge, North Atlantic Ocean.

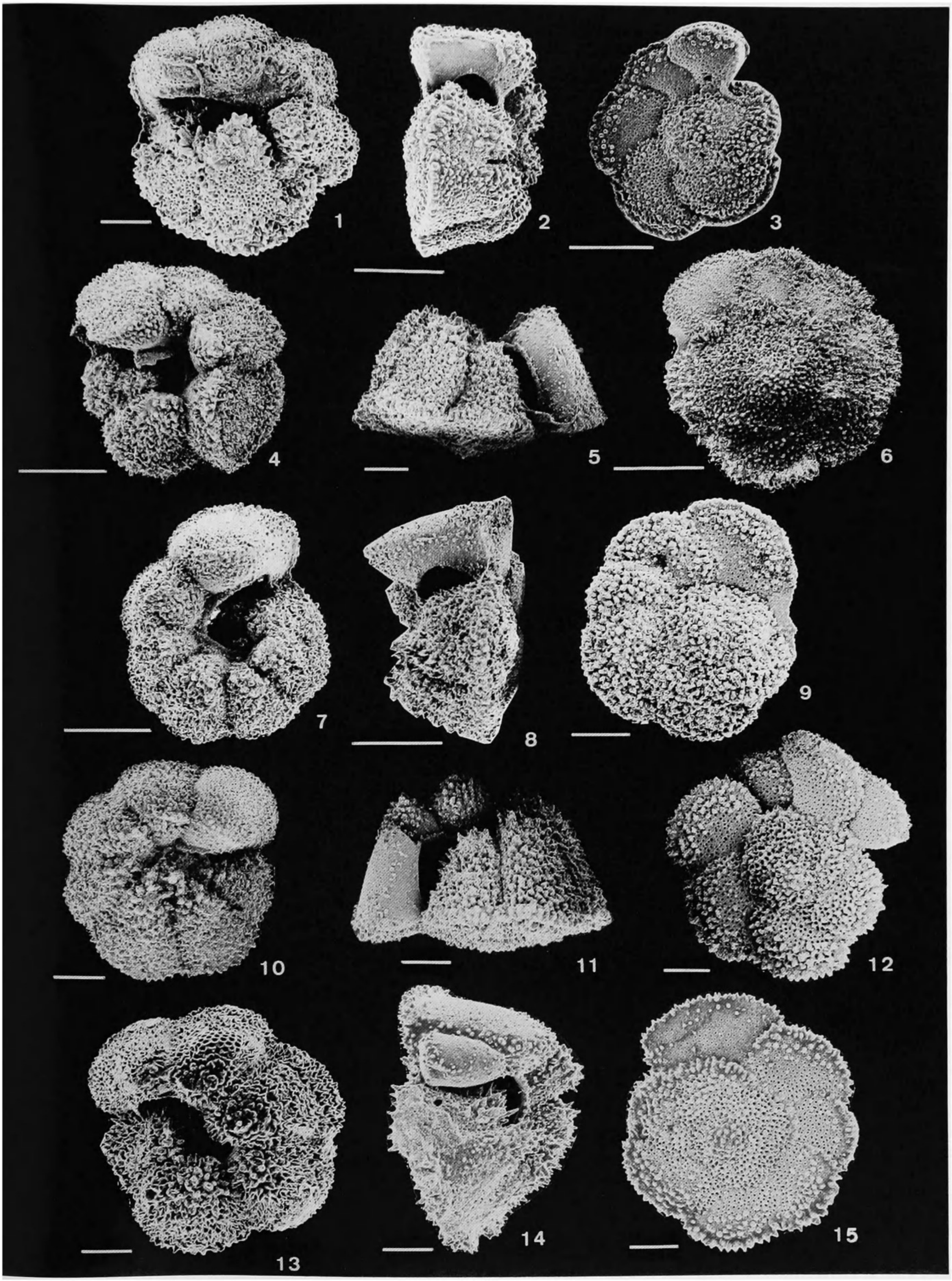
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PLATE 51

Morozovella occlusa (Loeblich and Tappan, 1957)

(bars = 100 μm)

FIGURES 1-3.—Zone P4, DSDP Site 465/4/1: 62–64 cm.

FIGURES 4, 8, 9.—Zone P4, Velasco Fm., Tamaulipas, Mexico.

FIGURES 5, 6.—Zone P4, DSDP Site 384/6/CC; southeast Newfoundland Ridge, North Atlantic Ocean.

FIGURE 7.—Zone P4, ODP Hole 758A/29/4: 50–52 cm; Ninetyeast Ridge, Indian Ocean.

FIGURES 10, 11.—Zone P4, DSDP Site 465/4/4: 62–64 cm.

FIGURES 12, 15.—Zone P4?, ODP Hole 864C/13/2: 73–75 cm; East Pacific Rise, eastern central Pacific Ocean.

FIGURES 13, 14.—Zone P4, DSDP Site 465/3/3: 98–100 cm; Hess Rise, central North Pacific Ocean.

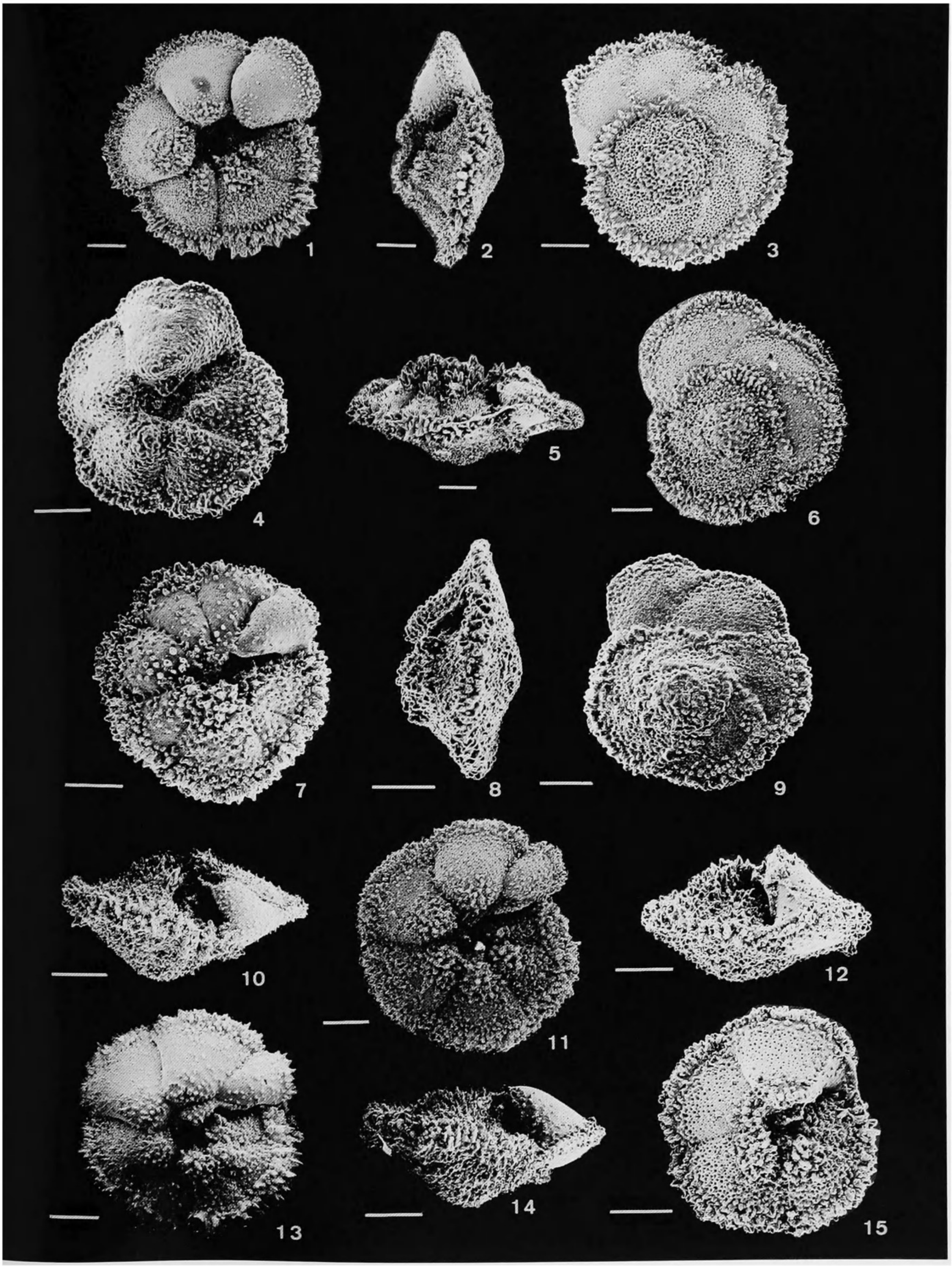
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PLATE 52

Morozovella pasionensis (Bermúdez, 1961)

(Figures 4, 5, 7, 8, 12, 14: bars = 100 μm; Figures 1–3, 6, 9–11, 13, 15: bars = 200 μm)

FIGURES 1–3, 10, 14.—Zone P3, DSDP Site 465/5/2: 62–64 cm.

FIGURES 4, 7, 13.—Zone P4, DSDP Site 465/3/3: 98–100 cm; Hess Rise, central North Pacific Ocean.

FIGURES 5, 8, 12.—Zone P4, ODP Site 865B/14/3: 138–140 cm; Allison Guyot, central equatorial Pacific Ocean.

FIGURE 6.—Zone P4, DSDP Site 384/7/1: 90–92 cm.

FIGURE 9.—Zone P4, DSDP Site 384/6/CC.

FIGURE 11.—Zone P4, DSDP Site 384/7/2: 106–108 cm.

FIGURE 15.—Zone P4, DSDP Site 384/6/3: 30–34 cm; southeast Newfoundland Ridge, North Atlantic Ocean.

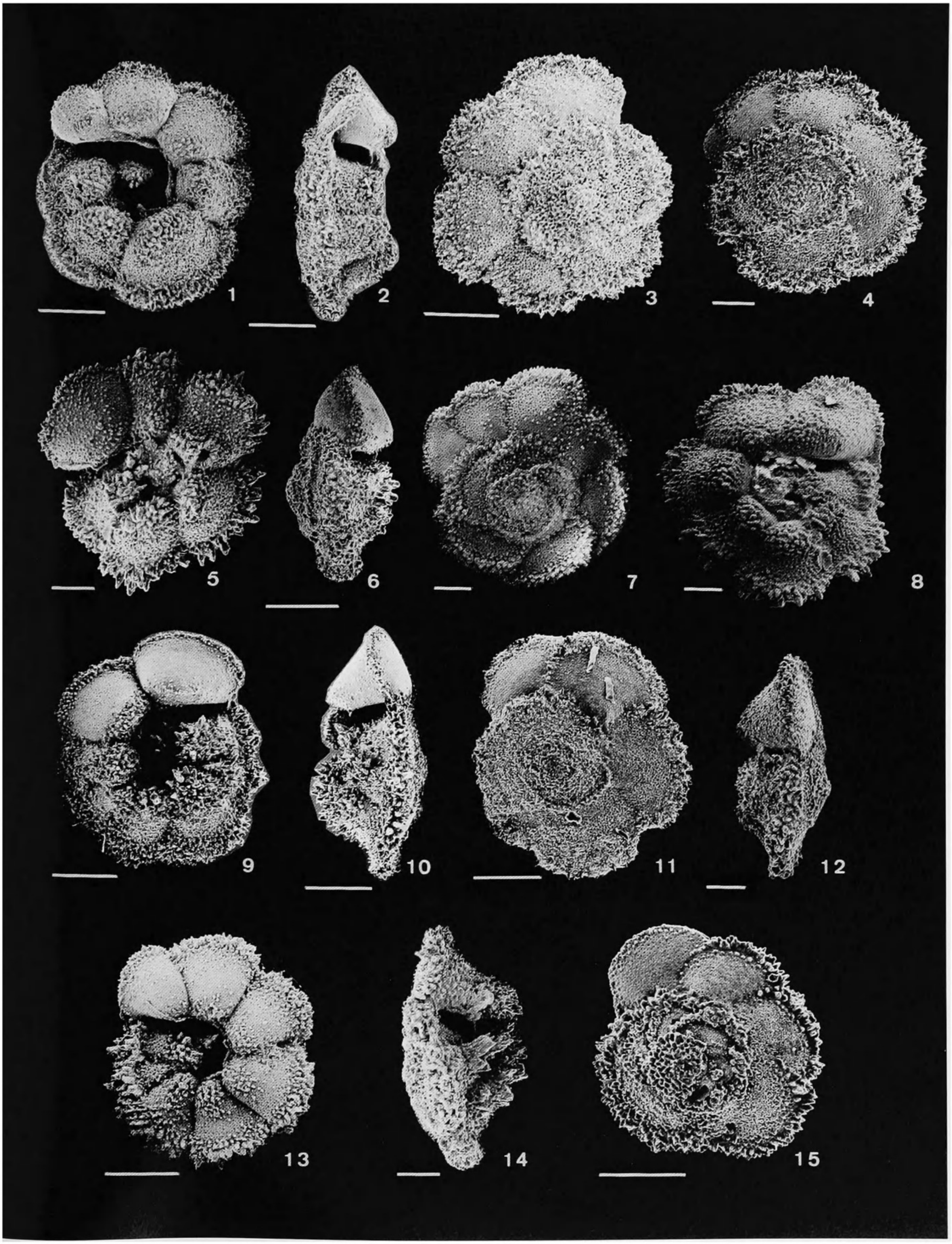
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PLATE 53

Morozovella praeangulata (Blow, 1979)

(bars = 100 μm)

FIGURES 1–3, 11–13.—Zone P3b, DSDP Site 356/24/2: 92–94 cm; São Paulo Plateau, South Atlantic Ocean.

FIGURES 4–6.—Zone P3, DSDP Site 384/10/5: 24–26 cm.

FIGURE 7.—Zone P3b, DSDP Site 465A/1/1: 52–54 cm; Hess Rise, central North Pacific Ocean.

FIGURE 8.—Zone P3, DSDP Site 384/10/CC.

FIGURES 9, 10.—Zone P2, DSDP Site 384/11/1: 86–90 cm; southeast Newfoundland Ridge, North Atlantic Ocean.

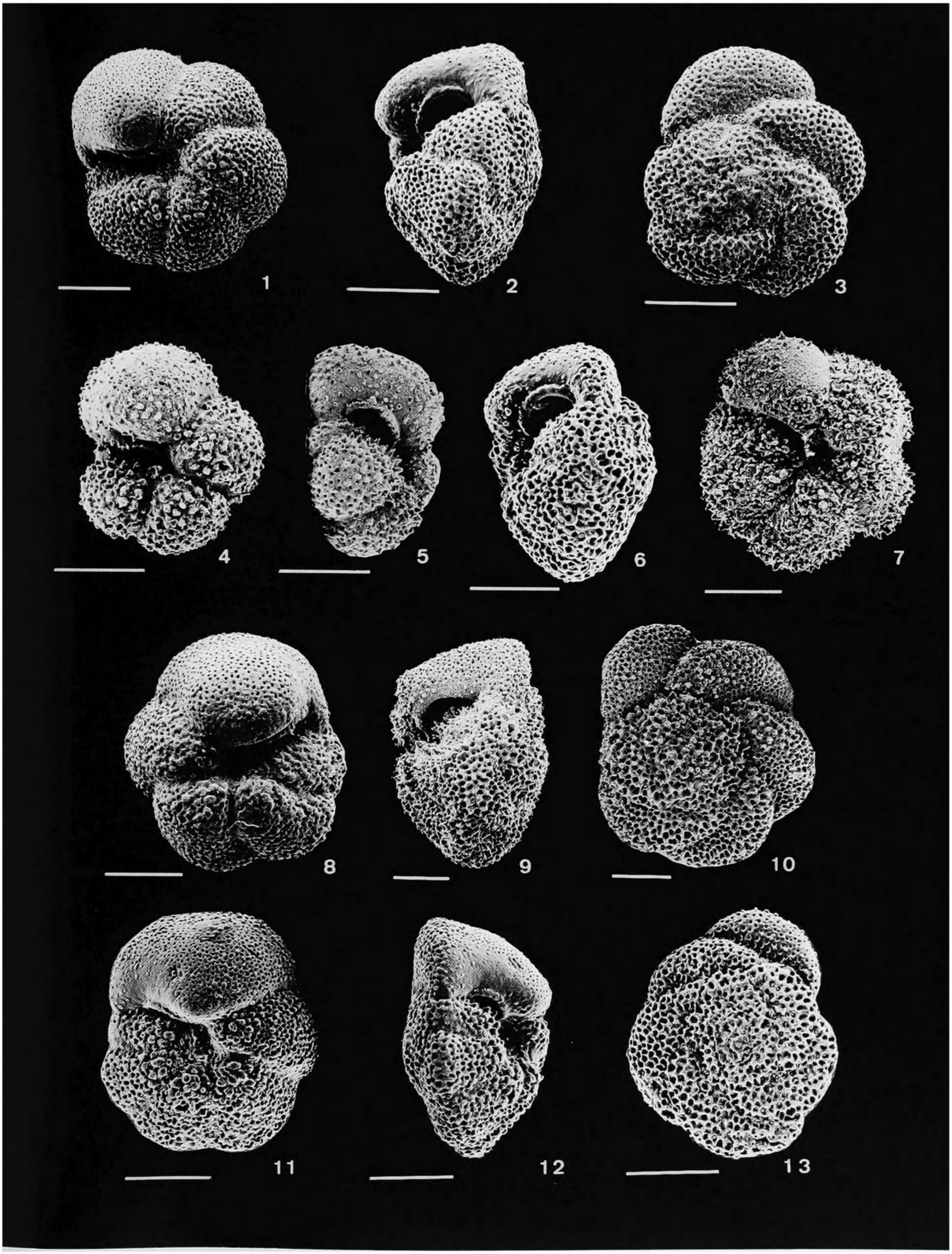
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PLATE 54

Morozovella subbotinae (Morozova, 1939)

(Figures 1–3: bars = 50 μm; Figures 4–12: bars = 100 μm)

FIGURES 1–3.—Zone AP6a, ODP Hole 738C/10R: 277.78 mbsf; southern Kerguelen Plateau, southern Indian Ocean.

FIGURES 4, 5.—Zone P5, ODP Hole 758A/28/1: 50–52 cm; Ninetyeast Ridge, Indian Ocean.

FIGURES 6–9.—Zone P4–P5, DSDP Site 465/3/1: 59–61 cm; Hess Rise, central North Pacific Ocean.

FIGURES 10–12.—Zone P5, DSDP Site 213/16/1: 104–106 cm; eastern Indian Ocean.

Morozovella gracilis (Bolli, 1957)

(bars = 100 μm)

FIGURES 13–15.—Zone P5, DSDP Site 213/16/1: 104–106 cm; eastern Indian Ocean.

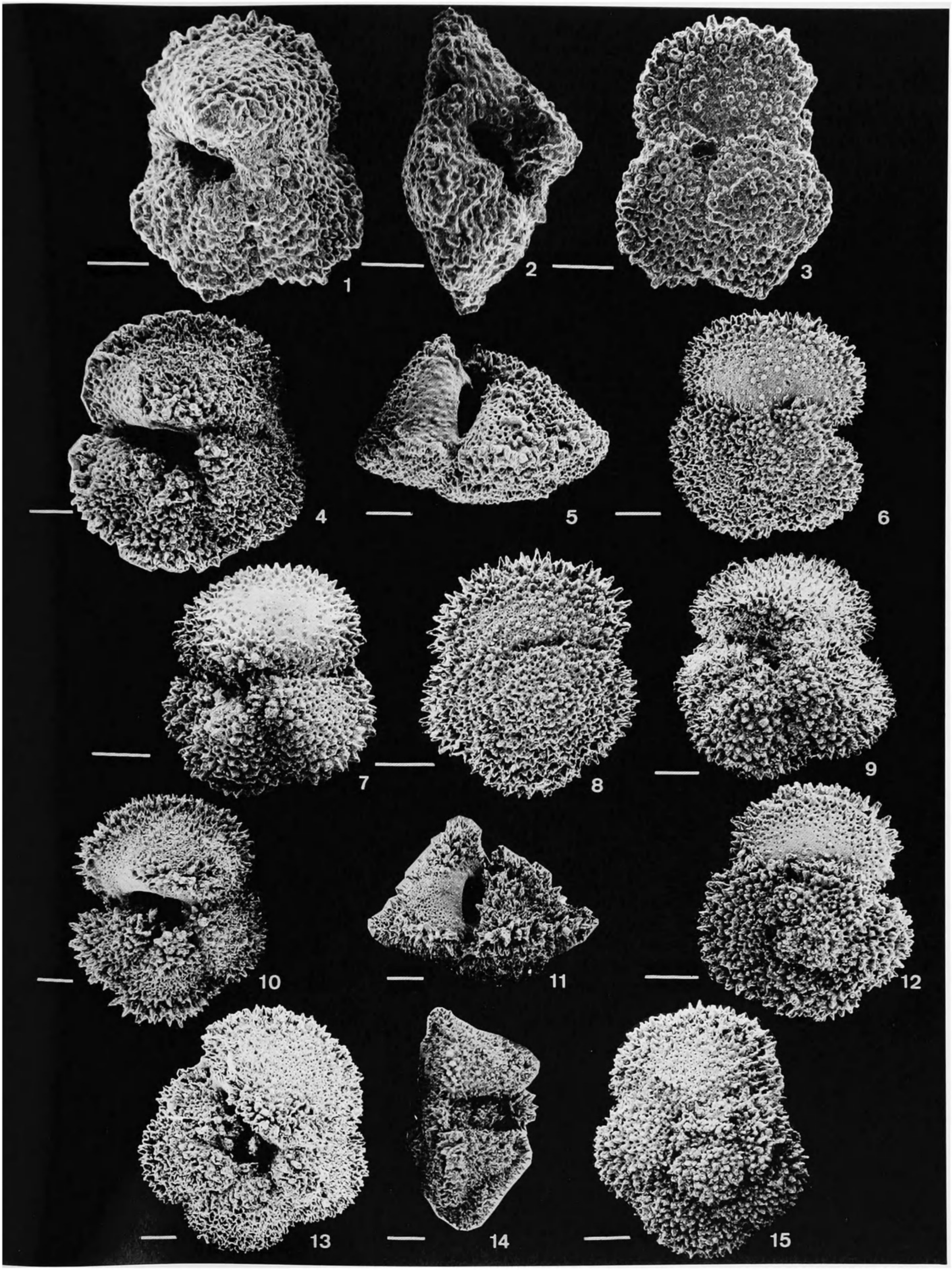
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PLATE 55

Morozovella velascoensis (Cushman, 1925)

(Figures 2, 3, 7, 12: bars = 100 μm; Figures 1, 4–6, 8–11, 13–15: bars = 200 μm)

FIGURES 1–3.—Zone P5, DSDP Site 213/16/1: 104–106 cm; eastern Indian Ocean.

FIGURES 4–6.—Zone P4, DSDP Site 465/3/1: 59–61 cm.

FIGURES 7–9.—Zone P4, ODP Hole 758A/28/1: 50–52 cm.

FIGURES 10, 12.—Zone P4, DSDP Site 465/3/4: 62–64 cm; Hess Rise, central Pacific Ocean.

FIGURE 11.—Zone P5, ODP Hole 758A/28/1: 50–52 cm; Ninetyeast Ridge, Indian Ocean.

FIGURES 13–15.—Zone P4, DSDP Site 384/9/CC; southeast Newfoundland Ridge, North Atlantic Ocean.

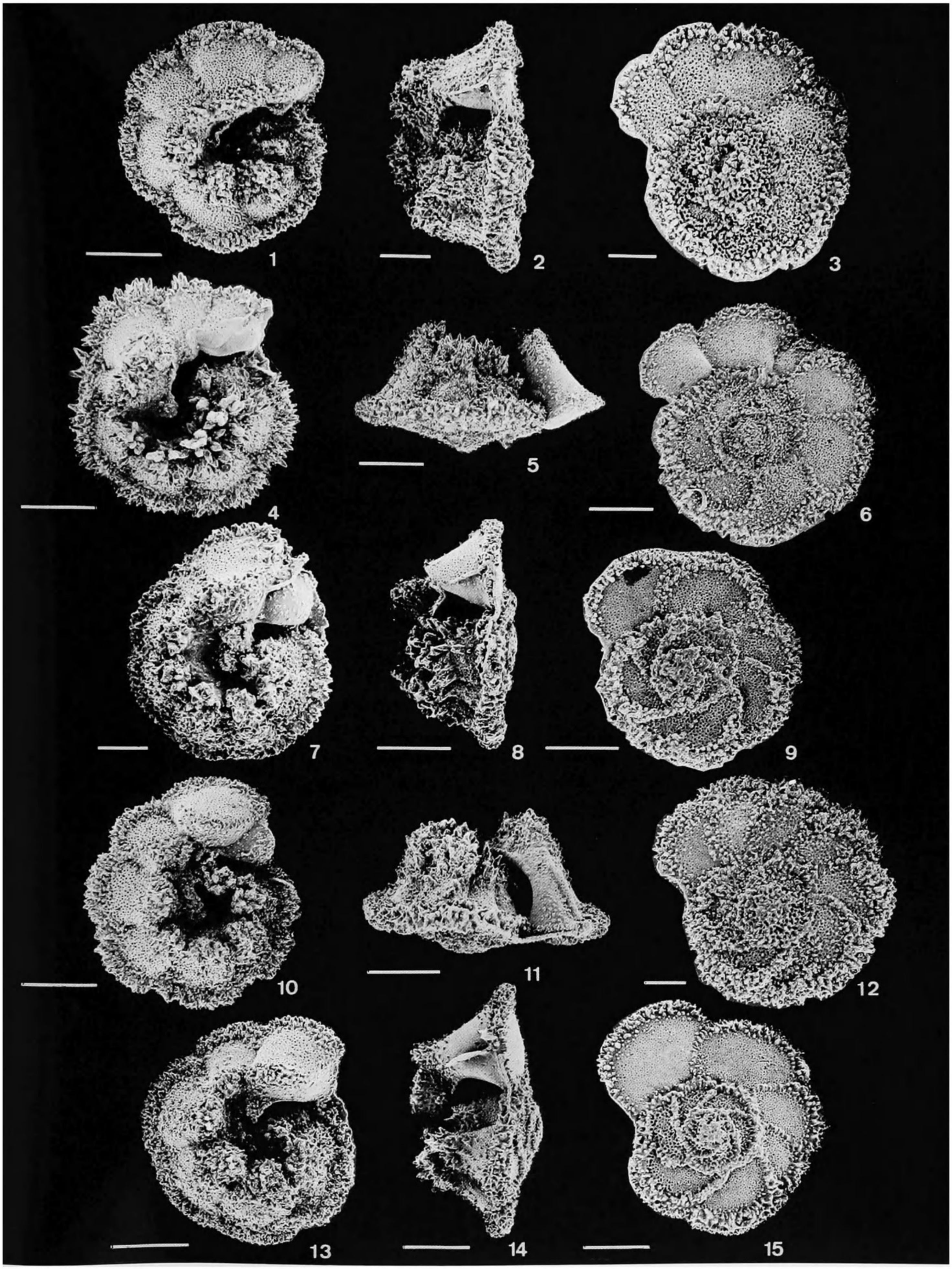
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PLATE 56

Igorina albeari (Cushman and Bermúdez, 1949)

(Figures 1–12, 16: bars = 100 μm; Figures 13, 15: bars = 40 μm; Figure 14: bar = 10 μm)

FIGURES 1–3, 9.—Zone P4, DSDP Site 465/3/3: 98–100 cm; Hess Rise, central North Pacific Ocean.

FIGURES 4, 8, 12.—Zone P4, DSDP Site 384/8/1: 126–128 cm; southeast Newfoundland Ridge, North Atlantic Ocean.

FIGURES 5–7, 10, 11.—Zone P4, ODP Hole 758A/29/4: 50–52 cm; Ninetyeast Ridge, Indian Ocean.

FIGURES 13, 16.—Zone P4, DSDP Site 356/24/2: 92–94 cm.

FIGURES 14, 15.—Zone P4, DSDP Site 356/24/1: 110–112 cm; São Paulo Plateau, South Atlantic Ocean.

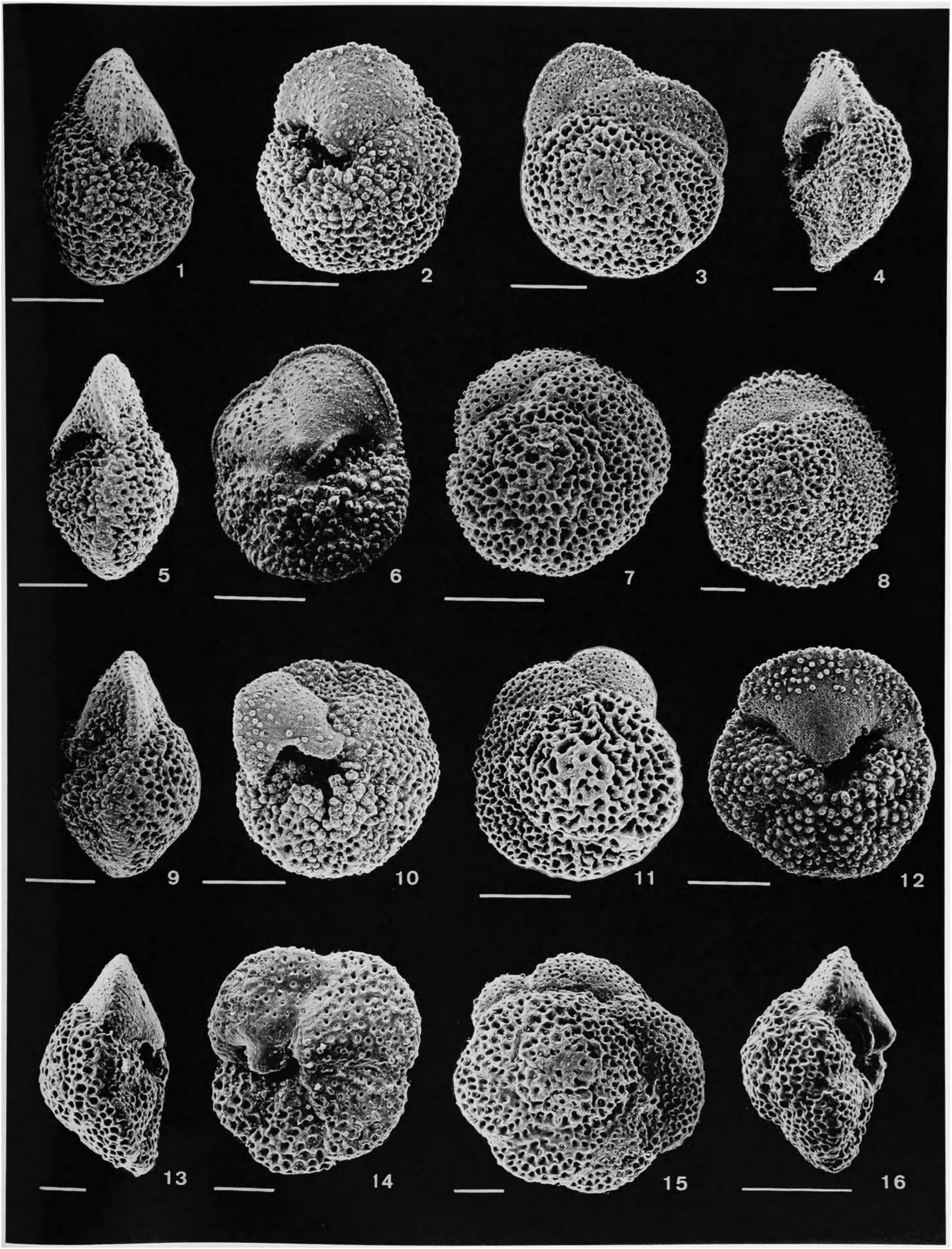
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PLATE 57

Igorina pusilla (Bolli, 1957)

(Figures 1, 2, 5, 9–11, 13–16: bars = 100 μm; Figures 3, 4, 6–8, 12: bars = 40 μm)

FIGURES 1, 2.—Zone P4, DSDP Site 384/7/3: 130–132 cm; southeast Newfoundland Ridge, North Atlantic Ocean.

FIGURES 3, 4.—Zone P3b, DSDP Site 3/21/CC; Gulf of Mexico.

FIGURE 5.—Zone P3, ODP Hole 761B/18X/2: 52–54 cm.

FIGURES 6–8, 12.—Zone P4, Vincentown Fm., Glendola Well, New Jersey, sample 286 feet.

FIGURES 9, 10.—Zone P3, DSDP Site 465/6/5: 66–68 cm.

FIGURE 11.—Zone P3, DSDP Site 465/5/4: 63–64 cm; Hess Rise, central Pacific Ocean.

FIGURES 13–16.—Zone P4, ODP Hole 761B/18X/1: 52–54 cm; Wombat Plateau, Indian Ocean.

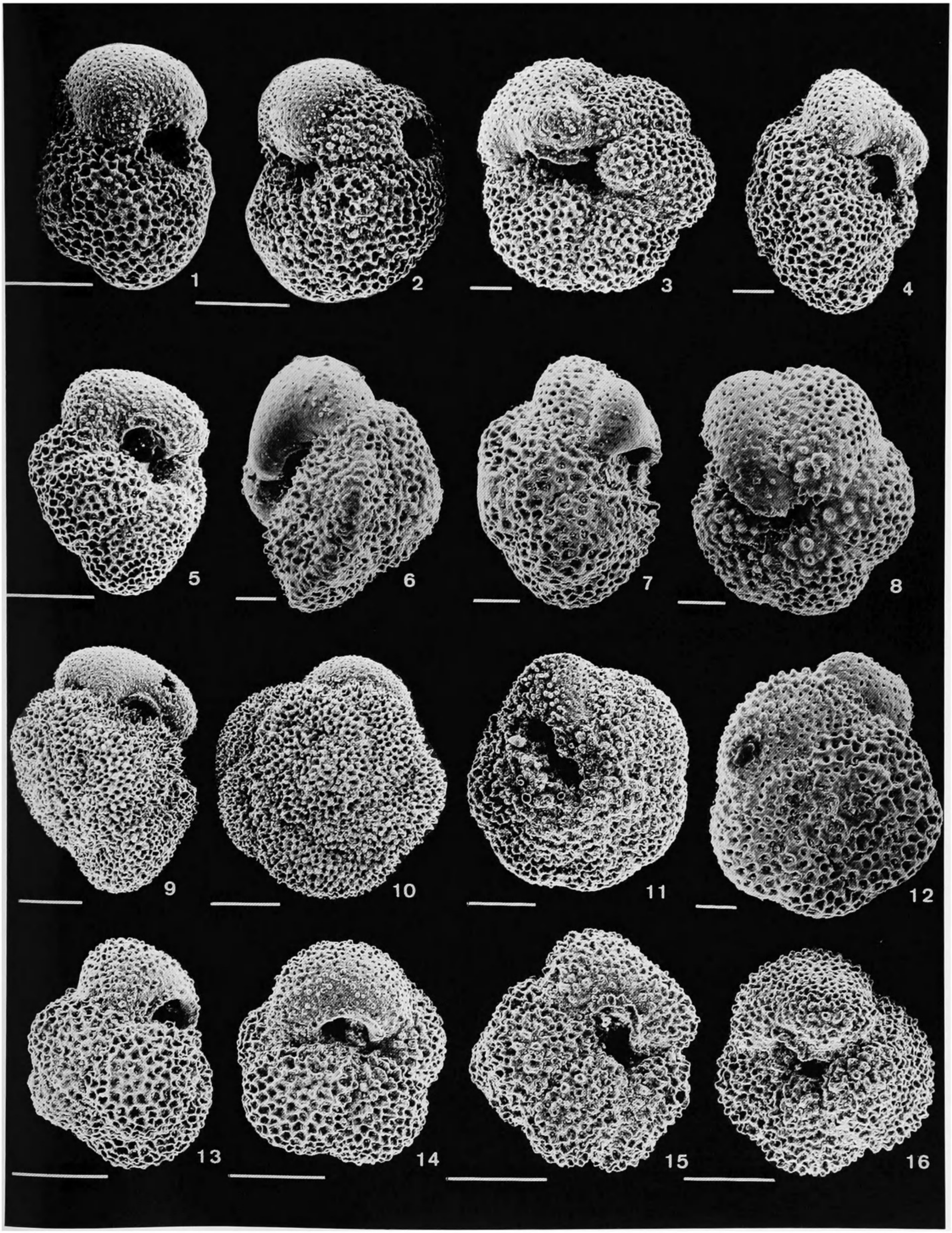
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PLATE 58

Igorina tadjikistanensis (Bykova, 1953)

(Figure 1: bar = 40 μm; Figures 2–12: bars = 100 μm)

FIGURES 1, 2, 4, 6, 8, 10, 12.—Zone P4, Velasco Fm., Tamaulipas, Mexico.

FIGURES 3, 5, 7, 9, 11.—Zone P4, Vincentown Fm., Glendola Well, New Jersey, sample 230–232 feet.

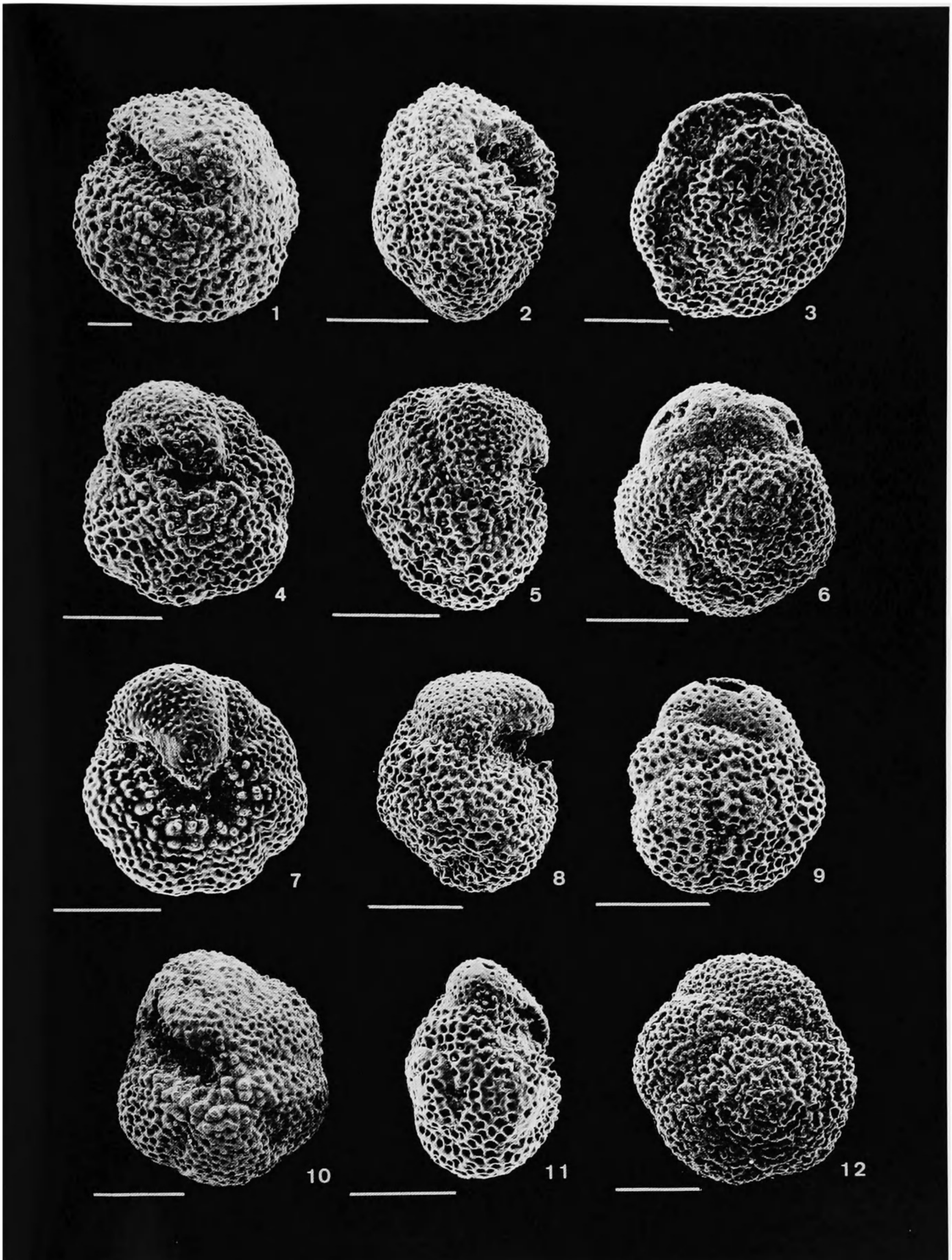
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PLATE 59

Praemurica inconstans (Subbotina, 1953)

(bars = 100 μm)

FIGURES 1–3, 13, 15.—Zone P3, DSDP Site 465/7/CC; Hess Rise, central Pacific Ocean.

FIGURES 4–7, 12, 16.—Zone P1c, DSDP Site 356/26/4: 117–118 cm; São Paulo Plateau, South Atlantic Ocean.

FIGURES 8–11.—Zone P1c, DSDP Site 527/30/4: 30–32 cm; Walvis Ridge, South Atlantic Ocean.

FIGURE 14.—Zone P2, DSDP Site 384/11/3: 30–32 cm; southeast Newfoundland Ridge, North Atlantic Ocean.

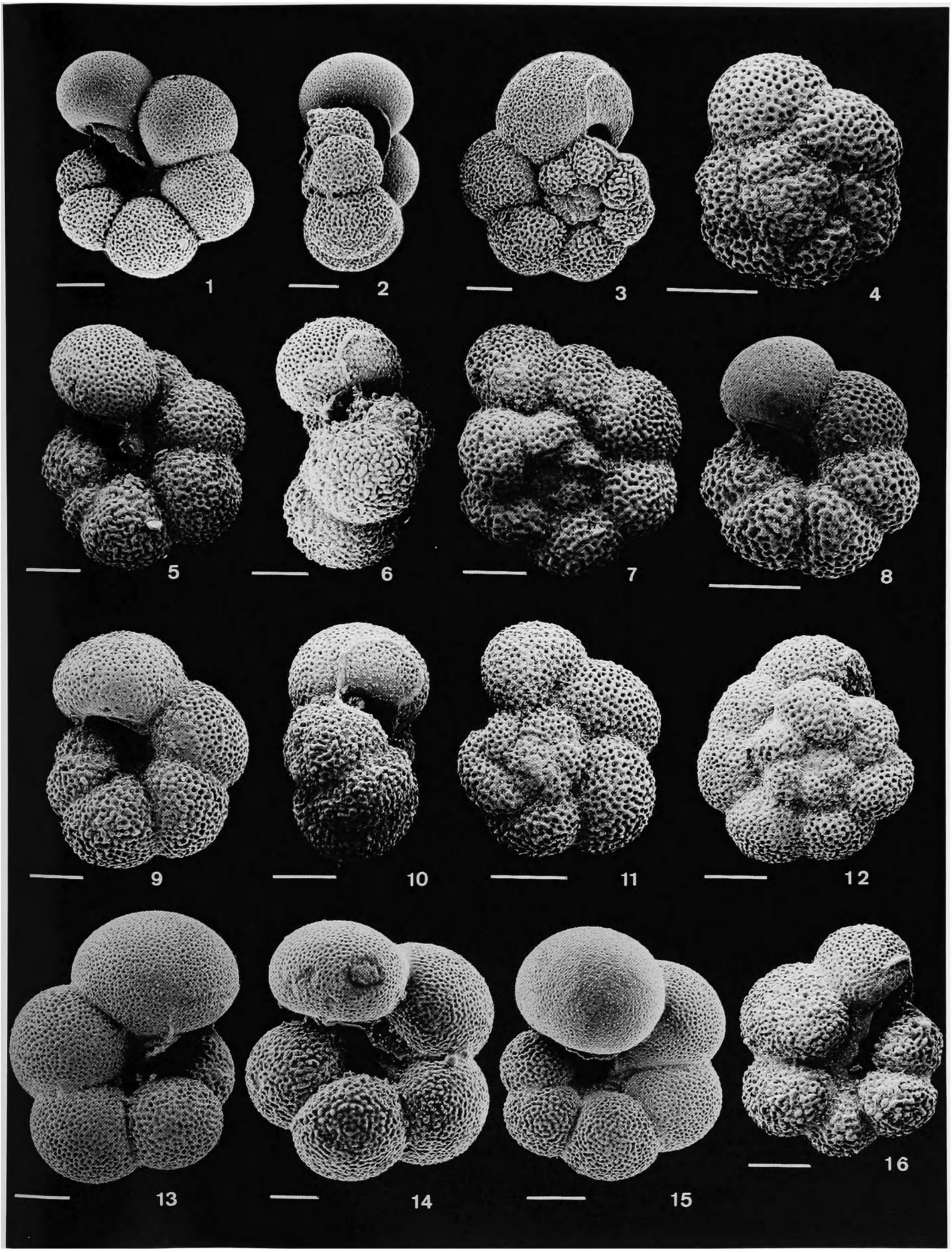
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PLATE 60

Praemurica pseudoinconstans (Blow, 1979)

(Figures 1–11: bars = 50 μm; Figures 12, 13: bars = 10 μm)

FIGURES 1, 3, 6.—Zone Pα, Millers Ferry, Alabama, core 226, sample 85.

FIGURES 2, 10–13.—Zone P1a, Millers Ferry, Alabama, core 225, sample 194; Figure 12 (view of 2nd chamber of Figure 11) and Figure 13 (view of 4th chamber of Figure 10) showing cancellate nonspinose wall texture.

FIGURE 4.—Zone P1a, DSDP Site 384/13/2: 140–142 cm; southeast Newfoundland Ridge, North Atlantic Ocean.

FIGURE 5.—Zone P2, DSDP Site 356/25/5: 148–150 cm; São Paulo Plateau, South Atlantic Ocean.

FIGURES 7, 9.—Zone P1a, Millers Ferry, Alabama, core 225, sample 216.

FIGURE 8.—Zone P1a, DSDP Hole 465A/3/3: 120–122 cm; Hess Rise, central Pacific Ocean.

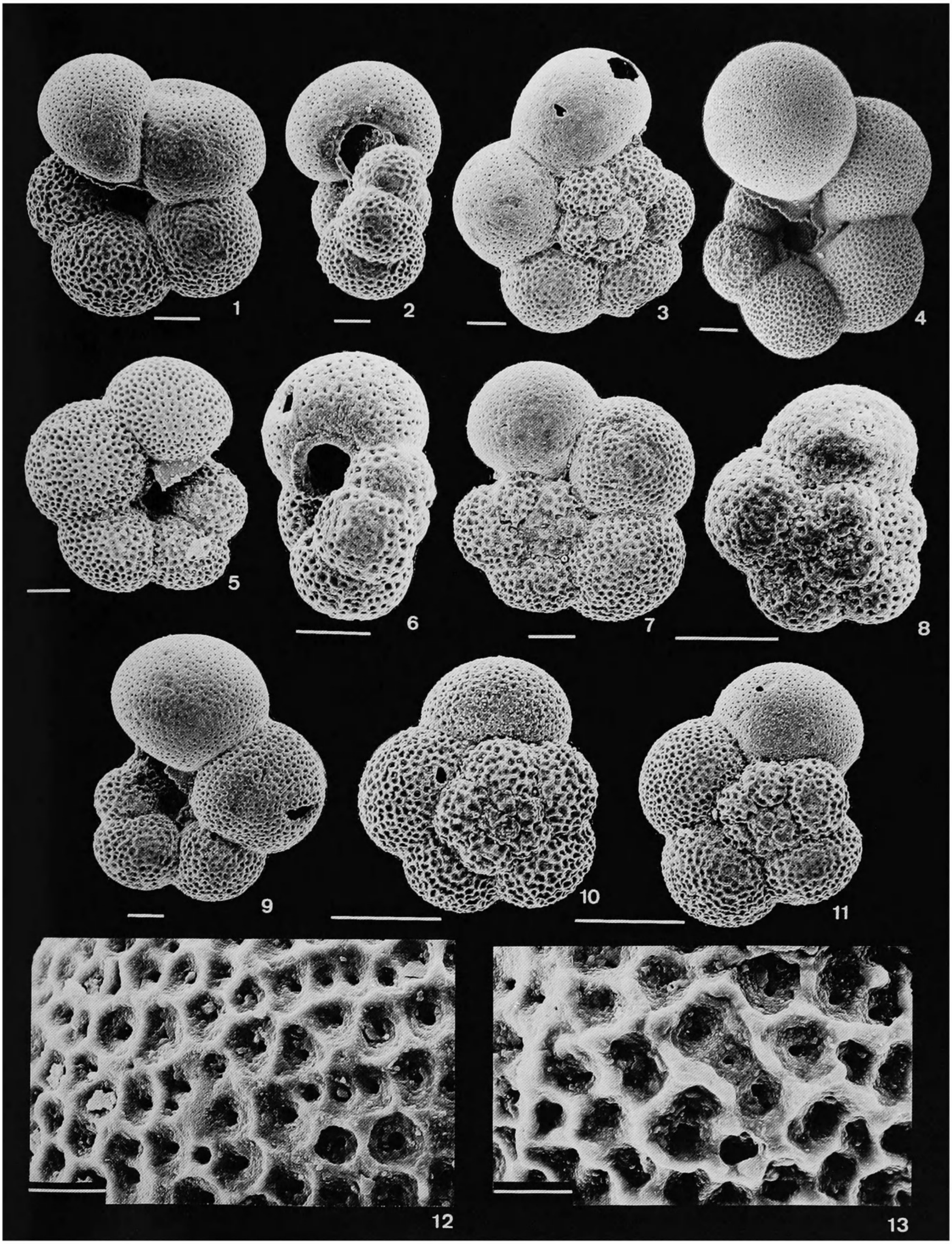
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PLATE 61

Praemurica taurica (Morozova, 1961)

(Figures 2, 4, 7, 9, 11, 12: bars = 100 μm; Figures 1, 3, 5, 6, 8, 10, 15: bars = 40 μm; Figures 13, 14: bars = 10 μm)

FIGURES 1, 3.—Zone P1a, Millers Ferry, Alabama, core 225, sample 216.

FIGURES 2, 4.—Zone P1a, Millers Ferry, Alabama, core 225, sample 194.

FIGURE 5.—Zone Pα, Millers Ferry, Alabama, core 226, sample 5.

FIGURE 6.—Zone P1a, ODP Hole 750A/15/2: 8–12 cm; southern Kerguelen Plateau, southern Indian Ocean.

FIGURES 7, 9, 13, 14.—Zone P1a, Millers Ferry, Alabama, sample 30 feet above Prairie Bluff; Figures 13, 14, views of wall of Figure 9 showing cancellate nonspinose wall texture.

FIGURE 8.—Zone Pα, Millers Ferry, Alabama, core 225, sample 334.

FIGURE 10.—Zone Pα, Millers Ferry, Alabama, core 226, sample 15.

FIGURES 11, 12, 15.—Zone P1c, DSDP Site 356/26/CC; São Paulo Plateau, South Atlantic Ocean.

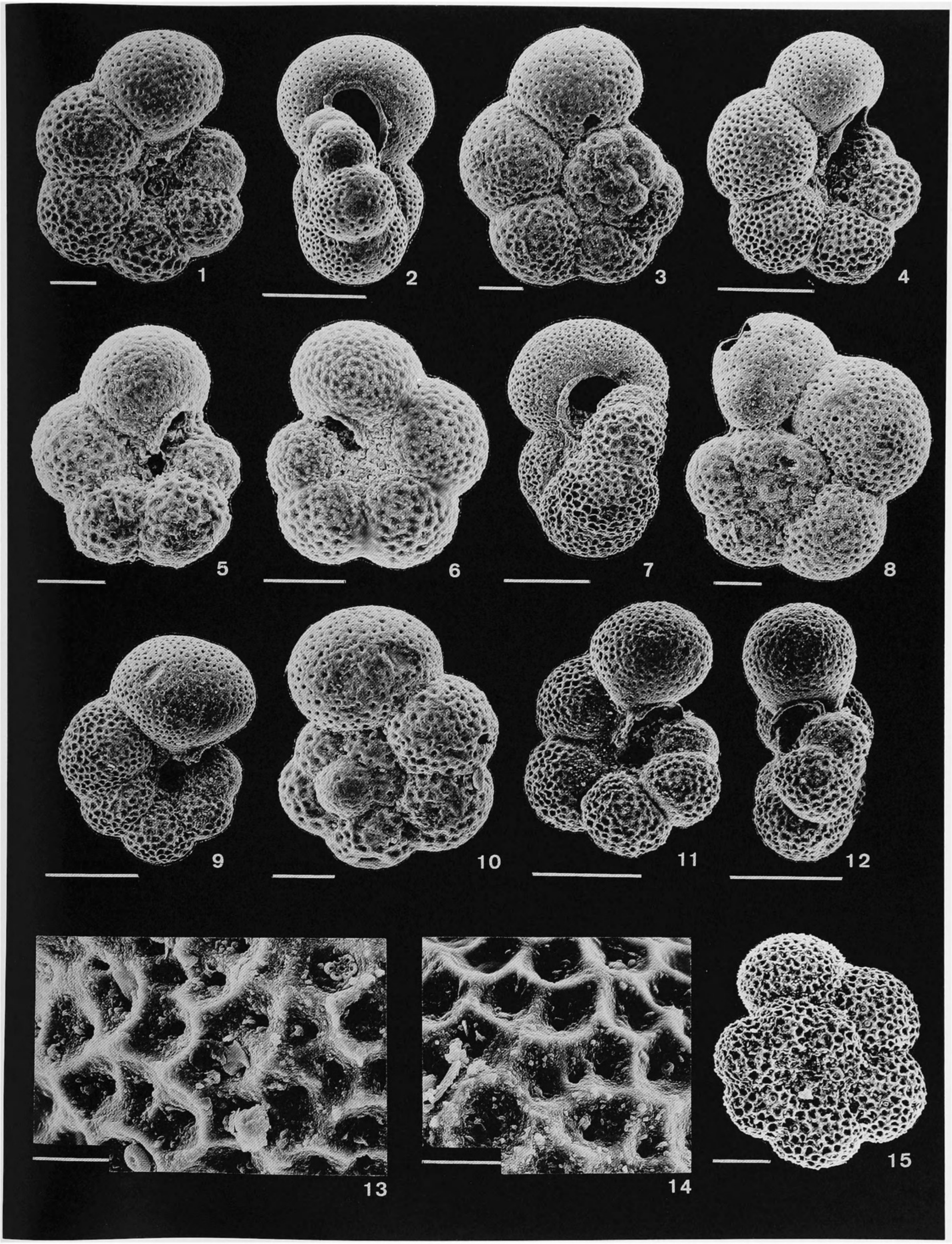
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PLATE 62

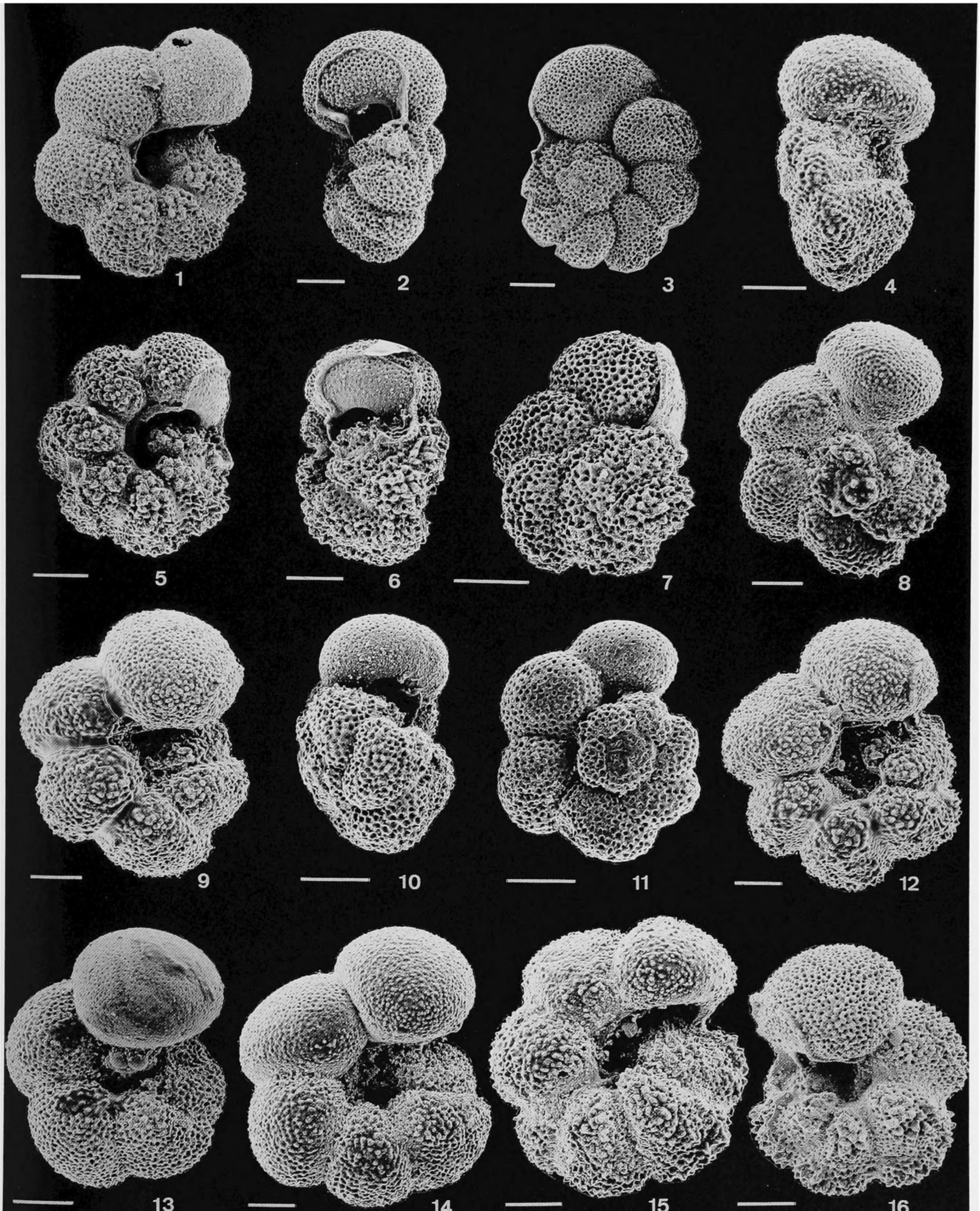
Praemurica uncinata (Bolli, 1957)

(bars = 100 μm)

FIGURES 1–3, 5–7, 16.—Zone P3, DSDP Site 465/7/CC; Hess Rise, central Pacific Ocean.

FIGURES 4, 8, 9, 12–15.—Zone P2, DSDP Site 384/11/3: 30–32 cm.

FIGURES 10, 11.—Zone P2, DSDP Site 384/11/3: 136–138 cm; southeast Newfoundland Ridge, North Atlantic Ocean.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