species. This possibility needs further investigation. Blow (1979) figured specimens from Zone P10 in a North Atlantic piston core that he identified as *G. planoconica.* These specimens have 7 to 8 chambers in the ultimate whorl and a high arched aperture that extends slightly over the axial periphery onto the spiral side. He considered these forms ancestral to *Pseudohastigerina danvillensis* (Howe and Wallace, 1932). Except for the greater number of chambers, Blow's specimens are similar to *G. planoconica* in that they possess a well-developed imperforate peripheral margin, but they differ in the apertural lip, which widens as a tooth-like projection into the umbilical area. It would appear that these morphotypes may be related to *G. planoconica.* The morphologic range of this species and its relationship to other species in the Eocene needs further study.

STABLE ISOTOPES.—No data available.

STRATIGRAPHIC RANGE.—Upper Zone P4 to lower Eocene.

GLOBAL DISTRIBUTION.—As discussed above, the taxonomy of this species needs further clarification before its distribution can be reliably plotted. At present, a middle to low latitude distribution is probable.

ORIGIN OF SPECIES.—The strong imperforate peripheral margin allies this species with the *chapmani* lineage and suggests that it was derived from this species in upper Zone P4.

REPOSITORY.—Holotype (No. 4081) and paratypes (No. 4082, 4083) deposited in the micropaleontological collections at VNIGRI (378/118), St. Petersburg. Holotype examined by FR.

Globanomalina pseudomenardii (Bolli, 1957)

FIGURE 18; PLATE 14: FIGURES 5–7; PLATE 38: FIGURES 1–16

Globorotalia membranacea (Ehrenberg).—Subbotina, 1953:205, pl. 16: fig. 13a–c [Paleocene, Tarkhankut Peninsula, Crimea] [in part, not pl. 16: figs. 7a–12c]. [Not *Planulina membranacea* Ehrenberg, 1854.]

Globorotalia pseudomenardii Bolli, 1957a:77, holotype: pl. 20: figs. 14–16; paratype: pl. 20: fig. 17 [*Globorotalia pseudomenardii* Zone, Lizard Springs Fm., Trinidad].—Loeblich and Tappan, 1957a:193, pl. 47: fig. 4a–c [Zone P4, Salt Mountain Limestone, Alabama], pl. 49: fig. 6a–c [lower Zone P4, Hornerstown Fm., New Jersey], pl. 54: figs. 10a–13c [Zone P4, Vincentown Fm., New Jersey], pl. 59: fig. 3a–c [Zone P4, Aquia Fm., Maryland], pl. 60: fig. 8a–c [Zone P4, Nanafalia Fm., Alabama], pl. 63: fig. 1a–c [Zone P4, Velasco Fm., Mexico] [in part, not pl. 45: fig. 10a–c].—Bolli and Cita, 1960:26, pl. 33: fig. 2a–c [*Globorotalia pseudomenardii* Zone, Paderno d'Adda section, northern Italy].

Globorotalia (*Globorotalia*) *pseudomenardii* Bolli.—Hillebrandt, 1962:126, pl. 12: figs. 5a–6b [upper Paleocene beds of Reichhall-Salzburg Basin, Austria].—Blow, 1979:892, pl. 89: figs. 1–5 [Zone P4, DSDP Hole 21A/3/5: 74–76 cm; Rio Grande Rise, South Atlantic Ocean], pl. 94: figs. 1–5 [Zone P4, Lindi area, Tanzania], pl. 108: figs. 4–7 [Zone P4, DSDP Hole 20C/6/3: 76–78 cm; Brazil Basin, South Atlantic Ocean], pl. 111: figs. 1–4, pl. 112: figs. 2, 3, 9, 10 [Zone P4, Moogli Mudstones, Papua] [in part, not pl. 105: figs. 3, 7–10].

Planorotalites pseudomenardii Bolli.—Nederbragt and Van Hinte, 1987:587, pl. 1: figs. 1–16 [Zone P4, DSDP Site 605/46/4, 46/6, 46/3, 52/2; New Jersey margin, western North Atlantic Ocean].—Nocchi et al., 1991:269, pl. 1: figs. 7–9 [Zone P4, ODP Hole 698A/11R/CC; northeast Georgia Rise, South Atlantic Ocean].

ORIGINAL DESCRIPTION.—"Shape of test very low trochospiral, biconvex; equatorial periphery elongate, lobate, especially so in large specimens; axial periphery angular with distinct keel. Wall calcareous, perforate, surface smooth. Chambers strongly compressed; about 15, arranged in 3 whorls, the 5 chambers of the last whorl increasing rapidly in size. Sutures on spiral side strongly curved, especially so between last chambers of large specimens, depressed; on umbilical side radial, depressed. Umbilicus shallow, open. Aperture a low arch with a lip; interiomarginal, extraumbilical-umbilical. Largest diameter of holotype 0.34 mm., of figured paratype 0.66 mm." (Bolli, 1957a:77.)

DIAGNOSTIC CHARACTERS.—Distinct keel, sharply angled axial periphery, spiroconvex test, and narrow umbilicus distinguish species. Number of chambers in the ultimate whorl consistently 5, but 6-chambered form rarely observed (Plate 38: Figure 4).

DISCUSSION.—There is considerable variation in the shape of the equatorial periphery, which varies from fairly smooth to strongly lobulate, depending on the rate of size increase or decrease of the final few chambers in the ultimate whorl.

STABLE ISOTOPES.—*Globanomalina pseudomenardii* has $\delta^{18}O$ and $\delta^{13}C$ similar to *Parasubbotina varianta* and *S. velascoensis.* The species has distinctly more positive $\delta^{18}O$ and more negative $\delta^{13}C$ than *Morozovella, Acarinina,* and *Igorina.*

STRATIGRAPHIC RANGE.—Zone P4.

GLOBAL DISTRIBUTION.—Widely reported in the low to middle latitudes (Figure 18).

ORIGIN OF SPECIES.—There is general agreement among workers that *G. pseudomenardii* originated from *G. ehrenbergi* (= *G. haunsbergensis* Gohrbandt) by an increase in the test size and the development of a peripheral keel. The species becomes extinct at the top of Zone P4.

REPOSITORY.—Holotype (USNM P5061) and paratype (USNM P5062) deposited in the Cushman Collection, National Museum of Natural History. Examined by BTH and RKO.

Family TRUNCOROTALOIDIDAE Loeblich and Tappan, 1961

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

ORIGINAL DESCRIPTION.—"Primary aperture on the umbilical side, and secondary apertures on spiral side." (Loeblich and Tappan, 1961:309.)

DIAGNOSTIC CHARACTERS.—Test, a low to moderately elevated trochospire, with or without peripheral keel; chambers globular to conical shaped; wall cancellate to muricate, pustule growth moderate to heavy, usually around umbilical area or along a peripheral keel; aperture interiomarginal, umbilical-extraumbilical, with or without lip, may have supplementary apertures.

DISCUSSION.—This family tentatively includes *Acarinina, Igorina, Morozovella,* and *Praemurica.* As discussed in "Phylogeny," there are two views among the working group

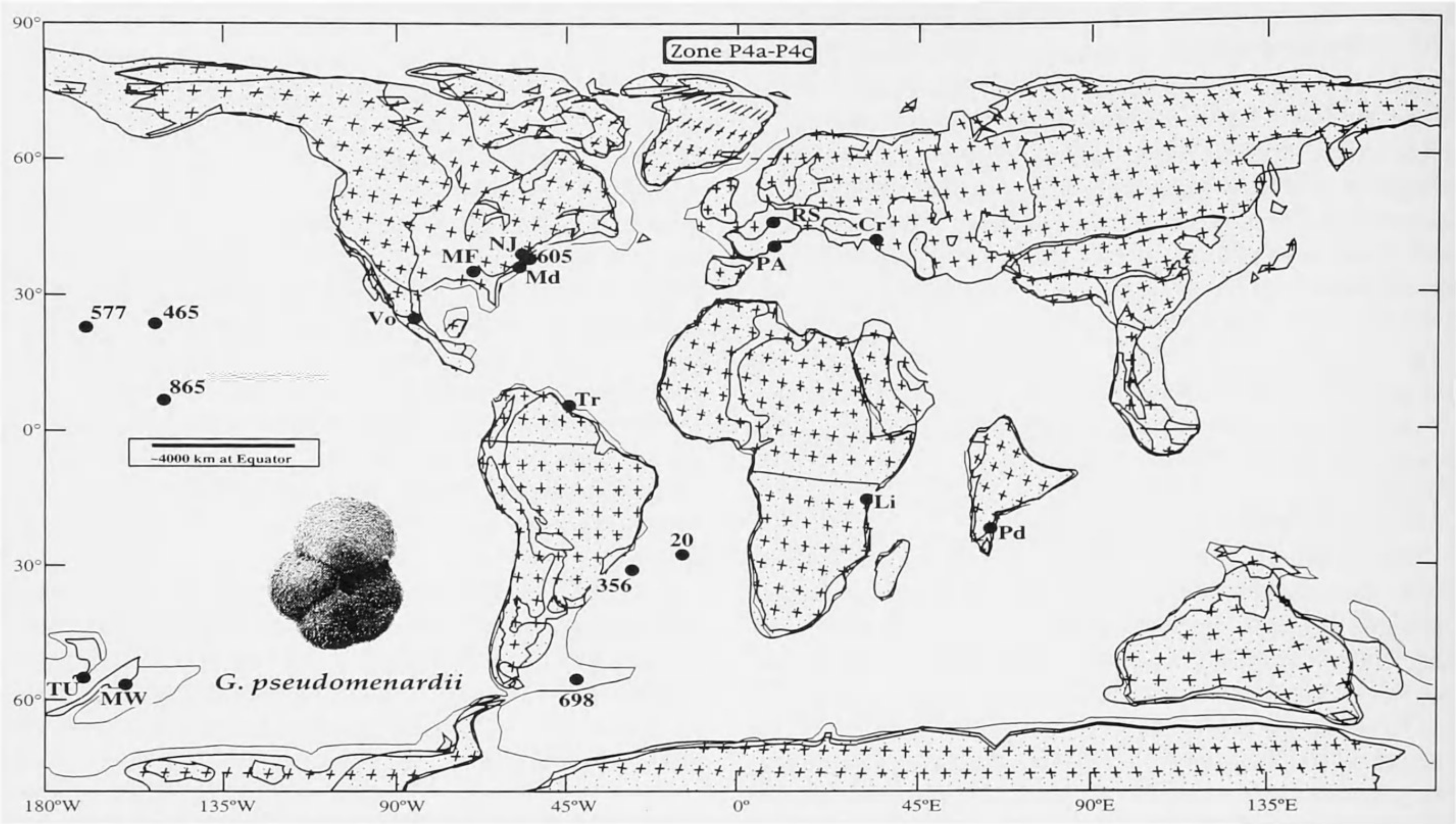

FIGURE 18.—Paleobiogeographic map showing distribution of *Globanomalina pseudomenardii* (Bolli) in Zone P4.

members on the relationships between these genera (see Figure 5*a,b*). The use of this family appears appropriate, for the time being, until these differences are resolved.

Genus *Acarinina* Subbotina, 1953

TYPE SPECIES.—*Acarinina acarinata* Subbotina, 1953 (= junior subjective synonym of *Globigerina nitida* Martin, 1943).

ORIGINAL DESCRIPTION.—"Test always strongly inflated, with chambers of the *Globigerina* type. Dorsal side slightly flattened, strongly convex ventrally. There is always an umbilicus; it may be small and barely discernible or large and very distinct. Peripheral margin without a keel, most frequently rounded. Chambers sometimes closely adjacent to one another, but in many species the chambers are loosely arranged. Aperture slitlike, along the marginal suture, often without a lip. Wall coarsely spinose; on the ventral side, near the umbilicus, the spines are longer than on the remainder of the test." (Subbotina, 1953:219; translated from Russian.)

DIAGNOSTIC CHARACTERS.—Test, a moderate to low trochospire; chambers ovoid shaped, generally with 4–6 chambers in final whorl, occasionally 7 or more; wall moderately to strongly muricate with moderate to strong pustule growth on umbilical shoulders surrounding aperture; aperture interiomarginal, umbilical-extraumbilical, with or without thin lip.

DISCUSSION.—The genus *Acarinina* was erected by Subbotina (1953) to include Paleogene taxa exhibiting morphologic features intermediate between *Globigerina* and *Globorotalia*, such as species with rounded chambers, spinose (muricate) test, and an umbilical-extraumbilical aperture. Three groups were originally distinguished:

1. Acarininids with angular chambers (e.g., *A. crassaformis*);
2. Acarininids with rounded chambers (e.g., *A. acarinata*);
3. Intermediate acarininids (e.g., *A. conicotruncata*).

Subsequent authors have questioned the inherent morphological homogeneity of this group by considering *Acarinina* to be a synonym for taxa as phylogenetically distinct as *Turborotalia* and *Globorotalia*. As conceived herein, *Acarinina* is characterized by rounded to subangular, unkeeled chambers that are covered with coarse pustules (muricae), which become dense, enlarged, and spike-like on the umbilical surface around the aperture. The heavy growth of pustules form deep funnel-shaped entrances to the pores and may also partially or completely close the pores. In Paleocene forms, the aperture has a very thin lip or none at all.

Acarinina coalingensis (Cushman and Hanna, 1927)

PLATE 39: FIGURES 1-16

Globigerina coalingensis Cushman and Hanna, 1927:205, pl. 14: fig. 4 [lower Eocene, California].—Mallory, 1959:46, pl. 34: fig. 6 [lower Eocene, California].

Globoquadrina primitiva Finlay, 1947:291, pl. 8: figs. 129-134.—Hornibrook, 1953:437 [middle Eocene, New Zealand].—Jenkins, 1965:1124, fig. 9 [outline drawing of Finlay's holotype].

Globigerina primitiva (Finlay).—Brönniman, 1952:11, pl. 1: figs. 10-12 [Soldado and Lizard Springs Fms., Trinidad].—Bolli, 1957a:71, pl. 15: figs. 6-8 [*Globorotalia rex* Zone, Trinidad].

Acarinina triplex Subbotina, 1953:230, pl. 23: figs. 1-5 [holotype from *Globorotalia marginodentata* Subzone of *Globorotalia subbotinae* Zone, lower Eocene, Khieu River, Nal'chik, northern Caucasus].—Blow, 1979:963, pl. 97: figs. 8, 9 [Zone P5, Linde area, Tanzania].—Pearson et al., 1993:125, pl. 1: figs. 11, 12 [Zone P11, middle Eocene, DSDP Hole 523, South Atlantic Ocean].—Lu and Keller, 1995:102, pl. 2: figs. 4, 5 [Zone AP 6A, lowermost Eocene; ODP Hole 738C/9R/1: 15-17 cm; Kerguelen Plateau, southern Indian Ocean].

Globigerina inaequispira Subbotina.—Loeblich and Tappan, 1957a:181, pl. 61: fig. 3 [Zone P4, upper Paleocene, Nanafalia Fm., Alabama] [in part, not pl. 49: fig. 2a-c, pl. 52: figs. 1a-2c, pl. 56: fig. 7a-c, pl. 62: fig. 2a-c]. [Not Subbotina, 1953.]

Globorotalia (*Acarinina*) *primitiva* (Finlay).—Hillebrandt, 1962:141, pl. 14: figs. 2, 4 [Zone G, lower Eocene, Austria].—Blow, 1979:949, pl. 143: figs. 6-9 [Zone P8, lower Eocene, DSDP Hole 20C/5/4: 77-79 cm; Brazil Basin, South Atlantic Ocean], pl. 249: figs. 1-4 [lower Bortonian, middle Eocene, New Zealand].

Pseudogloboquadrina primitiva (Finlay).—Jenkins, 1965:1124, fig. 9 [nos. 81-83 (holotype) and 84-86; Bortonian, middle Eocene, New Zealand].

Acarinina coalingensis (Cushman and Hanna).—Berggren, 1969b:152, pl. 1: figs. 27-29 [Zone NP 11/12, stratigraphically equivalent to Zone P6/7; lower Eocene 3, Katharinenhof, Fehmarn, northern Germany].—Huber, 1991b:439, pl. 3: fig. 2 [Zone AP6b/AP7, lower Eocene, ODP Hole 738C/6R: 247.83 msbf; Kerguelen Plateau, southern Indian Ocean].—Berggren, 1992:563, pl. 2: fig. 3 [*Acarinina wilcoxensis* Zone, lower Eocene, ODP Site 749C/10R/1: 40-44 cm; Kerguelen Plateau, southern Indian Ocean].

Globorotalia (*Acarinina*) *triplex* (Subbotina).—Blow, 1979:963, pl. 97: figs. 8, 9 [Zone P5, Lindi area, Tanzania].

Acarinina primitiva (Finlay).—Stott and Kennett, 1990:559, pl. 6: figs. 11, 12 [Zone AP8, lower Eocene, ODP Hole 689B/21H/1: 110-114 cm; Maud Rise, Weddell Sea, Southern Ocean].—Huber, 1991b:439, pl. 3: fig. 1 [Zone AP10, middle Eocene, ODP Site 738B/15X: 126.70 msbf; Kerguelen Plateau, southern Indian Ocean].—Berggren, 1992:563, pl. 2: figs. 4, 5 [Zone P6-7, ODP Hole 748B/18H/3: 80-84 cm; Kerguelen Plateau, southern Indian Ocean].—Lu and Keller, 1993:120, pl. 3: figs. 1, 2 [Zone AP7, lower Eocene, ODP Hole 738C/5R/2: 57-59 cm; Kerguelen Plateau, southern Indian Ocean].—Pearson et al., 1993:125, pl. 1: fig. 19 [Zone P11, middle Eocene, DSDP Hole 523, South Atlantic Ocean].

ORIGINAL DESCRIPTION.—"Test subglobular, the last three chambers making up nearly the whole periphery of the test, early chambers largely concealed by the ornamentation which is greatest over the early chambers; consisting of large projection bosses with a spinose surface, the succeeding chambers covered with a progressively decreasing ornamentation, the last-formed chamber with only a few short slender spines; aperture small, in the slightly open umbilicus of the ventral side. Diameter 0.60 mm." (Cushman and Hanna, 1927:205.)

DIAGNOSTIC CHARACTERS.—Robust test, 3-4 chambered final whorl, compact, subquadrate (*primitiva* morphotype) to subtriangular (*coalingensis* morphotype), strongly and bluntly muricate test; peripheral margin broadly rounded, less commonly subangular in edge view; chambers arranged at distinct right angles to each other and usually separated by deep, incised sutures (particularly between preantepenultimate and antepenultimate chambers) on umbilical side, and increase rapidly in size; aperture interiomarginal, umbilical-extraumbilical.

DISCUSSION.—There are two basic morphotypes that characterize this robust and strongly muricate species: a form with a triangular-subquadrate appearance characterized by (predominantly) globular chambers (typified by *Globigerina coalingensis* Cushman and Hanna, 1927, and its junior synonym *Acarinina triplex* Subbotina, 1953), and a form with a subquadrate to quadrate appearance characterized by straight and circumumbilically pointed, smooth (nonmuricate) globoquadrinid-like chambers (typified by *Globoquadrina primitiva* Finlay, 1947). These two morphotypes have been synonymized by some workers (Berggren, 1977) and distinguished by others (Pearson et al., 1993; Pearson, 1993). After having considered these forms synonymous, Berggren (1977) distinguished them at Kerguelen Plateau sites based on the perception of their morphologic differences and different stratigraphic ranges (Berggren, 1992). Our work described herein suggests that the earlier interpretation may be more correct. One of us (WAB) has examined topotypic material of *A. coalingensis* (including the reillustrated holotype, Berggren, 1977, pl. 10), *A. primitiva,* and the holotype and topotypes of *A. triplex* and now believes that these forms belong to a single taxon that exibits a gradual replacement through time of the *coalingensis* morphotype by the *primitiva* morphotype. Inasmuch as consistent distinction between these two morphotypes appears impossible, we believe it more appropriate to use a single name for this "taxon" and suggest that authors provide careful descriptions to denote the presence/development of one morphotype relative to the other should this prove useful for biostratigraphic purposes.

STABLE ISOTOPES.—No data available.

STRATIGRAPHIC RANGE.—Zone P4c to Zone P14; *coalingensis* morphotype dominant over interval of P5-P7/8.

GLOBAL DISTRIBUTION.—*Acarinina coalingensis* has a cosmopolitan distribution from the tropics to the Southern Ocean and from the open ocean into epicontinental seaways.

ORIGIN OF SPECIES.—We believe that *Acarinina coalingensis* has its closest affinities with (and is probably a direct descendant of) *A. nitida* from which it differs primarily in its larger and more strongly muricate test, reduced number of chambers, and more pronounced involute coiling. It is also possible that *A. coalingensis* originated from the *A. subsphaerica*-*A. mckannai* group because these taxa are also characterized by well-developed large muricae on the umbilical surface, a feature that would have evolved twice if *A. coalingensis* evolved independently from *A. nitida*.

REPOSITORY.—Museum of the California Academy of Sciences, San Francisco (No. 2548).

Acarinina mckannai (White, 1928)

FIGURE 19; PLATE 40: FIGURES 1–16

Globigerina mckannai White, 1928:194, pl. 27: fig. 16a–c [Velasco Fm., Mexico].—Loeblich and Tappan, 1957a:181, pl. 47: fig. 7a–c [Zone P4, Salt Mountain Fm., Alabama], pl. 53: figs. 1a–2c [Zone P4, Vincentown Fm., New Jersey], pl. 57: fig. 8a–c [Zone P4, Aquia Fm., Virginia], pl. 62: figs. 5a–6c [Zone P4, Velasco Fm., Tamaulipas, Mexico], pl. 62: fig. 7a–c [designated lectotype, Columbia University No. 19878, Velasco Fm., Mexico].

Globorotalia mckannai (White).—Bolli, 1957a:79, pl. 19: figs. 16–18 [*Globorotalia pseudomenardii* Zone, lower Lizard Springs Fm., Trinidad].—Bolli and Cita, 1960:383, pl. 33: fig. 6a–c [*Globorotalia velascoensis* Zone, Paderno d'Adda, northern Italy].

Globorotalia (*Acarinina*) *mckannai* (White).—Hillebrandt, 1962:140, pl. 14: figs. 8a–10c [Zone F = *Globorotalia velascoensis* Zone, Reichenhall-Salzburg Basin, Austro-German border].—Jenkins, 1971:82, pl. 3: figs. 89–93 [Waipawan Stage, Middle Waipara River section, New Zealand].

Acarinina mckannai (White).—Krasheninnikov and Hoskins, 1973:116, pl. 2: figs. 6–8 [*Globorotalia velascoensis* Zone, DSDP Site 199/8; Caroline Abyssal Plain, eastern Equatorial Pacific Ocean].—Toumarkine and Luterbacher, 1985:116, text-fig. 18 [3a–c, reillustration of Bolli, 1957a, pl. 19: figs. 16–18; 5a–c, reillustration of holotype from White, 1928; 6a–c, specimen from northern Caucasus illustrated by Shutskaya, 1958] [in part, not 4a–c, reillustration of holotype of *Globogerina subsphaerica* Subbotina].—Lu and Keller, 1993:118, pl. 2: figs. 14–16 [Zone AP4, upper Paleocene, ODP Hole 738C/11R/CC; Kerguelen Plateau, southern Indian Ocean].

Muricoglobigerina mckannai (White).—Belford, 1984:13, pl. 22: fig. 408 [upper Paleocene, WABAG Sheet area, Papua, New Guinea].—Stott and Kennett, 1990:559, pl. 3: figs. 7, 8 [Zone AP6, ODP Hole 690B/17H/5: 36–40 cm; Maud Rise, Wedell Sea, Southern Ocean].

Acarinina praecursoria Morozova.—Huber, 1991b:439, pl. 1: figs. 3–5 [Zone AP5, ODP Hole 738C/16R: 332.15 mbsf; Kerguelen Plateau, southern Indian Ocean]. [Not Morozova, 1957.]

ORIGINAL DESCRIPTION.—"Test rotaliform, dorsal side slightly convex, ventral side very convex, umbilicate, periphery rounded; chambers usually six in the last whorl, gradually increasing in size, closely appressed; sutures distinct, deep, not limbate; wall granular or subspinose, very finely perforate; aperture an elongate opening extending from the umbilicus about half way to the peripheral margin. Diameter of type specimen, 0.4 mm; height, 0.3 mm." (White, 1928:194.)

DIAGNOSTIC CHARACTERS.—Test large, $4^1/_2$–6 chambers in final whorl, moderate to low spired, final chamber often curving partly over umbilicus in high-spired variants; strongly muricate on umbilical surface with deep, funnel-shaped entrances to pores over the rest of test; chambers slowly increasing in size in final whorl; peripheral margin rounded, with chambers elongate parallel to coiling axis as well as elongate in direction of coiling; sutures deep, straight, and incised on umbilical surface, gently depressed on spiral side and slightly curved; umbilicus deep and large; aperture interiomarginal, umbilical-extraumbilical without a lip.

DISCUSSION.—*Acarinina mckannai* is one of the most common and broadly distributed upper Paleocene acarininids and is easily recognized by its large, globular, muricate test with generally 5 to 6 chambers in the final whorl. This species is closely allied with *A. subsphaerica*, and, indeed, complete intergradation exists between them in spire height, umbilical size, and the number of chambers in the final whorl. Shutskaya (1958, 1970a) figured a large number of specimens as *A. subsphaerica*, some of which are clearly referable to *A. mckannai* due to their low spire height.

STABLE ISOTOPES.—*Acarinina mckannai* has $\delta^{18}O$ slightly more negative than coexisting morozovellids, such as *M. velascoensis*, and shows no size related trends in $\delta^{18}O$ (Shackleton et al., 1985). The $\delta^{13}C$ of *A. mckannai* is much more positive than that of *Subbotina* and is similar to, or slightly more negative than, that of *Morozovella* and *Igorina* (Shackleton et al., 1985).

STRATIGRAPHIC RANGE.—Zone P4a to lower Zone P4c.

GLOBAL DISTRIBUTION.—*Acarinina mckannai* is a broadly distributed species in the tropical to subtropical oceans. Specimens have been reported from the high southern latitudes (Huber, 1991b), although these are neither as coarsely muricate nor as inflated as typical low-latitude representatives of the species (Figure 19).

ORIGIN OF SPECIES.—*Acarinina mckannai* evolved from *A. subsphaerica* by a reduction in spire height and an increase in whorl expansion rate. These taxa are the first acarininds to acquire a coarsely pustulose (muricate) ornamentation on the umbilical surface. *Acarinina subsphaerica* appears before *A. mckannai* in our material and retains the slightly anguloconic test shape of *A. nitida*, suggesting that *A. subsphaerica* is more primitive than *A. mckannai*.

REPOSITORY.—Columbia University Paleontology Collection (No. 19878); collection now at the American Museum of Natural History, New York. Examined by WAB.

Acarinina nitida (Martin, 1943)

PLATE 12: FIGURES 1–3; PLATE 41: FIGURES 1–16

Globigerina nitida Martin, 1943:115, pl. 7: fig. 1a–c [*Morozovella subbotinae* Zone, Lodo Fm., California].

Acarinina acarinata Subbotina, 1953:229, pl. 22: figs. 4, 5, 8, 10 [? figs. 6, 7, 9] [zone of compressed globorotaliids; *Globorotalia crassata* Subzone = Zone P5 this paper, Khieu River section, Nal'chik, northern Caucasus].—Shutskaya, 1970b:118, 228, pl. 27: fig. 13a–c [*Acarinina acarinata* Zone, Tarkhankut Peninsula, Crimea].—Krasheninnikov and Hoskins, 1973:116, pl. 1: figs. 1–3 [*Globorotalia velascoensis* Zone, DSDP Site 199/8; Caroline Abyssal Plain, western Pacific Ocean].

Globigerina stonei Weiss, 1955:18, pl. 5: figs. 16–18 [holotype; middle Paleocene, Peru] [in part, not pl. 5: figs. 19–21].

Globorotalia whitei Weiss.—Bolli, 1957a:79, pl. 19: figs. 10–12 [*Globorotalia pseudomenardii* Zone, lower Lizard Springs Fm., Trinidad]. [Not Weiss, 1955.]

Globigerina cf. *G. soldadoensis* Brönnimann.—Loeblich and Tappan, 1957a:182, pl. 53: fig. 4a–c [Zone P4, Vincentown Fm., New Jersey]. [Not Brönnimann, 1952.]

Globorotalia (*Acarinina*) *acarinata acarinata* (Subbotina).—Blow, 1979:904, fig. 7 [Zone P5 of Blow, 1979 = Subzone P4c this paper; Tanzania].

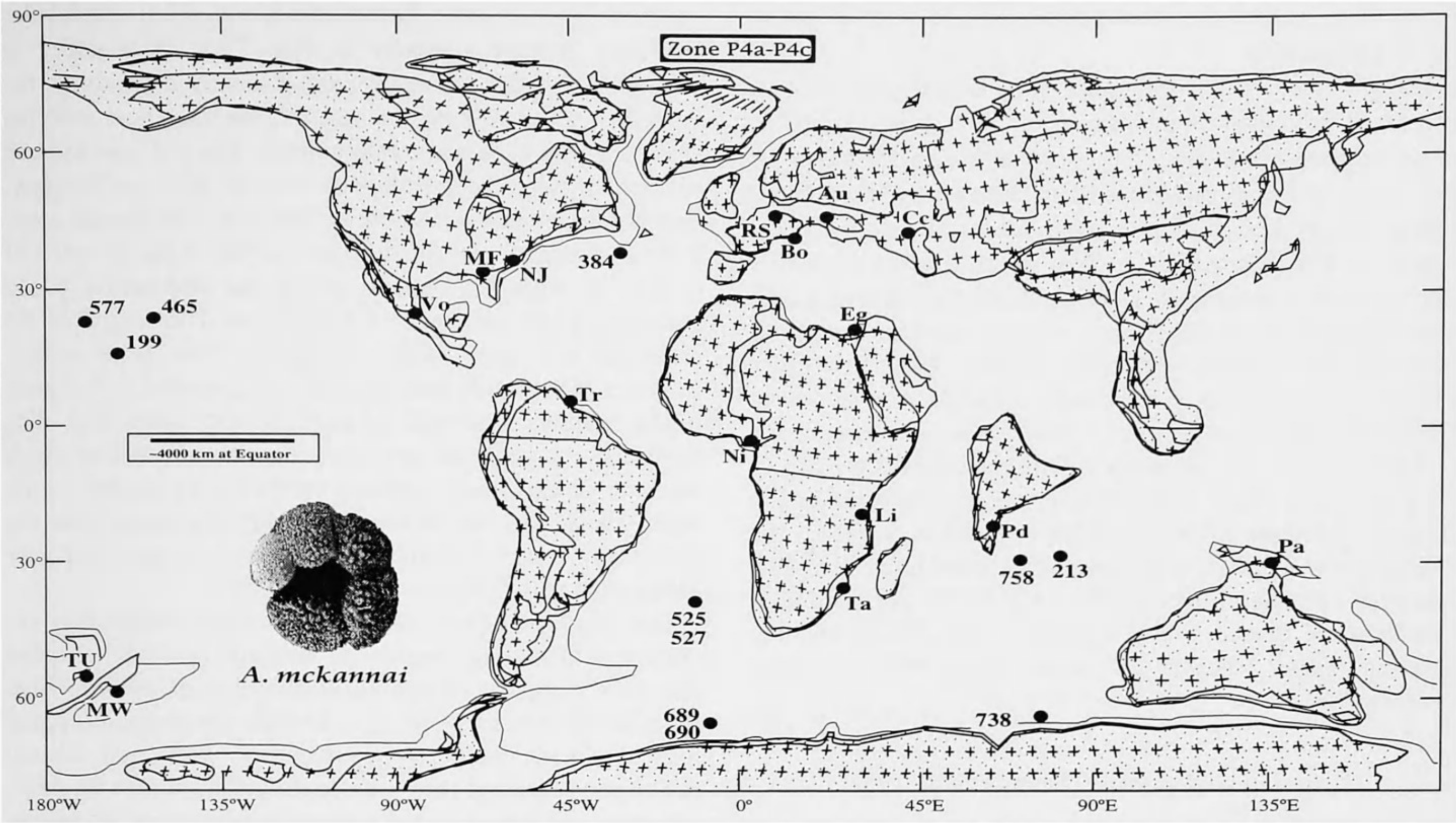

FIGURE 19.—Paleobiogeographic map showing distribution of *Acarinina mckannai* (White) in Zones P4 and P5.

ORIGINAL DESCRIPTION.—"Test subglobular, more convex ventrally than dorsally; wall calcareous, finely perforate, completely covered with numerous fine papillae giving a granular appearance; periphery broadly rounded, slightly lobulate; all chambers exposed on dorsal side, only last whorl of five visible on ventral side; chambers inflated, increasing rapidly in size as added, last chamber extending slightly beyond previous ones, overhanging on ventral side to form a depressed umbilical area; dorsal sutures more or less distinct, nearly straight, slightly depressed; apertural face of last chamber flat, aperture a narrow slit extending from umbilicus about halfway along base of chamber toward periphery bordered on outer edge by a slight lip. Maximum diameter 0.29 mm; minimum diameter 0.28 mm; maximum thickness 0.28 mm." (Martin, 1943:115.)

DIAGNOSTIC CHARACTERS.—Compact, small, trochospiral, subcircular to subquadrate test with 4 (rarely 5) rounded, tightly packed, radially compressd and axially elongate chambers; early whorls raised above surface of last whorl; surface moderately muricate, particularly on umbilical side, with deep, funnel-shaped entrances to pores.

DISCUSSION.—This form is generally recognized to be a senior synonym of *Acarinina acarinata* (Subbotina), type species of the genus *Acarinina* (Stainforth et al., 1975; Luterbacher, 1975b; Berggren, 1977, who compared the holotype of *nitida* with topotypes of *acarinata*; Toumarkine and Luterbacher, 1985). It is one of the earliest acarininids appearing together with *A. subsphaerica* at the base of Zone P4. *Acarinina nitida* represents an intermediate stage between the weakly muricate *A. strabocella* and the more strongly muricate upper Paleocene acarininids. Subbotina (1953) considered that *acarinata* ranged up to the base of her zone of conical globorotaliids (= P6a/b boundary of this work). Our observations agree more closely with Blow (1979), who indicated its LAD occurs in his Zone P5 or possibly lower P6.

The holotype of *Acarinina intermedia* Subbotina, 1953 (Plate 12: Figures 4–6), is a poorly preserved specimen with a missing ultimate chamber and an obscured umbilicus. The general morphology of this specimen shows four chambers in the ultimate whorl and heavily muricate umbilical shoulders suggesting a linkage to *nitida*. *Acarinina nitida* has also been previously identified under different names (see synonomy) by Weiss (1955), Bolli (1957a), and Loeblich and Tappan (1957a).

STABLE ISOTOPES.—*Acarinina nitida* has $\delta^{18}O$ values similar to co-existing morozovellids, such as *M. velascoensis* and *M. subbotinae,* and shows a slight negative size-trend in $\delta^{18}O$ (D'Hondt et al., 1994). The $\delta^{13}C$ of *A. nitida* is much more positive than that of *Subbotina* and is similar to that of *Morozovella* (D'Hondt et al., 1994).

STRATIGRAPHIC RANGE.—Zone P4a to lower Zone P4c.

GLOBAL DISTRIBUTION.—This form is geographically widespread in (sub)tropical regions and has been reported from high southern latitudes on the Kerguelen Plateau (Huber, 1991b) and

Maud Rise, Weddell Sea (Stott and Kennett, 1990) at 62° S and 65° S, respectively.

ORIGIN OF SPECIES.—*Acarinina nitida* is related to unkeeled morozovellids with which the acarininids share a similar ornamentation consisting of deep funnel-shaped entrances to the pores, short, weakly developed muricae at the interpore ridges, deeply incised sutures, and a tendency toward slightly anguloconical chambers in the final whorl. *Acarinina nitida* is derived from *A. strabocella* from which it differs in having only four chambers in the final whorl, more involute coiling, and a more coarsely muricate surface texture. Bolli (1957a) and Blow (1979) suggested that *Globorotalia whitei*/*A. acarinata*, respectively, was the ancestor of *A. wilcoxensis* and we concur.

REPOSITORY.—Holotype (No. 7400) in Stanford University Paleontological Type Collection. Paratypes deposited in the National Museum of Natural History (USNM 559454); the University of California, Berkeley (No. 35066); the American Museum of Natural History (No. MT-1015); the California Academy of Sciences, San Francisco (No. 7877); and the Paleontological Research Institution, Ithaca, N.Y. Paratypes examined by WAB.

Acarinina soldadoensis (Brönnimann, 1952)

FIGURE 20; PLATE 15: FIGURES 4, 7, 8; PLATE 42: FIGURES 1–16

Globigerina soldadoensis Brönnimann, 1952:7, 9, pl. 1: figs. 1–9 [Lizard Springs Fm., Trinidad; type locality of *Globigerina velascoensis* Zone of Bolli, 1957a:64 = Zone P5 this paper].—Bolli, 1957a:71, pl. 16: figs. 7–9 [? figs. 10–12] [*Globorotalia formosa* Zone, upper Lizard Springs Fm., Trinidad]; 1957b:162, pl. 35: fig. 9a–c [*Globorotalia palmerae* Zone, Navet Fm., Trinidad].

Acarinina clara Khalilov, 1956:250, pl. 5: fig. 4 [upper Paleocene, Akhchakumia, northeastern Azerbaizhan].

Globorotalia (*Acarinina*) *soldadoensis* (Brönnimann).—Hillebrandt, 1962:142, pl. 14: figs. 5, 6 [Zone G = Zone P6 this paper; Reichenhall-Salzburg Basin, Austro-German border].—Jenkins, 1971:73, pl. 4, figs. 94–98 [*Globigerina triloculinoides* Zone, Waipawan Stage, Middle Waipara River section, New Zealand].

Acarinina soldadoensis (Brönnimann).—Berggren, 1971b:76, pl. 5: figs. 1–3 [*Morozovella velascoensis* Zone, DSDP Hole 20C/6/4: 5–7 cm; South Atlantic Ocean].—Huber, 1991b:439, pl. 2: fig. 16 [Zone AP6a, lower Eocene, ODP Hole 738C/10R: 275.25 msbf; Kerguelen Plateau, southern Indian Ocean].

Muricoglobigerina soldadoensis soldadoensis (Brönnimann).—Blow, 1979:1120, pl. 98: figs. 1–3 [sample FCRM 1670, Zone P5 of Blow, 1979 = Zone P4c this paper; Lindi area, Tanzania], pl. 107: figs. 1–5 [Zone P6 of Blow, 1979; DSDP Hole 20C/6/3: 76–78 cm; South Atlantic Ocean], pl. 109: fig. 8 [Zone P6, DSDP Hole 47.2/8/4: 78–81 cm], pl. 110: fig. 1 [Zone P6, DSDP Hole 47.2/8/4: 78–81 cm], pl. 124: figs. 1, 3, 5 [Zone P7, DSDP Hole 47.2/8/3: 83–85 cm], pl. 131: figs. 1–3, 6 [Zone P8, DSDP Hole 47.2/8/2: 71–73 cm; Shatsky Rise, northwestern Pacific Ocean].—Stott and Kennett, 1990:559, pl. 3: figs. 1, 4 [Zone AP5, ODP Hole 689B/22X/5: 110–114 cm; Maud Rise, Weddell Sea, Southern Ocean].

ORIGINAL DESCRIPTION.—"The low trochoid test is composed of about two volutions. The four-chambered, occasionally five-chambered adult is lobulate in typical specimens. The spiral side is centrally more or less elevated, the umbilical side is convex. The umbilicus is large and deep showing the arcuate apertures of the latter formed chambers. The subglobular chambers increase gradually in size. They are rounded to slightly flattened peripherally and distinctly elongate in the direction of the axis of the test. At the umbilical side the chambers tend to be somewhat pointed. The end chamber can be smaller than the penultimate one or even rudimentary. Except for the indistinct sutures of the early ontogenetic stage, those of the spiral side are deep and curved in the direction of coiling, or they are oblique giving the impression of an overlapping arrangement of the chambers. The sutures of the umbilical side are straight throughout. The large arcuate apertures of the last formed chambers are provided with minute liplike boarders. The wall are perforate and rather thick. The surface is covered with irregularly distributed papillae which are stronger and more prominent on the early chambers of the adult whorl; they are absent or weakly developed near the aperture of the end chamber. The species is predominantly coiled sinistrally." (Brönnimann, 1952:7.)

DIAGNOSTIC CHARACTERS.—Low trochoid, moderately evolute test of 4–5 moderately to strongly muricate, rounded chambers distinctly elongated in the axis of coiling; final chamber often reduced in size; lobulate periphery; deep and relatively wide umbilicus revealing (in some individuals) earlier chambers and their arcuate foramina; sutures on spiral side deep and curved and/or tangential in direction of coiling, chambers often overlapping.

DISCUSSION.—This taxon is characterized by a test composed of 4 to 5 chambers arranged in a relatively loose (lax) coil, resulting in a relatively open and deep umbilicus and moderate to strong lateral chamber compression (giving an angulate appearance to the peripheral margin of some chambers), which culminates in the descendant angulate species *angulosa*. *Acarinina clara* Khalilov (1956) from the upper Paleocene of Azerbaizhan exhibits the typical lobulate test and elongated chamber morphology of *A. soldadoensis* and is herein regarded as a junior synonym of this species.

STABLE ISOTOPES.—No data available.

STRATIGRAPHIC RANGE.—Zone P4c to Zone P9.

GLOBAL DISTRIBUTION.—This species has a widespread geographic distribution from equatorial to subantarctic regions (Figure 20).

ORIGIN OF SPECIES.—*Acarinina soldadoensis* is a sister taxon to *A. mckannai* from which it differs in being somewhat more evolute and in having more umbilically elongate chambers.

REPOSITORY.—Holotype (USNM 370085) deposited in the Cushman Collection, National Museum of Natural History. Examined by WAB.

Acarinina strabocella (Loeblich and Tappan, 1957)

FIGURE 21; PLATE 15: FIGURES 1–3; PLATE 43: FIGURES 1–16

Globorotalia angulata (White) var. *praepentacamerata* Shutskaya, 1956:94, 95, pl. 3: fig. 3 [*Acarinina praepentacamarata* Zone, Elburgan Fm., Khieu River section, northern Caucasus].

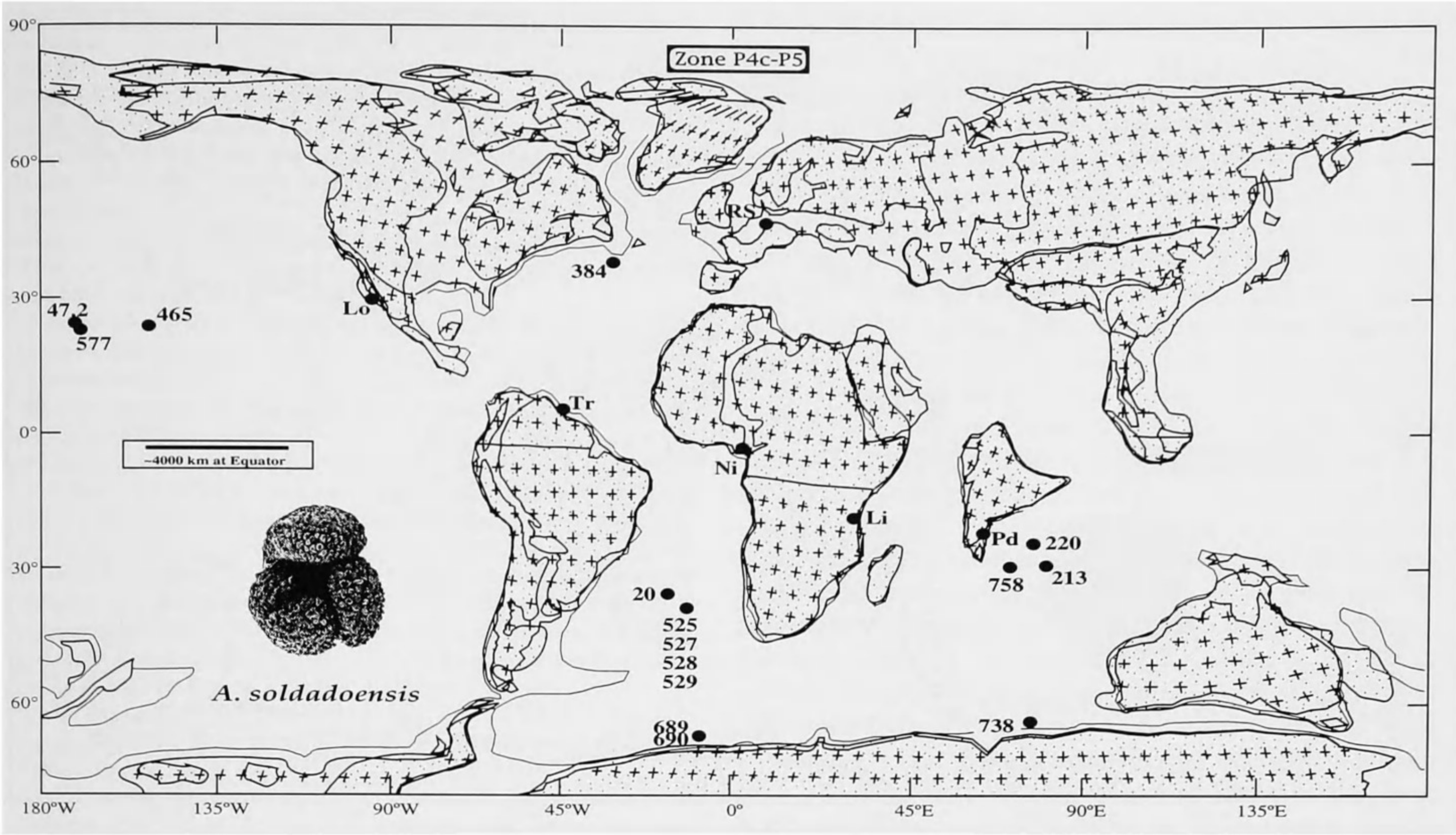

FIGURE 20.—Paleobiogeographic map showing distribution of *Acarinina soldadoensis* (Brönnimann) in Zones P5 and P6.

Globorotalia strabocella Loeblich and Tappan, 1957a:195, pl. 61: fig. 6a–c [Nanafalia Fm., Alabama].

Globorotalia praepentacamerata Shutskaya.—Luterbacher, 1964:665, pl. 40: fig. 45 [*Acarinina tadjikistanensis djanensis* Zone, Elburgan Fm., Khieu River, northern Caucasus; topotype determined by Shutskaya].

Acarinina praepentacamerata (Shutskaya).—Shutskaya, 1970b:118–120, pl. 21: figs. 8, 10 [*Acarinina praepentacamerata* Zone, Chaldzhin Fm., Malyi Balkhan, western Turkmenia], pl. 22: fig. 2 [lower subzone of *Acarinina tadjikistanensis djanensis* Zone, Lower Danatin Mbr., Malyi Balkhan Ridge, western Turkmenia].—Stott and Kennett, 1990:558, pl. 4: figs. 9, 10 [Zone A4, ODP Hole 689B/23X/1: 108–112 cm; Maud Rise, Weddell Sea, Southern Ocean].—Huber, 1991b:439, pl. 2: figs. 1, 2 [Zone AP5, ODP Hole 738C/11R: 286.04 msbf; Kerguelen Plateau, southern Indian Ocean].

Globorotalia (*Acarinina*) *strabocella* Loeblich and Tappan.—Jenkins, 1971:84, pl. 4: figs. 102–104 [*Globigerina triloculinoides* Zone, lower Waipawan Stage, New Zealand].

Acarinina praeangulata (Blow).—Huber, 1991a:439, pl. 1, figs. 6, 7 [Zone AP4, ODP Hole 738C/16R: 332.15 mbsf; Kerguelen Plateau, southern Indian Ocean]. [Not Blow, 1979.]

ORIGINAL DESCRIPTION.—"Test free, of medium size, trochospiral, sides moderately convex, umbilical shoulder rounded, umbilicus broad and open, periphery broadly rounded, peripheral outline lobulate; chambers increasing gradually in size as added, of greater breadth than height, 4 per whorl in the early stages, increasing to 5 or 6 per whorl in the adult, early whorls somewhat elevated above the level of the final whorl, each successive chamber on the spiral side added somewhat below the level of that preceding, resulting in an imbricated appearance; sutures distinct, depressed, curved and oblique on the spiral side, radial and nearly straight on the umbilical side; wall calcareous, finely perforate, surface finely spinose, especially on the umbilical side; aperture an interiomarginal, extraumbilical-umbilical opening extending to the periphery.

"Holotype is 0.33 mm in greatest diameter." (Loeblich and Tappan, 1957a:195.)

DIAGNOSTIC CHARACTERS.—Five to 6 chambered, nearly circular test with weakly lobulate outline; axial periphery broadly rounded to subangular, chambers on umbilical side moderately convex, early whorls on spiral side elevated above later whorl(s); umbilicus usually broad and open exposing earlier whorls; test weakly pustulose (muricate) over entire surface, aperture an interiomarginal, umbilical-extraumbilical slit.

DISCUSSION.—Shutskaya (1956; see also 1970a, 1970b) described *Globorotalia angulata* var. *praepentacamerata* from the lower Paleocene of the northern Caucasus and showed that it had a wide distribution in the southwestern part of the former Soviet Union. Luterbacher (1964:665) suggested that *Globorotalia strabocella* Loeblich and Tappan may be a junior synonym. We agree with this assessment particularly inasmuch as comparison of our material with the holotype of *G. strabocella* at the NMNH shows them to be morphologically

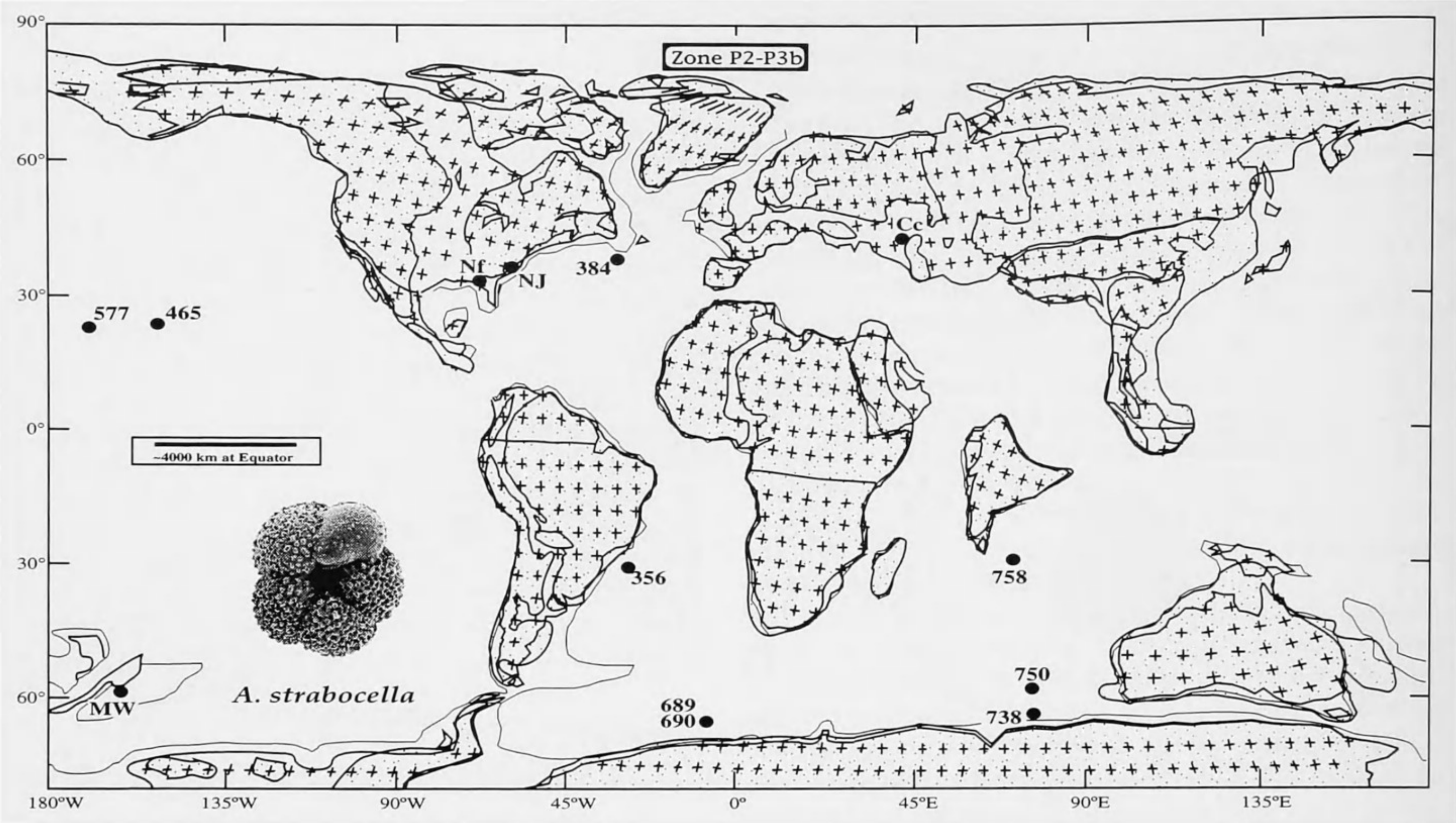

FIGURE 21.—Paleobiogeographic map showing distribution of *Acarinina strabocella* (Loeblich and Tappan) in Zone P3.

similar. In view of the fact that there is no original (type) material remaining of Shutskaya's taxon (nor of any other taxa that she described, for that matter, with rare exception), we prefer to use the name *strabocella* for this taxon because of the fact that there is well-preserved type material at a readily accessible museum (the NMNH in Washington), which aids in stabilizing the nomenclature.

Shutskaya (1970b:118, 120, fig. 13) showed that *A. praepentacamerata* is restricted to the *A. praepentacamerata* Zone and the lower subzone of the overlying *A. tadjikistanensis djanensis* Zone in the southwestern part of the former Soviet Union [= Zone P3 (middle part) to ? P4 [lower part)]. This is similar to our observations. The forms referred to *A. wilcoxensis strabocella* from Zones P6–P8b by Blow (1979:970, pls. 114, 129, 132, 251) are considered unrelated to *strabocella*; they differ in their more evolute coiling, flatter spiral coil, and strongly muricate ornament. They represent a younger, more advanced acarininid morphology than that seen in *A. strabocella*. In fact, we view *A. strabocella* as representing the stem form of the acarininid radiation that occurred at the P3–P4 zonal transition.

STABLE ISOTOPES.—No data available.

STRATIGRAPHIC RANGE.—Zone P3 (lower part) to Zone P4 (lower part).

GLOBAL DISTRIBUTION.—Northern middle latitudes to the Southern Ocean (Figure 21).

ORIGIN OF SPECIES.—The origin of the first *Acarinina* species is somewhat obscure. The wall surface of *A. strabocella* is smooth with simple and coalescent pustules (Plate 5: Figure 1) that become more heavily developed on the older part of the test. The origin of this species may be linked with the moderately pustulose *Morozovella praeangulata* in the lower part of Zone P3 and may have diverged from early forms of this species. Alternatively, *A. strabocella* may have evolved from *Praemurica inconstans* by developing a tighter coil and a lower rate of chamber enlargement. In any case, *A. strabocella* represents the stem form of the acarininid radiation. Reduction of the number of chambers in the final whorl and the increased development of muricae are seen in the derivation of *A. nitida* from *A. strabocella*.

REPOSITORY.—Holotype (USNM P5879) and paratypes (USNM CC38526) deposited in the Cushman Collection, National Museum of Natural History. Examined by WAB and RDN.

Acarinina subsphaerica (Subbotina, 1947)

FIGURE 22; PLATE 15: FIGURES 9, 10; PLATE 44: FIGURES 1–16

Globigerina subsphaerica Subbotina, 1947:108, pl. 5: figs. 26–28 [holotype: *Globigerina* ex gr. *canariensis* Zone, Assu River section, northern Caucasus], pl. 5: figs. 23–25 [zone of compressed globorotaliids, Osetiya, Assu River section, northern Caucasus]; 1953:59, pl. 2: fig. 15a–c [holotype refigured].—Shutskaya, 1956:91, pl. 3: fig. 1 [holotype from Foraminiferal Bed (F1), zone of compressed globorotaliids, Assu River section, northern Caucasus, also recorded from equivalent levels in Assu River section, Osetiya, northern Caucasus].

Globoconusa quadripartitaformis Khalilov, 1956:249, pl. 5: fig. 3a–c [holotype No. 238, sample 35 (1946), foothills of Malyi Caucasus, Azerbaizhan].

Globigerina chascanona Loeblich and Tappan, 1957a:180, pl. 49: fig. 5a–c [holotype, lower Zone P4, uppermost Hornerstown Fm., New Jersey] [in part, not pl. 49: fig. 4a–c, pl. 61: fig. 8a–c].

Globigerina spiralis Bolli.—Loeblich and Tappan, 1957a:182, pl. 47: fig. 3a–c [Zone P4, Salt Mountain Limestone, Alabama], pl. 49: fig. 3a–c [Zone P4, Hornerstown Fm., New Jersey], pl. 51: figs. 6a–9c [Zone P4, Vincentown Fm., New Jersey], pl. 53: fig. 3a–c [Zone P4, Vincentown Fm., New Jersey]. [Not Bolli, 1957a.]

Acarinina subsphaerica (Subbotina).—Shutskaya, 1958:89, pl. 2: figs. 12–14, pl. 3: figs. 1–3 [all figured specimens from Nal'chik Horizon, Sunzha River section, Groznensk Oblast, northern Caucasus] [in part, not pl. 2: figs. 6–11, pl. 3: figs. 4–21 = *Acarinina mckannai*]; 1960:249, pl. 2: fig. 8; 1970b:118–120, pl. 2: fig. 8a–c [*Acarinina acarinata* Zone, Kachan Stage, Belbek River, Bakhchisaray Region, southwestern Crimea], pl. 6: fig. 3a–c [*Globorotalia aequa* Zone, Bakhchisarayan Stage, Belbek River, Bakhchisaray Region, southwestern Crimea], pl. 26: fig. 3a–c [*Acarinina subsphaerica* Zone, Nal'chik Region, Khieu River, northern Caucasus].

Acarinina falsospiralis Davidzon and Morozova, 1964:26, 28, pl. 1: fig. 5a–c [upper Paleocene, upper Bukhara Beds, lower Karatag Horizon, Tutkaul Village, Sanglak Range, Tadzhik Depression, Tadzhikistan].

Acarinina microsphaerica Morozova in Morozova, Kozhevnikova, and Kuryleva, 1967:195, pl. 6: figs. 3, 4 [Thanetian Stage, upper Paleocene, Kacha River, Crimea].

Globorotalia (Acarinina) subsphaerica (Subbotina).—Blow, 1979:960, pl. 91: figs. 4–6 [Zone P4, DSDP Hole 21A/3/6: 74–76 cm; South Atlantic Ocean], pl. 92: figs. 1–3 [Zone P4, DSDP Hole 47.2/9/5: 74–76 cm; Shatsky Rise, northwestern Pacific Ocean].

Muricoglobigerina chascanona (Loeblich and Tappan).—Blow, 1979:1126, pl. 91: figs. 1, 2 [lower Zone P4, DSDP Hole 21A/3/6: 74–76 cm; South Atlantic Ocean], pl. 92: fig. 3 [Zone P4, DSDP Hole 47.2/9/5: 70–72 cm], pl. 93: figs. 7–9, pl. 235: figs. 1–3 [Zone P4, DSDP Hole 47.2/9/3: 70–72 cm], pl. 101: figs. 5, 6 [Zone P5, DSDP Hole 47.2/9/1: 64–66 cm; Shatsky Rise, northwestern Pacific Ocean].

Acarinina chascanona (Loeblich and Tappan).—Huber, 1991b:439, pl. 2: fig. 3 [Zone AP4, ODP Hole 738C/15R: 322.07 msbf; Kerguelen Plateau, southern Indian Ocean] [in part, not pl. 2: fig. 4]. [Not Loeblich and Tappan, 1957a.]

ORIGINAL DESCRIPTION.—"Test small, nearly spherical; viewed from the ventral side, it very often resembles a slightly bursting chestnut. Test consists of three or three and one-half whorls, of which the first two are disproportionately small as compared with the final whorl. In the final whorl there are five to six chambers gradually increasing in size. In the middle of the ventral side there is a small umbilicus. The chambers are trapezoidal on the dorsal side, and triangular on the ventral side; they have a smooth outer surface and adhere closely to one another. Septal sutures depressed, slightly curved in the direction of coiling. Aperture semi-rounded, occupying approximately one-third of the distance between the umbilicus and the periphery. Wall reticulate, finely porous. Average dimensions: greatest diameter 0.27 mm.; height 0.25 mm." (Subbotina, 1947:108; translated from Russian.)

DIAGNOSTIC CHARACTERS.—Characterized by strongly elevated spire and tightly coiled, small test giving species a sphaerical, globular shape. Umbilicus narrow, deep, and surrounded by coarse pustules (muricae). Usually with a diminutive final chamber with an arched aperture.

DISCUSSION.—The strongly conical spire and small, tightly coiled muricate test makes this one of the most distinctive taxa of the middle Paleocene. Yet it remains one of the least understood taxa among the acarininids. Although Subbotina described *subsphaerica* as resembling "a slightly bursting chestnut" (1947:108), she also indicated that the test is "reticulate, finely porous," but she made no mention of its most distinctive character: its high conical spire. In fact, Subbotina (1953:53) retained *subsphaerica* among her "polythalamous species of *Globigerina*" characterized by possessing five or more closely packed chambers in the last whorl (together with such taxa as *edita* Subbotina, *compressa* Plummer, *pseudobulloides* Plummer, *postcretacea* Mjatliuk, and *tarchanensis* Subbotina and Chutzieva). This oversight is difficult to comprehend and may be partly ascribed to the poor state of preservation (recrystallized tests) of most northern Caucasus Paleocene material. It remained for Shutskaya (1958) to provide the first adequate characterization of this taxon, to clearly illustrate the high degree of variability in this taxon (Shutskaya, 1958, 1970a), in particular, its distinctive high spire, and to transfer it to its appropriate home in the genus *Acarinina*. In fact, Morozova (1958, fig. 5), in a paper dealing with the morphologic characters important in the classification of Paleogene taxa of the Globigerinidea, observed that the microspheric generation among "globigerinids" typically possess a higher spire and more whorls of chambers than megalospheric forms, and she cited *Globigerina subsphaerica* Subbotina as a good illustration of this feature.

This taxon has been considered a junior synonym of *Acarinina mckannai* (White) by some workers (Hillebrandt, 1962; Krasheninnikov and Ponikarov, 1965; Stainforth et al., 1975; Berggren, 1977) because of their supposed similarity. The latter is distinguished by its significantly larger test, relatively low spire, and more evolute coiling pattern resulting in a wide and open umbilicus. In our material, *A. mckannai* stratigraphically appears somewhat higher/later than *A. subsphaerica* from which we suggest it is descended (cf. Stainforth et al., 1975).

We note that moderately to high-spired morphotypes with surficial morphology/ornament comparable to *A. subsphaerica* occur in upper lower to lower middle Eocene; these may represent a continuation of the late Paleocene acarininid radiation or an independent early Eocene radiation. This issue, however, is beyond the scope of this study. Similar high-spired acarinids, which we regard as synonymous with *A. subsphaerica,* have been described from middle Paleocene deposits in Azerbaizhan, Tadzhikistan, and the Crimea. These include *Globoconusa quadripartitaformis* Khalilov (1956), *Acarinina falsospiralis* Davidzon and Morozova (1964), and *Acarinina microsphaerica* Morozova (1967). *Globigerina chascanona* Loeblich and Tappan (1957a) is a small, very high-spired pustulose form, which we regard as an immature stage of *A.*

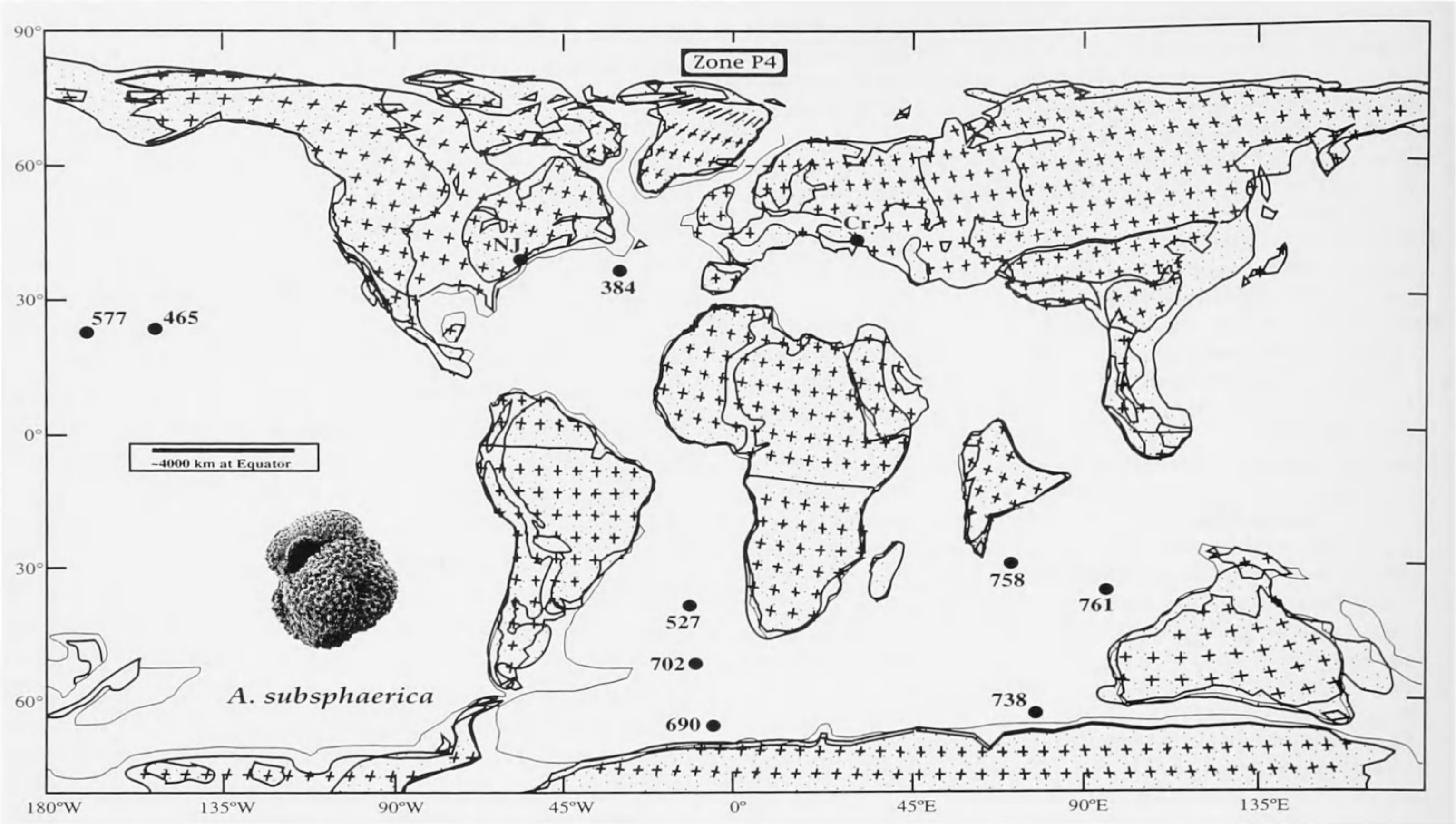

FIGURE 22.—Paleobiogeographic map showing distribution of *Acarinina subsphaerica* (Subbotina) in Zone P4a.

subsphaerica. Both Blow (1979) and Huber (1991b) noted these small forms, which they placed in *chascanona*. Larger (adult) forms of *A. subsphaerica* have been identified in middle Paleocene coastal plain deposits from Alabama and New Jersey by Loeblich and Tappan as *Globigerina spiralis* Bolli.

STABLE ISOTOPES.—No data available.

STRATIGRAPHIC RANGE.—Subzone P4a. We have not found *A. subsphaerica* associated with P3b faunas in any of our material nor have we found it to occur above the middle part of Zone P4 at low latitudes. Indeed, it is the short and distinct stratigraphic range of this taxon that renders it so useful for subdivision of Zone P4. We recognize high-spired acarininids from the upper Paleocene at the high southern latitude ODP Site 690. (This taxon was recently recorded by Lu and Keller (1995) in younger stratigraphic levels at DSDP Site 577 (Shatsky Rise), northwestern Pacific Ocean and by Huber (1991b) at ODP Site 738, southwestern Kerguelen Plateau (southern Indian Ocean) near the Paleocene/Eocene boundary.)

GLOBAL DISTRIBUTION.—This species appears global in distribution in spite of an apparent bias to a Tethyan distribution, which is probably related to numerous citations in the Russian literature (Figure 22).

ORIGIN OF SPECIES.—*Acarinina subsphaerica* evolved from *A. nitida* by an increase in spire height and the development of a coarsely muricate umbilical surface, which is a feature characteristic of all subsequent acarininids. Both *A. subsphaerica* and *A. nitida* share an anguloconic, umbilically inflated test as juveniles and, in many of the geologically older examples, a flat or gently domed spiral surface. *Acarinina subsphaerica* gave rise to *A. mckannai* by an increase in whorl expansion rate.

REPOSITORY.—Holotype in the collections of VNIGRI, St. Petersburg, Russia.

Genus *Morozovella* McGowran in Luterbacher, 1964

TYPE SPECIES.—*Pulvinulina velascoensis* Cushman, 1925.

ORIGINAL DESCRIPTION.—"Test trochoid, coiling random to strongly preferential; chambers becoming laterally compressed, then more or less conical, during ontogeny, developing an angular margin and sometimes a strongly and irregularly thickened marginal keel, umbilical shoulders may become thickened; surface more or less roughened primilarly, especially at margins; secondarily accentuated so that the test may become coarsely spinose or nodular at margins and on umbilical shoulders. Pores rather coarse and tending to funnel outwards, especially secondarily. Test umbilicate; aperture basal and umbilical, a low rimmed arch surrounded by a poreless area. Paleogene." (McGowran in Luterbacher, 1964:641.)

DIAGNOSTIC CHARACTERS.—Strongly anguloconical chambers throughout ontogeny. Surface texture strongly pustulose (muricate) on parts of spire and umbilicus. Most species with muricocarina.

DISCUSSION.—The morozovellids split into two lineages early in their evolution: (1) the *M. angulata–M. velascoensis* group characterized by the development of muricate adumbilical ridges, a strong muricocarina, and the absence of muricae on parts of the chamber surfaces; and (2) the *M. apanthesma–M. subbotinae* group whose members are initially unkeeled and entirely covered with fine, thin muricae.

Morozovella acuta (Toulmin, 1941)

PLATE 45: FIGURES 1–14

Globorotalia wilcoxensis Cushman and Ponton var. *acuta* Toulmin, 1941:608, pl. 82: figs. 6–8 [Zone P4, Salt Mountain Limestone, Wilcox Group, Alabama].—Cushman and Renz, 1942:12, pl. 3: fig. 2a–c [Zone P4, Soldado Fm., Trinidad].—Cushman, 1944a:48, 49, pl. 8: fig. 5a,b [Zone P3b, Naheola Fm., Alabama]; 1944b:15, pl. 2: fig. 16a,b [Zone P5, Bashi Fm., Wilcox Group, Alabama].—Shifflett, 1948:73, pl. 4: fig. 23a–c [Zone P4, Aquia Fm. Maryland].

Globorotalia velascoensis (Cushman) var. *parva* Rey, 1954:209, pl. 12: fig. 1a,b [Zone P4, Sample TB 450, Well No. 11, Koudiat Bou-Khelif, near Ouezzane, northern Morocco].

Globorotalia acuta Toulmin.—Loeblich and Tappan, 1957a:185, pl. 47: fig. 5a–c [Zone P4, Salt Mountain Limestone, Wilcox Group, Alabama], pl. 55: figs. 4a–5c [Zone P4, Vincentown Fm., New Jersey], pl. 58: fig. 5a–c [Zone P4, Aquia Fm., Virginia].—Aubert, 1962:54, pl. 1: fig. 3a–c [Zone P4, Koudiat Bou Khelif, Morocco].—Luterbacher, 1964:686–689, text-fig. 101a–c [Zone P4, El Quss Abu Said, Farafrah Oasis, Egypt], text-figs. 102a–104c [Zone P5, Velasco Fm., Ebano, eastern Mexico].

Globorotalia velascoensis parva Rey.—Bolli and Cita, 1960:392–393, pl. 35: fig. 5a–c [Zone P4, Paderno d'Adda, northern Italy].—Aubert, 1963:54, pl. 1: fig. 2a–c [Zone P4, N. Morocco].

Globorotalia velascoensis acuta (Toulmin).—Shutskaya, 1970a:119–120, pl. 27: fig. 11a–c [*Acarinina acarinata* Zone, Kachan Stage, Tarkhankut Peninsula, Crimea], pl. 28: fig. 4a–c, pl. 29: fig. 9a–c [*Globorotalia aequa* Zone, Bakhchisarayan Stage, Tarkhankut Peninsula, Crimea].

Globorotalia (*Morozovella*) *acuta* Toulmin.—Jenkins, 1971:106, pl. 9: figs. 205–207 [*Globigerina triloculinoides* Zone = Zone P4 this paper, Waipawan D Stage, Middle Waipara River section, New Zealand].

Globorotalia (*Morozovella*) *velascoensis parva* Rey.—Jenkins, 1971:106, 107, pl. 9: figs. 211–213 [*Globigerina triloculinoides* Zone = Zone P4 this paper, Waipawan Stage, Middle Waipara River section, New Zealand].—Blow, 1979:1030, 1031, pl. 95: figs. 3–6 [Zone P5, Sample FRCM 1670, Lindi area, Tanzania].

Morozovella acuta (Toulmin).—Toumarkine and Luterbacher, 1985:111, text-fig. 14 (7, reillustration of holotype; 8, reillustration of Loeblich and Tappan, 1957a, pl. 55: fig. 4a–c, from the Vincentown Fm., New Jersey; incorrectly ascribed to the Salt Mountain Fm., Alabama].

ORIGINAL DESCRIPTION.—"Test trochiform, plano-convex, dorsal side flat, ventral side strongly convex, deeply umbilicate, periphery strongly lobate, acute, and bounded by a thick flange; chambers distinct, about 4 1/2 in the last whorl, increasing regularly in size as added; sutures distinct, on the dorsal side slightly curved, limbate, slightly if at all depressed, on the ventral side radiate, depressed; wall roughened with minute, low spinose processes, especially along the peripheral border; aperture an arched opening on the ventral side of the final chamber extending from the peripheral flange to the umbilicus. Length 0.46 mm.; width 0.37 mm.; thickness 0.24 mm." (Toulmin, 1941:608).

DIAGNOSTIC CHARACTERS.—Conicotruncate, distinctly muricocarinate test with (typically) 5 chambers in last whorl; intercameral sutures radial, depressed on umbilical side and strongly recurved and tangential, distinctly ornamented on, and flush with, spiral side; periumbilical collar weakly to moderately well-ornamented with muricae; umbilicus (typically) wide and open but narrow in more tightly coiled individuals; aperture interiomarginal, umbilical-extraumbilical with (typically) well-developed, triangular, circumumbilical "teeth."

DISCUSSION.—Considerable controversy surrounds the characterization and recognition of this, and closely related, forms of the *velascoensis* group. The "typical" *M. acuta* is generally believed to be distinguishable from *M. velascoensis* in its average smaller size, more rapid increase in chamber growth, proportionately larger final chamber, more subdued periumbilical ornamentation, and reduced number of chambers in the final whorl (Loeblich and Tappan, 1957a; Luterbacher, 1964; Blow, 1979). Other authors (Bolli, 1957a; Hillebrandt, 1962; Proto Decima and Zorzi, 1965, among others) believe these (and other) forms are linked by continuous gradations and consider them synonymous.

At the same time, another commonly cited form is *Globorotalia velascoensis parva* (auct. non) that we believe shares a close morphologic relationship with *M. acuta*. Whether the forms illustrated by various authors as *parva* are, indeed, referable to Rey's taxon is a moot point, however. Luterbacher (1964) showed that the typical *parva* from the type sample from Morocco has four large, nearly equal-sized chambers in the final whorl, slightly raised and beaded sutures on the spiral side, and a relatively narrow umbilicus lacking the periumbilical ornament characteristic of the *velascoensis–acuta* forms. We concur with his analysis that forms identified as *parva* by Bolli and Cita (1960), Gartner and Hay (1962), and Gohrbandt (1963) differ from the type-level specimens of *parva* by possessing a heavy keel and a flat spiral side. The individuals illustrated by Aubert (1962) as *velascoensis parva* (pl. 1: fig. 2a–c) and *acuta* (pl. 1: fig. 3a–c), respectively, from Koudiat Bou Khelif, Morocco, are virtually identical, and the individual illustrated as *acuta* by Blow (1979, pl. 104: fig. 2) is virtually indistinguishable from the one he figured on pl. 95: fig. 6 as *parva*. We believe that the two morphotypes *parva* (auct) and *acuta* are virtually indistinguishable in late Paleocene assemblages.

STABLE ISOTOPES.—*Morozovella acuta* has $\delta^{18}O$ and $\delta^{13}C$ similar to other species of *Morozovella* (*M. occlusa, M. velascoensis*). *Morozovella acuta* has more positive $\delta^{13}C$ and more negative $\delta^{18}O$ than *Subbotina* spp. (Shackleton et al., 1985).

STRATIGRAPHIC RANGE.—Zone P4b to Zone P5 (top). Several authors suggest that *M. acuta* occurs somewhat higher than *M. velascoensis*. We record its lowest occurence in Zone P4b and have not found it to extend above *M. velascoensis* at

DSDP Site 213 (Indian Ocean). Shutskaya (1970a) gave the range of *M. acuta* as extending from the *A. acarinata* Zone (= Subzone P4b this paper) to the top of the *G. aequa* Zone (= top of Zone P5 this paper), which is, essentially, the same as observed herein.

GLOBAL DISTRIBUTION.—*Morozovella acuta* is an essentially subtropical to tropical form with somewhat narrower biogeographic distribution than *velascoensis* (see also Loeblich and Tappan, 1957a).

ORIGIN OF SPECIES.—This species evolved from *M. velascoensis* through a reduction in umbilical size and ornament and chamber number.

REPOSITORY.—Three paratypes (USNM CC38526) deposited in the Cushman Collection, National Museum of Natural History. Examined by WAB and RDN.

Morozovella acutispira (Bolli and Cita, 1960)

PLATE 46: FIGURES 1–15

Globorotalia californica Smith, 1957:190, pl. 28: figs. 22a–23c [homonym]. [Not *Globorotalia californica* Cushman and Todd, 1946.]

Globorotalia acutispira Bolli and Cita, 1960:15, pl. 33: fig. 3a–c [Zone P4, Paderno d'Adda, northern Italy].

Globorotalia kolchidica Morozova, 1961:17, pl. 2: fig. 2a–c [Zone Ms1 IV(?) (*Cibicides lectus* Zone = Zone P3 this paper, upper part), Khokodz' River section, Crimea].

Globorotalia sp. aff. *G. kolchidica* Morozova.—Luterbacher, 1964:668, text-figs. 61, 62 [*Globorotalia pusilla* Zone, Gubbio section, central Apennines, Italy].

Globorotalia sp. aff. *G. acutispira* Bolli and Cita.—Shutskaya, 1970b:118–120, pl. 25: fig. 7a–c [upper subzone of *Acarinina tadjikistanensis djanensis* Zone, Olen Platform, boring 210, 517–527 m, Kachan Stage, Tarkhankut Peninsula, Crimea].

Globorotalia (*Morozovella*) *occlusa acutispira* (Bolli and Cita).—Belford, 1984:9, pl. 17: figs. 14–21 [upper Paleocene, WABAG Sheet, Papua, New Guinea].

ORIGINAL DESCRIPTION.—"Test trochospirally coiled, the dimensions medium for the genus, constituted of 11–12 regularly and rapidly increasing chambers, with 4 in number in the last whorl. Chambers petaloid, bordered by a very large and projecting banded keel; spiral suture arcuate and retroversed; umbilical sutures depressed and radial; umbilical cavity very small and tight. Aperture slender, interiomarginal, extraumbilical-umbilical. Wall finely punctate. The peculiar characteristic of this species, from which is derived the specific name we intentionally selected, stems from the exceptional height of the spire corresponding to the initial whorl; this confers a biconvex profile to *Globorotalia acutispira,* characterized by a particularly sharp rise, quite angular, from the opposite side to that of the ultimate chamber. The spire thus rises to occupy an eccentric position with respect to the center of the fossil figure, which causes the noticeable increase in height of the chambers constituting the ultimate whorl." (Bolli and Cita, 1960:15; translated from Italian.)

DIAGNOSTIC CHARACTERS.—Lenticular to subcircular, plano-convex to biconvex test with apiculate early whorls and lobulate outline, 4–6 chambers in last whorl; umbilical sutures radial, slightly curved, depressed; spiral sutures curved, raised and ornamented by the extension of the strongly muricate keel; chambers tend to be flattened along the peripheral margin; aperture a low, interiomarginal, umbilical-extraumbilical arch extending from a narrow, deep umbilicus.

DISCUSSION.—This species has been little used in the literature on Paleocene morozovellids. The distinctive character of this form is the raised early part of the test containing the neanic chambers; this feature can vary considerably among individuals in a given sample. Our studies support the diagnosis of Blow (1979) of a biconvex test with a very narrow umbilicus linking it with *M. occlusa.* If *Globorotalia californica* Smith, 1957, is indeed a homonym of *Globorotalia californica* Cushman and Todd, 1946 (according to Blow, 1979), and a senior synonym of *Globorotalia acutispira* Bolli and Cita, 1960, it should be renamed, although we can agree (provisonally) with Blow that this may be unnecessary.

A closely related, if not identical, morphospecies is *M. kolchidica* (Morozova). Morozova (1961) referred to the flat or weakly convex central part of the spiral side of the test, which we have confirmed by examinaton of the holotype (3510/12 in the micropaleontological collections of GAN, Moscow). Comparison with the refigured holotype of *M. acutispira* Bolli and Cita (in Luterbacher, 1964, text-fig. 72a–c) reveals two virtually identical forms. Blow's (1979) interpretation of *M. kolchidica* as a junior synonym of *G.* (*M.*) *formosa gracilis* Bolli is considered anomalous and incorrect (although the two forms are clearly homeomorphic in the same manner as are *M. velascoensis* and *M. caucasica*). *Morozovella kolchidica* was described from (and is characteristic of) Zone P3 (as well as Zone P4); *M. gracilis* was described from (and is characteristic of) Zone P6 (as well as Zone P7). *Morozovella acutispira* is also homeomorphic with *M. marginodentata* (Subbotina), but the latter bears a consistently more massive muricocarina and lacks the apiculate early portion of the test (see also Berggren, 1977).

Illustrated on Plate 11: Figures 13–15 is a specimen from the collections of Shutskaya (no. 645) in VNIGRI (St. Petersburg), which is probably referable to *M. acutispira.* Although the slide containing this specimen is labeled as *Globorotalia angulata* var. *kubanensis* Shutskaya, the illustration of the holotype resembles *M. conicotruncata* (Subbotina); however, because the holotype in Moscow is lost, the identity of this taxon cannot be determined. Further confusing the taxonomic status of Shutskaya's taxon is the other specimen from the same slide (no. 645) illustrated on Plate 11: Figures 10–12. This specimen is probably referable to *M. apanthesma.*

STABLE ISOTOPES.—The $\delta^{13}C$ of *Morozovella acutispira* is similar to that of coexisting morozovellids but is more positive than that of *Subbotina* and *Globanomalina.* The $\delta^{18}O$ of *M. acutispira* is lighter than that of *Globanomalina* and *Subbotina* (Berggren and Norris, 1997).

STRATIGRAPHIC RANGE.—Near the Zone P3/P4 boundary to the top of Zone P4b.

GLOBAL DISTRIBUTION.—The geographic distribution of this morphospecies appears characteristic of subtropical to tropical regions as does that of *occlusa*.

ORIGIN OF SPECIES.—This morphospecies is closely related to, and probably evolved from, *M. pasionensis* by an increase in spire height, development of a biconvex test, a decrease in the number of chambers in the final whorl, and a decrease in the size of the umbilicus. *Morozovella acutispira* is closely related to *M. occlusa* as herein described.

REPOSITORY.—Holotype (No. 1278) in the micropaleontological collections of the Laboratory of Micropaleontology, Institute of Paleontology, University of Milan.

Morozovella aequa (Cushman and Renz, 1942)

PLATE 15: FIGURES 11, 12, 15; PLATE 47: FIGURES 1–16

Globorotalia crassata (Cushman) var. *aequa* Cushman and Renz, 1942:12, pl. 3: fig. 3a–c [near base *Globorotalia subbotinae* Zone, Soldado Fm., Trinidad].

Globorotalia lacerti Cushman and Renz, 1946:47, pl. 8: figs. 11, 12 [lower zone of Lizard Springs Fm., Ravine Ampelu, Lizard Springs area, southeastern Trinidad].

Globorotalia (*Truncorotalia*) *crassata* (Cushman) var. *aequa* Cushman and Renz.—Cushman and Bermúdez, 1949:37, pl. 7: figs. 7–9 [near San Ramon, about 900 m SW of Carretera San Ramon, Pinar del Rio Province, Cuba; Bermúdez Sta. 536].

Globorotalia praenartanensis Shutskaya, 1956:98, pl. 3: fig. 5a–c [*Acarinina acarinata* Zone, Nal'chik Horizon, lower part of Abazin Formation, Kuban River Basin, central pre-Caucasus].—Luterbacher, 1964:671, text-fig. 73a–c [topotypes from *Acarainina acarinata* Zone, Kuban River section, northern Caucasus].

Globorotalia aequa Cushman and Renz.—Bolli, 1957a:74, pl. 17: figs. 1–3, pl. 18: figs. 13–15 [*Globorotalia velascoensis* Zone = Zone P5 this paper; upper Lizard Springs Fm., Trinidad].—Loeblich and Tappan, 1957a:186, pl. 59: fig. 6a–c [Zone P4, Aquia Fm., Virginia], pl. 64: fig. 4a–c [Zone P4, Velasco Fm., Tamaulipas, Mexico] [in part, not pl. 46: figs. 7a–8c (? = *M. angulata*), pl. 50: fig. 6a–c, pl. 55: fig. 8a–c].—Bolli and Cita, 1960:377, 378, pl. 33: fig. 5a–c [Zone P4, Paderno d'Adda section, northern Italy].—Luterbacher, 1975b:64, pl. 2: figs. 22–24 [*Globorotalia subbotinae* Zone], pl. 2: figs. 28–30 [*Globorotalia pseudomenardii* Zone, Possagno section, Treviso Province, northern Italy].

Globorotalia angulata (White).—Loeblich and Tappan, 1957a:187, pl. 48: fig. 2a–c [Zone P4, Salt Mountain Limestone, Alabama], pl. 58: fig. 2a–c [Aquia Formation, Virginia] [in part, not pl. 45: fig. 7a–c, pl. 50: fig. 4a–c, pl. 55: figs. 2a–c, 6a–7c, pl. 64: fig. 5a–c]. [Not White, 1928.]

Globorotalia (*Truncorotalia*) *aequa aequa* (Cushman and Renz).—Hillebrandt, 1962:133, 134, pl. 13: fig. 1a–c [Zone F = Zone P5 this paper, Bad Reichenhall-Salzburg Basin, Austro-German border].

Globorotalia (*Morozovella*) *aequa bullata* Jenkins, 1965:1110, fig. 10, no. 87–91 [*Globigerina triloculinoides* Zone, lower Waipawan Stage, Middle Waipara River section, New Zealand]; 1971:100, pl. 7: figs. 172–176 [reillustration of holotype and paratype specimens].

Globorotalia loeblichi El-Naggar, 1966:218–220, pl. 23: fig. 1a–c [*Globigerina wilcoxensis* Zone = Zone P6 this paper, sample S 68, Thebes Calcareous Shale, Thebes Fm., Gebel Owaina section].

Truncorotaloides (*Morozovella*) *aequus* (Cushman and Renz).—McGowran, 1968:190, pl. 1: figs. 3–7 [*Planorotalites simplex* Zonule, Boongerooda Greensand, Cape Range, Australia], figs. 8–12 [*Truncorotaloides* (*A.*) *mckannai* Zonule, Boongerooda Greensand, Cape Range, Australia].

Globorotalia (*Morozovella*) *aequa aequa* Cushman and Renz.—Jenkins, 1971:100, pl. 7: figs. 167–169 [*Globigerina triloculinoides* Zone, Middle Waipara River section, New Zealand], figs. 170, 171 [*Globigerina triloculinoides* Zone, lower part of type Waipawan Stage, Te Uri Stream section, New Zealand].—Blow, 1979:975–977, pl. 96: figs. 4–9, pl. 218: figs. 1–6 [Zone P5 of Blow, 1979; Sample FCRM 1670, Lindi area, Tanzania], pl. 99: fig. 5 [Zone P5 of Blow, 1979; DSDP Hole 47.2/9/1: 64–66 cm; Shatsky Rise, northwestern Pacific Ocean], pl. 102: figs. 6, 9, 10, pl. 103: fig. 1, pl. 211: figs. 3–5 [Zone P6 of Blow, 1979; DSDP Hole 20C/6/3: 76–78 cm; Brazil Basin, South Atlantic Ocean], pl. 118: figs. 8–10, pl. 211: figs. 1, 2 [Zone P7 of Blow, 1979; DSDP Hole 47.2/8/3: 83–85 cm; Shatsky Rise, northwestern Pacific Ocean].

Morozovella aequa (Cushman and Renz).—Berggren, 1971b:76, pl. 5: fig. 6 [*Morozovella velascoensis* Zone = Zone P5 this paper, DSDP Hole 20C/6/4: 5–7 cm; Brazil Basin, South Atlantic Ocean].—Snyder and Waters, 1985:446, pl. 7: figs. 5–7 [Zone P4/5, DSDP Site 549/16/5: 57–60 cm; Pendragon Escarpment, Goban Spur, northeastern Atlantic Ocean].—[not Lu and Keller, 1995:102, pl. 1: fig. 15 (Zone P3, DSDP Site 577/11/3: 19–21 cm; Shatsky Rise, northwestern Pacific Ocean)].—[not Stott and Kennett, 1990:560, pl. 6: figs. 13–15 (Zone AP 6, ODP Hole 690B/16H/7: 36–40 cm; Maud Rise, Weddell Sea, Southern Ocean (? = *Acarinina wilcoxensis*))].

Acarinina aequa (Cushman and Renz).—Tjalsma, 1977:508, pl. 3: fig. 13 [*Morozovella velascoensis* Zone, DSDP Site 329/32/4: 107–109 cm; Maurice Ewing Bank, South Atlantic Ocean].

Globorotalia (*Morozovella*) *aequa lacerti* (Cushman and Renz).—Blow, 1979:977–979, pl. 138: figs. 1–3 [Zone P8b of Blow, 1979 = Zone P7 this paper; DSDP Hole 20C/5/5: 72–74 cm; Brazil Basin, South Atlantic Ocean], pl. 115: fig. 6 [Zone P7 of Blow, 1979 = Zone P6b this paper; Sample RS 80, Kilwa area, Tanzania, as ex interc *G.* (*M.*) *aequa lacerti*–*G.* (*M.*) *subbotinae*].

Globorotalia (*Morozovella*) *aequa tholiformis* Blow, 1979:979–981, pl. 102: figs. 7, 8 [Zone P6 of Blow, 1979; DSDP Hole 20C/6/3: 76–78 cm; Brazil Basin, South Atlantic Ocean], pl. 119: figs. 1, 2 [holotype], fig. 3 [Zone P7 of Blow, 1979; DSDP Hole 47.2/8/3: 82–85 cm], pl. 125: figs. 1, 2, pl. 127: figs. 8, 9, pl. 129: fig. 6 [Zone P8a of Blow, 1979; DSDP Hole 47.2/8/2: 71–73 cm], pl. 133: fig. 9 [Zone P8b of Blow, 1979; DSDP Hole 47.2/8/1: 77–79 cm; Shatsky Rise, northwestern Pacific Ocean].

ORIGINAL DESCRIPTION.—"Variety differing from the typical in the much smoother surface, and the chambers especially in the later ones, broader and more arcuate.

"Holotype of variety (Cushman Coll. No. 38210) from the Midway Eocene, Soldado Formation, Soldado Rock, Trinidad, B.W.I. Coll. Dr. H.G. Kugler (sample K. 2950)." (Cushman and Renz, 1942:12.)

DIAGNOSTIC CHARACTERS.—Subquadrate, plano-convex, muricocarinate test with moderately lobulate peripheral outline and 4 (less commonly 5) chambers in last whorl; intercameral sutures on umbilical side straight, radial; raised, curved on spiral side; umbilicus narrow, bordered by low apertural slit extending nearly to periphery; test surface generally covered with muricae, particularly on umbilical shoulder and along peripheral margin.

DISCUSSION.—This taxon has a complicated and intricate taxonomic history due, in no small part, to the (minor) morphologic variability (and resulting complex nomenclature) ascribed to this species (see discussion by Blow, 1979:975–982). Cushman and Renz (1942) described a subquadrate, planoconvex, carinate morozovellid from the terminal Paleocene of Trinidad, which has come to serve as the central type of a plexus of late Paleocene to early Eocene forms generally linked by the features listed in the diagnosis above; however, we see little justification, or utility, in using these minor morphologic differences in distinguishing the forms listed in the synonymic list above.

STABLE ISOTOPES.—*Morozovella aequa* has more positive $\delta^{13}C$ and more negative $\delta^{18}O$ than *Subbotina* and *Globanomalina* and a similar isotopic signature to coexisting morozovellids, such as *M. velascoensis* (Lu and Keller, 1996; Berggren and Norris, 1997).

STRATIGRAPHIC RANGE.—Zone P4c to Zone P7.

GLOBAL DISTRIBUTION.—*Morozovella aequa* is a geographically widespread species, having been recorded from areas circumscribed by latitudes 50°N (Goban Spur, northeastern Atlantic Ocean; Snyder and Waters, 1985) and 50°S (Falkland Plateau; Tjalsma, 1977); it occurs as far south as nearly 60° (Kerguelen Plateau; Berggren, 1992) during the brief early Eocene (Zone P6) temporal excursion of (sub)tropical morozovellids.

ORIGIN OF SPECIES.—*Morozovella aequa* evolved from *M. apanthesma* through concomitant reduction in the number of chambers and the development of both more involute coiling (resulting in a more closed umbilicus) and a peripheral muricocarina. We have observed this transition both in our material and particularly at DSDP Site 384, where it occurs at the base of Zone P4c together with the appearance of various acarininid taxa of the *soldadoensis* and *primitiva/coalingensis* plexus in the younger part of Chron C25r. We have not found this form in lower parts of the stratigraphic record (cf. Blow, 1979; Lu and Keller, 1995).

REPOSITORY.—Holotype (USNM CC38210) deposited in the Cushman Collection, National Museum of Natural History. Examined by WAB and RDN.

Morozovella angulata (White, 1928)

FIGURE 23; PLATE 48: FIGURES 1–16

Globigerina angulata White, 1928:191, pl. 27: fig. 13 [Zone P4, Velasco Fm., Mexico].

Globorotalia angulata (White).—Glaessner, 1937b:383, pl. 4: figs. 35a–c; ? 36a–c (? = *M. aequa*), fig. 37a–c (*M. conicotruncata*) [upper Paleocene, Anapa section, Goryachi Kliutch Fm. and Il'sk, northwestern Caucasus; lower part of Sumgait Group, southeastern Caucasus, lower Foraminiferal Beds of Dagestan].—Bykova, 1953:82–86, text-figs. 7a–11c ["Montian Stage," western Turkmenia].—Shutskaya, 1956:92, 93, text-fig. 1, pl. 3: fig. 2a–c [Elburgan Fm., Khieu River section, central Caucasus].—Bolli, 1957a:74, pl. 17: figs. 7–9 [*Globorotalia pusilla* Zone, lower Lizard Springs Fm., Trinidad].—Loeblich and Tappan, 1957a:187, pl. 50: fig. 4a–c [Zone P3b, Hornerstown Fm., New Jersey, cf. Blow, 1979:985], pl. 64: fig. 5a–c [Zone P4, Velasco Fm., Mexico, cf. Blow, 1979:986] [in part, not pl. 45: fig. 7a–c, pl. 48: fig. 2a–c (= *M. aequa* (Cushman and Renz)), pl. 55: figs. 2a–c, 6a–7c (probably transitional to *M. apanthesma* (Loeblich and Tappan)), pl. 58: fig. 2a–c (= *M. aequa* (Cushman and Renz))].—Bolli and Cita, 1960:376, 377, pl. 35: fig. 8a–c [*Globorotalia pusilla* Zone, Paderno d'Adda section, northern Italy].—Olsson, 1960:44, pl. 8: figs. 14–16 [Zone P3b, Hornerstown Fm., New Jersey].—Toumarkine and Luterbacher, 1985:111, text-fig. 14: 5a–c [holotype reillustrated], text-fig. 14: 6a–c [reillustration of Bolli, 1957a, pl. 17: figs. 10–12 "transitional form between *Globorotalia uncinata* Bolli, new species and *Globorotalia angulata* (White)"].

Globorotalia (Truncorotalia) angulata (White).—Hillebrandt, 1962:131, 132, pl. 13: figs. 14a–15c [Zone D = *G. pusilla* Zone, Richenhall-Salzburg Basin, Austro-German border].

Truncorotaloides (Morozovella) angulatus (White).—McGowran, 1968:190, pl. 1: figs. 13–18 [middle Paleocene, Boongerooda Greensand, Australia].

Globorotalia (Morozovella) angulata (White).—Blow, 1979:984, pl. 86: figs. 7–9 [figs. 7, 8, given as *G. (M.)* cf. *angulata*], pl. 87: fig. 1 [Zone P3, DSDP Hole 47.2/10/1: 72–74 cm; Shatsky Rise, northwestern Pacific Ocean].

Morozovella protocarina Corfield, 1989:98, pl. 1: figs. 1–12 [Zone P3, DSDP Site 577/11/6: 30–31 cm; Shatsky Rise, northwestern Pacific Ocean].

ORIGINAL DESCRIPTION.—"Test rotaliform, dorsal side flat, ventral side convex, umbilicate, periphery sharply angled; chambers few, usually four or five in the last whorl, inflated, rapidly increasing in size; sutures distinct, curved, deep, not limbate; wall granular or subspinose, very finely perforate; aperture an elongate opening extending from the umbilicus almost to the peripheral margin and sometimes provided with a narrow lip. Diameter of type specimen, 0.35 mm.; height, 0.25 mm." (White, 1928:191.)

DIAGNOSTIC CHARACTERS.—Muricate, nonspinose angulo-conical test, spiral side flat, early chambers slightly elevated, 10–12 chambers arranged in 2½ whorls, 4–6 chambers in final whorl, periphery lobulate, (sub)acute, imperforate band (muricocarina) developed along peripheral margin; weak circumumbilical collar formed around narrow, deep umbilicus by elevated chambers, particularly last chamber; sutures depressed, straight, radial on umbilical side, strongly recurved on spiral side; aperture, low, interiomarginal, umbilical-extraumbilical low arch with weakly developed lip.

DISCUSSION.—Blow (1979:984) drew a distinction between peripherally muricocarinate (*angulata*) and (putatively ancestral) non-carinate (*praeangulata*) morphotypes of the early *angulata* lineage. Following Blow (1979) in this distinction, we maintain both morphotaxa in the genus *Morozovella* (contra Pearson, 1993).

Considerable confusion and misidentification has surrounded this taxon, not the least because of the long (about 50 year) sequestration of the White collection at Columbia University, which ended with its rediscovery by T. Saito and its subsequent transfer to the American Museum of Natural History in the early 1980s. We have followed Blow (1979) in adopting the concept of *angulata* sensu Bolli (1957a) in identifying this form. We regard *Morozovella protocarina* Corfield (1989) as falling within this concept of *M. angulata*. Our studies, however, support the range of *M. angulata* given by Bolli (1957a) (Zone P3 to middle part of Zone P4) rather than that of Blow (1979) (Zone P3 to basal Zone P5).

STABLE ISOTOPES.—*Morozovella angulata* has more negative $\delta^{18}O$ and more positive $\delta^{13}C$ than *Parasubbotina* and *Subbotina* (Douglas and Savin, 1978; Boersma and Premoli Silva, 1983; Shackleton et al., 1985). The species displays a distinct trend toward increased $\delta^{13}C$ with increased test size and little or no trend in $\delta^{18}O$ with size (Shackleton et al., 1985).

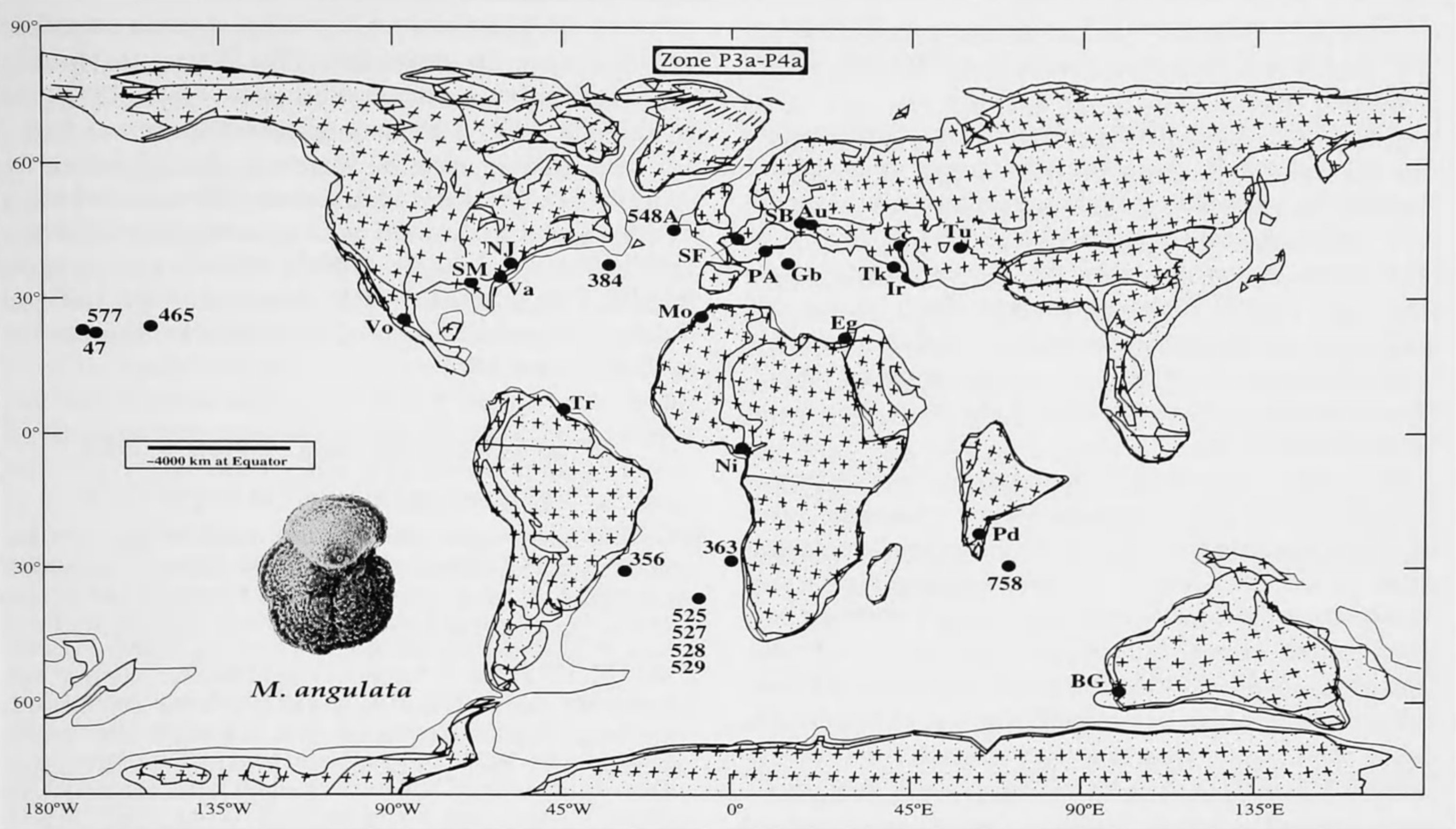

FIGURE 23.—Paleobiogeographic map showing distribution of *Morozovella angulata* (White) in Zones P3 and P4.

STRATIGRAPHIC RANGE.—Zone P3 to lower Zone P4.

GLOBAL DISTRIBUTION.—This form is essentially restricted to (sub)tropical to temperate regions (circumscribed by 50°N and S latitudes); it has not been reliably reported from high northern or southern (subantarctic) regions (Figure 23).

ORIGIN OF SPECIES.—This species evolved from *Morozovella praeangulata* (Blow) at or near the Zone P2/3 transition by elaboration of the muricae, development of a peripheral muricocarina, and establishment of anguloconical chambers throughout the last whorl.

REPOSITORY.—Columbia University Paleontology Collection (No. 19876), collection now at the American Museum of Natural History, New York.

Morozovella apanthesma (Loeblich and Tappan, 1957)

PLATE 17: FIGURES 1–3; PLATE 49: FIGURES 1–15

Globorotalia apanthesma Loeblich and Tappan 1957a:187, pl. 48: fig. 1a–c [Zone P4, Salt Mountain Limestone, Clarke Co., Alabama], pl. 55: fig. 1a–c [Zone P4, Vincentown Fm., New Jersey], pl. 58: fig. 4a–c (paratype), pl. 59: fig. 1a–c (holotype) [Zone P4, Aquia Fm., Virginia].

Globorotalia (*Morozovella*) *apanthesma* Loeblich and Tappan.—Jenkins, 1971:102, pl. 8: figs. 186–188 [*Globigerina triloculinoides* Zone, Waipawan Stage, Middle Waipara River section, New Zealand].—Belford, 1984:9, pl. 16: figs. 1–8 [Zone P4, Papua, New Guinea].

? *Globorotalia* (*Morozovella*) *apanthesma* Loeblich and Tappan.—Blow, 1979:988, pl. 251: fig. 2 [Zone P7 of Blow, 1979 = Zone P6 this paper; Sample HK 1831, type level of *G. rex* Zone, "Carmen Jones Ravine," tributary of Cascas River, southern Trinidad].

Acarinina apanthesma (Loeblich and Tappan).—Huber, 1991b:446, pl. 4: figs. 1, 2 [Zone AP4, ODP Hole 738C/16R: 332.15 mbsf; Kerguelen Plateau, southern Indian Ocean].

Not *Morozovella apenthesma* [sic] Lu and Keller, 1995:102, pl. 1: figs. 18, 19 [Zone P3b/P4x of Lu and Keller; DSDP Site 577/11/2: 52–54 cm; Shatsky Rise, northwestern Pacific Ocean].

ORIGINAL DESCRIPTION.—"Test free, trochospiral, planoconvex, umbilicoconvex, with rather wide, deep and open umbilicus, periphery subacute, peripheral outline lobulate; chambers hemispherical, flattened to gently convex and appearing lunate in side view from the spiral side, strongly inflated to subangular on the umbilical side, 4 to 5 in the final whorl, commonly somewhat obliquely overlapping earlier chambers, the forward margin of each chamber protruding slightly above the general level of the spiral side, the posterior margin of the succeeding chamber beginning at a slightly lower level; sutures distinct, strongly curved and slightly depressed on the spiral side, radial and strongly depressed on the umbilical side, wall calcareous, rather coarsely perforate, surface spinose, most strongly on the umbilical side; aperture interiomarginal, extraumbilical-umbilical, a broad arched opening, with a narrow bordering lip present in well-preserved specimens.

"Hypotypes range from 0.23 to 0.45 mm. in diameter and from 0.15 to 0.33 mm. in thickness." (Loeblich and Tappan, 1957a:187–188.)

DIAGNOSTIC CHARACTERS.—Planoconvex, umbilicoconvex, test with lobulate, weakly muricocarinate periphery; 4–5 chambers in last whorl, inflated to subangular on umbilical side, moderately convex, triangular (lunate) in edge view; intercameral sutures on umbilical side depressed, radially curved and slightly depressed on spiral side; umbilical side distinctly muricate, coarsely perforate on spiral side; umbilicus relatively narrow, deep; aperture an interiomarginal, umbilical–extraumbilical arch with narrow, continuous intraperiumbilical lip.

DISCUSSION.—Blow (1979) drew attention to an important distinction within this plexus: *apanthesma* exhibits the essentially quadrate chamber pattern of the related (and descendant) *aequa* in the early whorls, whereas *angulata* (and related forms) retains the more "vorticiform," strongly recurved, early whorl pattern. In view of these, and other pertinent observations based on personal observations of type material (Blow, 1979), it is strange that he presented, almost as an afterthought, only a single, spiral view of a form assigned to *apanthesma* from (his) Zone P7 (= Zone P6 this paper) whose affinities are somewhat hard to evaluate. Earlier this species was considered a junior synonym of *M. conicotruncata* (Subbotina) by Luterbacher (1964) and of *M. angulata* (White) by Berggren (1977).

Illustrated on Plate 11: Figures 10–12 is a specimen from the collections of Shutskaya (no. 645) in VNIGRI (St. Petersburg) that is probably referable to *M. apanthesma.* Although the slide containing this specimen is labeled as *Globorotalia angulata* var. *kubanensis* Shutskaya, the illustration of the holotype resembles *M. conicotruncata* (Subbotina). Because the holotype in Moscow is lost, the identity of this taxon cannot be determined. Further confusing the taxonomic status of Shutskaya's taxon is the other specimen from the same slide (no. 645) illustrated on Plate 11: Figures 13-15. This specimen is probably referable to *M. acutispira.*

STABLE ISOTOPES.—Limited isotopic data suggest *M. apanthesma* is similar in $\delta^{18}O$ and $\delta^{13}C$ to other morozovellids and has a more positive $\delta^{13}C$ and more negative $\delta^{18}O$ than coexisiting *Globanomalina* and *Subbotina* (Lu and Keller, 1996; Berggren and Norris, 1997).

STRATIGRAPHIC RANGE.—Zone P3b to Zone P4c.

GLOBAL DISTRIBUTION.—Northern middle latitudes to the Southern Ocean.

ORIGIN OF SPECIES.—*Morozovella apanthesma* and its descendants, *M. aequa* and *M. subbotinae,* differ from the *M. angulata–M. velascoensis* group in possessing a relatively even distribution of fine muricae (pustules) over the surface of the test in contrast to the development of muricae-free surfaces between the murcorcarina and adumbilical ridges in the *M. velascoensis* plexus. *Morozovella apanthesma* shares characteristics intermediate between *M. praeangulata* (its antecedent) and *M. aequa* (its descendant). The former is generally somewhat smaller (contra Loeblich and Tappan, 1957a; see also Jenkins, 1971), with more subdued muricate wall texture and more strongly recurved chambers when seen from the spiral surface. Compared to its ancestor, *M. aequa* exhibits a reduced number of chambers and a more anguloconical test.

REPOSITORY.—Holotype (USNM P5860) and paratypes (USNM P5868, P5861, P5862) deposited in the Cushman Collection, National Museum of Natural History. Examined by WAB, RDN, and RKO.

Morozovella conicotruncata (Subbotina, 1947)

PLATE 11: FIGURES 10–15; PLATE 50: FIGURES 1–15

Globorotalia conicotruncata Subbotina, 1947:115, pl. 4: figs. 11–13 [holotype, zone of "Danian Foraminifera," Assu River section, northern Caucasus], pl. 9: figs. 9–11 [zone of "Danian Foraminifera," Khieu River section, Nal'chik, northern Caucasus].—Luterbacher, 1964:660, text-fig. 40 [zone of rotalid globorotaliids, Khieu River section, northern Caucasus], text-figs. 41, 42 [as *G. angulata abundocamerata*: topotypes from *Globorotalia pusilla pusilla* Zone, lower Lizard Springs Fm., Trinidad], text-figs. 46–49 [*Globorotalia pseudomenardii* Zone], text-fig. 51 [*Globorotalia pusilla pusilla* Zone, Gubbio section, central Apennines, Italy]; 1975a:726, pl. 1: figs. 6, 7 [*Globorotalia pusilla pusilla* Zone, DSDP Site 305/14/CC; Shatsky Rise, northwestern Pacific Ocean].—Pujol, 1983:645, pl. 2: fig. 8 [Zone P3 (mid-part), DSDP Hole 516F/87/4: 43–44 cm; Rio Grande Rise, South Atlantic Ocean].

Acarinina conicotruncata (Subbotina).—Subbotina, 1953:220, pl. 20: fig. 5a,b [zone of rotalid globorotaliids, Foraminiferal Beds, Suite F1 (lower part), Khieu River, Nal'chik, northern Caucasus], pl. 20: fig. 6a–c [holotype reillustrated], pl. 20: fig. 7a–c [specimen reillustrated from Subbotina, 1947, pl. 9: figs. 9–11, same sample as holotype], pl. 20: fig. 8a–c [same sample as fig. 7a–c] [in part, not pl. 20: figs. 10a–12c].

Globorotalia angulata (White) var. *kubanensis* Shutskaya, 1956:93, pl. 3: fig. 4a–c [holotype No. 3525/19, GAN, Bed 6, Marl, Elburgan Fm., Kuban River Section, northern Caucasus].

Globorotalia angulata abundocamerata Bolli, 1957a:74, pl. 17: figs. 4–6 [*Globorotalia pusilla pusilla* Zone, lower Lizard Springs Fm., Trinidad].—Bolli and Cita, 1960:379, pl. 35: figs. 6a–c [*Globorotalia pusilla pusilla* Zone, Paderno d'Adda section, northern Italy].

Globorotalia (*Truncorotalia*) *angulata* Hillebrandt, 1962:131, pl. 13: figs. 14a–15c [Zone D = correlative with upper part of *Globorotalia pusilla pusilla* Zone, Reichenhall-Salzburg Basin, Austro-German border]. [Not White, 1928.]

Globorotalia kubanensis (Shutskaya).—Shutskaya, 1970b:118–120, pl. 21: fig. 1a–c [*Acarinina praepentacamerata* Zone, Malyi Balkhan Ridge, Chaal'dzhin Group, western Turkmenia].

Morozovella conicotruncata (White).—Berggren, 1971b:74, pl. 4: figs. 8, 9 [Zone P4, DSDP Hole 20C/6/5: 8–10 cm], figs. 10–14 [Zone P4, DSDP Hole 20C/6/4: 100–102 cm; Brazil Basin, South Atlantic Ocean].—Snyder and Waters, 1985:446, pl. 8: figs. 4, 5 [Zone P4/5, DSDP Site 549/16/4: 57–60 cm], fig. 6 [DSDP Site 549/16/5: 57–60 cm; northeast Atlantic Ocean].

Globorotalia (*Morozovella*) *angulata conicotruncata* (White).—Blow, 1979:986, pl. 87: fig. 3 [Zone P3, DSDP Hole 47.2/10/1: 72–74 cm; Shatsky Rise, northwestern Pacific Ocean].

ORIGINAL DESCRIPTION.—"Test a truncated cone. There are two whorls. Dorsal side flat except in the slightly raised central portion occupied by the first whorl; ventral side strongly convex, sloping toward the dorsal side at an angle of about 50° to 60°. Umbilicus open, deep, not very broad for *Globorotalia*. Periphery broadly lobate, acute, not keeled. The final whorl usually consists of five chambers which are alate on the dorsal side and triangular on the ventral side. Each chamber of the first whorl is approximately one-half the size of the corresponding chamber of the second whorl. The chambers increase very slowly in size within each whorl, so that each pair of adjacent chambers seems to be equal. One of the characteristic features is the uniform thickness (the dorsoventral elongation), due to which their umbilical ends are almost in the same plane. The chambers adhere closely to one another. Septal sutures on the dorsal side simple, arcuately curved, depressed; on the ventral side, they diverge radially from the umbilicus to the periphery, in the form of straight, strongly depressed furrows. Spiral sutures weakly lobate, nearly smooth, depressed, most often indistinct. Aperture slitlike, very weakly curved to nearly straight, extending from the umbilicus to approximately half-way between the umbilicus and the periphery on the ventral side. Wall densely covered with short and relatively thick spines, usually larger on the ventral side than on the dorsal side. Final chamber usually smoother. Spines most distinct at the periphery." (Subbotina, 1947:115; translated from Russian.)

DIAGNOSTIC CHARACTERS.—Subcircular, moderately lobulate, low trochospiral test with 5–7 subangular, inflated, essentially equidimensional chambers in last whorl, spiral side flat to slightly convex in early whorls; umbilical sutures straight to weakly curved, radial, incised; spiral sutures distinctly curved, incised; axial periphery (sub)acute, peripheral muricocarina variable, generally fused on early chambers of last whorl whereas later chambers generally subrounded (although muricocarinae fuse consistently along peripheral margin on individuals of this form as it transforms into *M. velascoensis* in Zone P3b); umbilicus narrow, deep; aperture a low interiomarginal, umbilical-extraumbilical slit.

DISCUSSION.—This is a distinct middle Paleocene planoconvex morozovellid species characterized by 5–7 equidimensional chambers in the last whorl. Our studies support Blow's (1979) observation that this form appears virtually simultaneously with typical *angulata*-types (cf. Bolli, 1957a); however, we do not agree with the extended range given this taxon by Blow (1979) of mid-Zone P3 through Zone P4, extending possibly into Zone P5. Our studies support, rather, the range given by Bolli (1957a) of its extension into the lower part of the *Globorotalia pseudomenardii* Zone.

STABLE ISOTOPES.—*Morozovella conicotruncata* has $\delta^{13}C$ similar to *M. angulata* and more positive than *Subbotina* and *Globanomalina* (Boersma and Premoli Silva, 1983; Berggren and Norris, 1997). The $\delta^{18}O$ of *M. conicotruncata* is slightly lighter than *M. angulata* in samples from DSDP Site 384 (Berggren and Norris, 1997) and is distinctly lighter than coexisting *Globanomalina* and *Subbotina* (Boersma and Premoli Silva, 1983; Berggren and Norris, 1997).

STRATIGRAPHIC RANGE.—Zone P3 to lower Zone P4.

GLOBAL DISTRIBUTION.—As with its closely related sister taxon *angulata*, this form has a predominantly tropical to temperate distribution (< 45° N and S) and has not been reliably reported from high northern or southern (subantarctic) latitudes. It is a common and distinct form in our material and is observed to grade into *M. velascoensis* in Subzone P3b.

ORIGIN OF SPECIES.—This morphospecies evolved from *Morozovella angulata* (White) in the lower part of Zone P3 by the development of a distinctly planoconvex test, a more open umbilicus than *M. angulata*, and a characteristic low rate of chamber enlargement, which results in equidimensional chambers throughout the final whorl.

REPOSITORY.—Holotype (No. 3085) and paratypes (Nos. 2178, 4085, 4086, 4087, 4099) deposited in the micropaleontological collections at VNIGRI, St. Petersburg, Russia. Examined by WAB.

Morozovella gracilis (Bolli, 1957)

PLATE 54: FIGURES 13–15

Globorotalia formosa gracilis Bolli, 1957a:75, pl. 18: figs. 4–6 [*Globorotalia rex* Zone, Trinidad Leasholds, Ltd., well Guayaguayare 159, core 3,707-13′, upper Lizard Springs Fm., Trinidad].—Luterbacher, 1964:692, text-fig. 115a–c [topotypes, *Globorotalia rex* Zone, Trinidad], text-fig. 117a–c [*Globorotalia formosa formosa*/*Globorotalia subbotinae* Zone, sample level G-58, Gubbio section, central Apennines, Italy], text-fig. 105a–c [*Globorotalia velascoensis* Zone, Ebano, eastern Mexico, as *G.* sp. aff. *formosa gracilis*], text-figs. 106a–107c [*Globorotalia velascoensis* Zone, sample level G-74, Gubbio section, central Apennines, Italy].—Shutskaya, 1970b:118–120, pl. 14: fig. 8a–c [*Globorotalia subbotinae* Zone, Churuk-Su, Kacha River section, Bakhchissaray region, Bakhchissarayan Stage, southwestern Crimea].—Luterbacher, 1975a:727, pl. 2: fig. 7a–c [DSDP Site 313/13/4: 71–73 cm; Mid-Pacific Mountains, North Pacific Ocean]; 1975b:65, pl. 4: figs. 10–12 [*Globorotalia subbotinae* Zone, Possagno section, Trevisiano Province, Italy].

Globorotalia bollii El-Naggar, 1966:202–203, pl. 22: fig. 6a–d [*Globigerina wilcoxensis* Zone, Thebes Calcareous Shale, Gebel Aweina, Egypt] [in part, not pl. 22: fig. 5a–d (holotype = *M. subbotinae* (Morozova))].

Globorotalia (*Morozovella*) *gracilis* Bolli.—Jenkins, 1971:105, pl. 9: figs. 202–204 [*Globigerina wilcoxensis* Zone, Middle Waipara River section, Waipawan Stage, New Zealand].

Morozovella gracilis (Bolli).—Berggren, 1971b:76, pl. 5: figs. 7, 8 [*Morozovella subbotinae* Zone, DSDP Hole 20C/5/6: 100–102 cm; South Atlantic Ocean].—Huber, 1991b:440, pl. 4: fig. 8 [Zone AP6A, ODP Hole 738C/10R, 277.78 mbsf; Kerguelen Plateau, southern Indian Ocean].—Lu and Keller, 1995:102, pl. 1: fig. 9 [Zone P6bx of Lu and Keller = Zone P6a this paper; DSDP Site 577/9/6: 53–55 cm; Shatsky Rise, northwestern Pacific Ocean].

Globorotalia (*Morozovella*) *subbotinae gracilis* Bolli.—Blow, 1979:1021–1024, pl. 111: figs. 9, 10, pl. 112: fig. 1 [Zone P7 of Blow, 1979; sample KRE 83F, Moogli Mudstone, Kagua Inlier, Kagua, Papua, New Guinea], pl. 115: figs. 7–10, pl. 223: figs. 3, 4 [Zone P7 of Blow, 1979; sample RS 80, Kilwa area, Tanzania], pl. 120: figs. 1–9, pl. 121: figs. 1–8 [Zone P7 of Blow, 1979; DSDP Hole 47.2/8/3: 83–85 cm; Shatsky Rise, northwestern Pacific Ocean], ? pl. 249: figs. 8, 9 [*Globorotalia pseudomenardii* Zone, sample/specimens collected by L.W. LeRoy as topotypic *Discorbina simulatilis* Schwager, 1883, and presented to R. Wright Barker; Maqfi section, Farafrah Oasis, Egypt].

Morozovella formosa gracilis (Bolli).—Snyder and Waters, 1985:446–447, pl. 8: figs. 7–9 [Zone P7, DSDP Site 549/12/4: 47–50 cm; Pendragon Escarpment, Goban Spur, northeastern Atlantic Ocean].—Toumarkine and Luterbacher, 1985:12, text-fig. 15: 12a–c [reillustration of holotype of Bolli, 1957a].

ORIGINAL DESCRIPTION.—"Shape of test very low trochospiral, spiral side almost flat or slightly convex, umbilical side distinctly convex; equatorial periphery lobate; axial periphery angular with a faint keel ornamented with spines. Wall calcareous, perforate, surface distinctly spinose. Chambers angular, inflated; about 12, arranged in 2½–3 whorls, the 5 or 6 chambers of the last whorl increasing rapidly in size. Sutures on the dorsal side slightly curved to oblique, slightly depressed; on umbilical side radial, distinctly depressed. Umbilicus fairly narrow, deep, open. Aperture a low arch; interiomarginal, extraumbilical-umbilical. Coiling between 90 and 100 percent dextral. Largest diameter of holotype 0.50 mm." (Bolli, 1957a:75.)

DIAGNOSTIC CHARACTERS.—Planoconvex to moderately biconvex test, with lobulate peripheral margin ornamented with well-developed muricocarina; 5–6 essentially equidimensional chambers in last whorl; umbilical intercameral sutures radial, straight, depressed; on spiral side, sutures strongly curved, distinctly muricate except for penultimate/ultimate chamber suture, which is straight giving cuneiform shape to final chamber (not unlike the shape in *Acarinina triplex*); umbilical surface covered with muricae, spiral side weakly muricate except for concentration of muricae along intercameral sutures and peripheral margin of ultimate whorl; small sutural openings along margin/junction of ultimate/penultimate whorl resulting from chamber addition along topographically separated/elevated muricate edges; umbilicus narrow, deep; aperture a low interiomarginal, umbilical-extraumbilical arch extending towards, but not to, the peripheral margin.

DISCUSSION.—*Morozovella gracilis* occupies a morphologic/phylogenetic position intermediate between *M. subbotinae* and *M. formosa* (see also Pearson, 1993). It differs from the former in the increased number of chambers (5–6) in the final whorl, which is associated with a looser (more evolute) coiling mode, and in the elevated spiral intercameral sutures. *Morozovella formosa* is characterized by a further increase in size and number of chambers (6–8) in the last whorl and concomitant increase in the width of the umbilicus. Like most other morozovellids, particularly those morphotypes closely associated with the *aequa-subbotinae-gracilis-marginodentata-formosa* plexus, it has a complicated taxonomic history, which is discussed in Berggren (1977) and Blow (1979). *Globorotalia bolli* El-Naggar (1966), it appears, includes morphotypes of this plexas. We regard his pl. 22: fig. 6a–d as a morphotype of *M. gracilis,* in contrast to the holotype (pl. 22: fig. 5a–d), which is a morphotype of *M. subbotinae.*

STABLE ISOTOPES.—No data available.

STRATIGRAPHIC RANGE.—Zone P5 to Zone P6b.

GLOBAL DISTRIBUTION.—This is a geographically widespread morphospecies recorded from (predominantly) (sub)tropical biogeographies. It occurs as far south as nearly 60° at ODP Sites 738 (Huber, 1991b) and 747 (Berggren, 1992) on the Kerguelen Plateau, southern Indian Ocean, as part of the earliest Eocene extra-tropical excursion of morozovellids.

ORIGIN OF SPECIES.—This species evolved from *M. subbotinae* through a reduction in spire height and an increase in the number of chambers.

REPOSITORY.—Holotype (USNM P5055) deposited in the Cushman Collection, National Museum of Natural History. Examined by WAB and RDN.

***Morozovella occlusa* (Loeblich and Tappan, 1957)**

PLATE 17: FIGURES 4–6; PLATE 51: FIGURES 1–15

? *Discorbina simulatilis* Schwager, 1883:120, pl. 29: fig. 15a–d [? Zone P4, Farafra Oasis, Egypt].

Globorotalia occlusa Loeblich and Tappan, 1957a:191, pl. 55: fig. 3a–c [Zone P4, Vincentown Fm., New Jersey], pl. 64: fig. 3a–c [holotype, Zone P4, Velasco Shale, Tamaulipas, Mexico].—Luterbacher, 1964:690, text-figs. 112a–113c [*Globorotalia velascoensis* Zone, Velasco Fm., Ebano, eastern Mexico], text-fig. 114a–c [*Globorotalia velacoensis* Zone, Gubbio section, central Apennines, Italy].

Globorotalia crosswicksensis Olsson, 1960:47, pl. 10: figs. 7–9 [Zone P3b, Hornerstown Fm., New Jersey].

Globorotalia (*Truncorotalia*) *velascoensis occlusa* Loeblich and Tappan.—Hillebrandt, 1962:139, pl. 13: figs. 22, 24, 25 [Zone F = Zone P4/5 this paper], pl. 13: figs. 23, 26 [Zone D = *Globorotalia pusilla pusilla* Zone (upper part), Reichenhall-Salzburg Basin, Austro-German border].

Globorotalia (*Morozovella*) *occlusa* Loeblich and Tappan.—Jenkins, 1971:106, pl. 9: figs. 208–210 [*Subbotina triloculinoides* Zone, Waipawan Stage, Middle Waipara River section, New Zealand].—Blow, 1979:1007, pl. 90: figs. 7, 10 [lower part of Zone P4, DSDP Hole 21A/3/6: 74–76 cm; South Atlantic Ocean], pl. 95: figs. 7–10, pl. 96: figs. 1–3 [Zone P5, sample FCRM. 1670, Lindi area, Tanzania], pl. 213: fig. 6, pl. 214: figs. 1–6, pl. 215: figs. 5, 6, pl. 103: figs. 4–6, pl. 108: figs. 9, 10 [Zone P6, lower part, DSDP Hole 20C/6/3: 76–78 cm; Brazil Basin, South Atlantic Ocean], pl. 118: figs. 1–7 [Zone P7, DSDP Hole 47.2/8/3: 83–85 cm; Shatsky Rise, northwestern Pacific Ocean].—Belford, 1984:9, pl. 17: figs. 6–14 [upper Paleocene, WABAG Sheet area, Papua, New Guinea].

Globorotalia (*Morozovella*) *occlusa* cf. *occlusa* Loeblich and Tappan.—Blow, 1979:1007, pl. 92: figs. 5, 6 [Zone P4, DSDP Hole 47.2/8/3: 83–85 cm; Shatsky Rise, northwestern Pacific Ocean].

Globorotalia (*Morozovella*) *occlusa crosswickensis* Olsson.—Blow, 1979:1011, pl. 88: figs. 1, 2, pl. 213: figs. 1, 2 [upper part of Zone P3, DSDP Hole 47.2/10/1: 72–74 cm; Shatsky Rise, northwestern Pacific Ocean], pl. 90: figs. 3–6, 8, 9, pl. 213: figs. 3–5, pl. 215: figs. 1–4 [lower part of Zone P4, DSDP Hole 21A/3/6: 74–76 cm; South Atlantic Ocean].

Morozovella simulatilis (Schwager).—Snyder and Waters, 1985:470, pl. 9: figs. 7–9 [Zone P4/5, DSDP Site 549/16/4: 57–60 cm; northeastern Atlantic Ocean].

ORIGINAL DESCRIPTION.—"Test free, of medium size, trochospiral, spiral side flat, umbilical side convex with a very small and deep umbilicus, periphery keeled, peripheral outline entire to slightly lobulate; chambers gradually increasing in size, 4 to 5, rarely 6, in the final whorl, of greatest thickness at the umbilical shoulder immediately adjacent to the narrow umbilicus, umbilical shoulder subacutely rounded; sutures distinct, curved and oblique, thickened and flush to slightly elevated on the spiral side; radial and moderately depressed on the umbilical side; wall calcareous, finely perforate, surface smooth except for the thickened sutures on the spiral side and the peripheral keel which may be marginally nodose to hirsute, umbilical side with a somewhat granular appearance, particularly in the early region of the final whorl; aperture an interiomarginal, umbilical-extraumbilcal arch with a distinct lip above.

"Greatest diameter of holotype 0.45 mm." (Loeblich and Tappan, 1957a:191.)

DIAGNOSTIC CHARACTERS.—Plano-convex to low biconvex, nearly circular test, 4–6 (rarely up to 8) chambers in last whorl, coalescing in a circular, subacute, weakly to moderately muricate umbilical shoulder and forming a narrow, deep umbilicus; umbilical sutures depressed, radial; elevated and beaded, tangentially curved on spiral side; sutures between final and penultimate whorl coarsely muricate; periphery distinctly muricocarinate; aperture an interiomarginal, umbilical-extraumbilical arch.

DISCUSSION.—The enhanced, expanded concept of *M. occlusa* applied by Hillebrandt (1962) to include biconvex forms with 5–8 chambers is followed herein (see also Gohrbandt, 1963; Luterbacher, 1964; Samanta, 1970). Blow (1979) interpreted this form as a morphologically and phylogenetically advanced (descendant) form of *M. crosswicksensis* Olsson, which was said to generally lack the circumumbilical muricate coronet present in *M. occlusa.* The former was described from Zone P3b (Hornerstown Fm., New Jersey); the latter was described from the Velasco Fm. (Zone P4) and is characteristic of Zones P4 and P5. We include *crosswicksensis* in the concept of the taxon *occlusa*; it bears a similar relationship to that observed in the *Acarinina coalingensis*/*triplex* (earlier rounded periphery)-*primitiva* (later angular periphery) morphotypic series.

STABLE ISOTOPES.—*Morozovella occlusa* has $\delta^{13}C$ and $\delta^{18}O$ similar to coexisting *M. velascoensis* and *Acarinina mckannai* and more positive $\delta^{13}C$ and more negative $\delta^{18}O$ than *Subbotina* spp. (Shackleton et al., 1985; Lu and Keller, 1996).

STRATIGRAPHIC RANGE.—Top of Zone P3b (typical *crosswicksensis*); Zone P4–P5 (typical *occlusa*).

GLOBAL DISTRIBUTION.—This species is widespread in the low to middle latitudes.

ORIGIN OF SPECIES.—This species probably evolved from *M. pasionenesis* by a decrease in umbilical size, development of a biconvex test, and reduction of the muricate, sharp adumbilical ridges to lightly muricate, gently rounded surfaces around the umbilicus. *Morozovella occlusa* is a sister species to *M. acutispira,* with which it shares the biconvex test shape and relatively constricted umbilicus.

REPOSITORY.—Holotype (USNM P5874) and paratypes (USNM P5866) deposited in the Cushman Collection, National Museum of Natural History. Examined by WAB, RDN, and RKO.

Morozovella pasionensis (Bermúdez, 1961)

PLATE 17: FIGURES 7–9; PLATE 52: FIGURES 1–15

Pseudogloborotalia pasionensis Bermúdez, 1961:1346, pl. 16: figs. 8a,b [sample G-58, Rio de Pasion, El Petén, Guatemala].

Globorotalia pasionensis (Bermúdez).—Luterbacher, 1964:690, text-fig. 108a–c [topotype, Rio de la Pasion, El Petén, Guatemala], text-figs. 109a–110c [*Globorotalia aequa* Zone, Gubbio section, central Apennines, Italy], text-fig. 111a–c [*Globorotalia velascoensis* Zone, Velasco Fm., Ebano, eastern Mexico; as *G.* sp. aff. *pasionensis*].—Samanta, 1970:629, figs. 11, 12 [Zone P4/5, upper Marlstone unit, Pondicherry Formation, India].

Globorotalia velascoensis caucasica Glaessner.—El-Naggar, 1966:242, pl. 19: fig. 6a–c [*Globorotalia velascoensis* Zone, Gebel Aweina, Egypt]. [Not Glaessner, 1937a.]

ORIGINAL DESCRIPTION.—"Test trochoid, planoconvex, dorsal side plane or slightly convex and ventral side strongly convex, peripheral border lobulate and keeled but not sharp; chambers in two spiral whorls; all visible on the dorsal side and on the ventral side only the six or seven of the last whorl which gradually increase in size, sutures of the chambers depressed, slightly oblique on the dorsal side and radial on the ventral side; umbilicus large where one can see some of the chambers of the primary portion of the test; wall thin, completely covered by short spines; aperture as a narrow groove at the base of the septal face of the last chamber. Diameter 0.50mm.; height 0.25 mm." (Bermúdez, 1961:1346; translated from Spanish.)

DIAGNOSTIC CHARACTERS: Relatively large, low umbilico-convex test with flat spiral side, distinctly lobulate, heavily keeled periphery; generally 5–7 (but up to 10, particularly in younger, Zone P4c–P5 horizons) relatively equidimensional chambers in final whorl, but with insertion of smaller chambers between larger chambers in some individuals; intercameral sutures depressed, radial on umbilical side; curved, moderately retorse, raised and beaded on spiral side; umbilicus wide but shallow, periumbilical collar only weakly developed; aperture a low slit extending along peri-intraumbilical margin to peripheral margin of last chamber.

DISCUSSION.—This highly variable taxon differs from the closely related *M. velascoensis* in having a more loosely coiled, less vaulted angulo-conical test and a widely varying number of chambers. The chambers may be either essentially equidimensional, or there may be smaller, kummeform-like chambers inserted in the normal chamber progression of the last whorl. *Morozovella pasionensis* also has a relatively wider and shallower umbilicus and a more weakly ornamented periumbilcial collar.

Basic analyses of this taxon were made by Luterbacher (1964) and Blow (1979). The latter observed that the "holotype" individual of *Pseudogloborotalia pasionensis* Bermúdez at the National Museum of Natural History is coiled in a direction (sinistral) opposite to that of the photograph (dextral) of the "holotype" (Bermúdez, 1961, pl. 16: fig. 8a,b); however, it is the specimen (identified as *Pseudogloborotalia velascoensis* (Cushman)) illustrated on pl. 16: fig. 11a,b (and not that illustrated as fig. 8a,b), which is the holotype of *pasionensis* and which was examined by Blow and ourselves in the Cushman Collection (USNM 639063). The holotype of *P. pasionensis* shows characters similar to *P. velascoensis,* which indicate its close relationship with that taxon, but it has a low conical test as opposed to the high conical test typical of *P. velascoensis.* Luterbacher (1964) provided a revised and amplified description of this species based on topotypes supplied by Bermúdez. The analyses of Blow and Luterbacher are essentially compatible, with the exception that Luterbacher (1964) recorded 5–7 chambers as typical of this form, whereas Blow (1979) noted 9–10 (and occasionally up to 12) chambers in the final whorl.

STABLE ISOTOPES.—*Morozovella pasionensis* has $\delta^{13}C$ and $\delta^{18}O$ similar to coexisting *M. velascoensis* and *Acarinina mckannai* and more positive $\delta^{13}C$ and more negative $\delta^{18}O$ than *Subbotina* spp. (Shackleton et al., 1985; Lu and Keller, 1996).

STRATIGRAPHIC RANGE.—Zone P3b to Zone P5. Luterbacher (1964) considered "*pasionensis*" restricted to the *Globorotalia aequa* Zone (= Zone P6a this paper), whereas Blow (1979) considered it restricted to (his) Zone P5 (i.e., prior to the appearance of *M. subbotinae*) with questionable or sporadic occurrences in (his) Zones P4 and P6. In our studies, we have found that *M. pasionensis* appears slightly higher or later than the initial appearance of *M. velascoensis* in Zone P3b, and that it ranges throughout Zones P4 and P5. We have not observed it ranging into post-*M. velascoensis* (Zone P5) levels. It was ancestral to *M. acutispira* and *M. occlusa,* which appear in the terminal part of Zone P3b.

GLOBAL DISTRIBUTION.—Our observations agree with those of Blow (1979) that *M. pasionensis* had an essentially tropical (but not necessarily solely equatorial Pacific Ocean) distribution.

ORIGIN OF SPECIES.—This species probably evolved from *M. velascoensis* through a reduction in spire height, a decrease in the ornament around the umbilicus, and an increase in the number of chambers.

REPOSITORY.—Holotype (USNM 639063) deposited in the Cushman Collection, National Museum of Natural History. Examined by WAB, RDN, and BTH.

Morozovella praeangulata (Blow, 1979)

PLATE 53: FIGURES 1–13

Transitional form between *Globorotalia uncinata* Bolli and *Globorotalia angulata* (White).—Bolli, 1957a:74, pl. 17: figs. 10–12 [Zone P3, lower Lizard Springs Fm., Trinidad].

? *Acarinina quadratoseptata* Davidzon and Morozova, 1964:28, 30, pl. 2: fig. 1a–c [holotype], figs. 2a–3c [Zone P2/3 equivalent, upper part of the Chaaldzha Fm. ("transitional beds"), Kizilcheshme well,, Kyurendag, Turkmenia] [in part, not text-fig. 1a–c (= *Acarinina mckannai* (White))].

Globorotalia (*Acarinina*) *praeangulata* Blow, 1979:942–944, pl. 82: figs. 5, 6 [Zone P2, Sample DB 176, type locality of *Globorotalia uncinata* Zone, near Pointe a Pierre, southern Trinidad], pl. 83: fig. 6 [Zone P2, DSDP Hole 47.2/10/3: 18–20 cm], pl. 84: figs. 1, 7, pl. 212: figs. 1, 2 [holotype], fig. 8 [Zone P3, DSDP Hole 47.2/10/2: 80–82 cm; Shatsky Rise, northwestern Pacific Ocean].

ORIGINAL DESCRIPTION.—"The test is comprised of about 11–12 chambers coiled in a low, but comparatively lax, trochospire with 5½ chambers visible in the last convolution of the test. In dorsal aspect, the chambers are longer tangentially than radially broad with the dorsal intercameral sutures strongly recurved to vorticiform in the earlier parts of the last convolution; the dorsal intercameral sutures are distinctly incised and are not pseudolimbate but are weakly muricate (see Plate 212: fig. 1). The equatorial profile is lobulate and the peripheral margin does not bear a continuous muricocarina. However, the peripheral margin is strongly muricate (cf. Plate 212: figs. 1 and 2) but the muricae are not fused or coalesced together. In axial-aperture profile, the test is plano-conic (cf. paratype in Plate 84: fig. 8) with the dorsal side nearly flat and the ventral side strongly vaulted; the peripheral margin is seen to be subacute in this axial-apertural aspect. In ventral aspect, the umbilicus is open and deep and the ventral intercameral sutures are radially disposed and quite deeply incised. The primary aperture opens from the umbilicus to about two-thirds of the way towards the periphery. The wall is muricate with a peripheral concentration of muricae. Maximum diameter of holotype 0.32 mm." (Blow, 1979:942.)

DIAGNOSTIC CHARACTERS.—Planoconvex, moderately lobulate test with 5–6 tangentially elongate chambers in last whorl; umbilical sutures straight to weakly curved, depressed/incised; spiral intercameral sutures incised, weakly muricate, strongly recurved; peripheral margin strongly muricate but not muricocarinate; umbilicus narrow, deep with aperture an interiomarginal, umbilical-extraumbilical slit (bordered by a distinct intraperiumbilical lip in well-preseved specimens) extending nearly to the peripheral margin.

DISCUSSION.—Examination of the holotype (3514/6) and several paratypes of *Acarinina quadratoseptata* Davidzon and Morozova, 1964, in the micropaleontological collections of GAN in Moscow suggests that this form may be a senior synonym of *M. praeangulata* Blow. We retain the name *praeangulata* in this work, however, for the reasons given below. The holotype and one of the paratypes (3514/7) of *quadratoseptata* are characterized by 5 chambers in the last whorl and slightly (but distinctly) curved sutures sloping to a rounded to subangular, lobulate, noncarinate periphery. In both specimens, the early whorls are obscured, the tests are poorly preserved (strongly recrystallized), and the last chamber for each is missing. Paratype 3514/8 has a quadrate test and flat early whorls, and the chambers of its last whorl slope toward a distinctly subangular periphery. The test of this paratype is homeomorphic with the Pliocene noncarinate *Globorotalia crassaformis.* The remaining paratype (3514/9) is distinctly different, as it comes from a different locality and stratigraphic level, and it is referable to *Acarinina mckannai.* The drawing of this specimen is misleading and gives the impression of a morozovellid. A further problem lies in the fact that the specimens coil in the opposite direction to what is shown in the illustrations. The negatives were apparently retouched and printed backwards.

The Russian authors compared their new species with *Acarinina pentacamerata* Morozova, 1961, and *A. praecursoria* Morozova, 1961. Although believing that *quadratoseptata* may indeed be a senior synonym of *praeangulata* by 15 years, the fact that the type material of *quadratoseptata* is very poorly preserved and has been virtually ignored in Soviet/Russian literature (it was not mentioned by Shutskaya, 1970a, 1970b, in her comprehensive review of Paleocene-lower Eocene planktonic foraminifera) leads us to retain the name *praeangulata* for this morphospecies.

STABLE ISOTOPES.—*Morozovella praeangulata* has $\delta^{13}C$ and $\delta^{18}O$ values similar to *M. angulata* and more positive $\delta^{13}C$ and more negative $\delta^{18}O$ values than *Subbotina* spp. (Shackleton et al., 1985).

STRATIGRAPHIC RANGE.—Zone P2 to Zone P3a.

GLOBAL DISTRIBUTION.—The few localities where this species has been identified suggests a low to middle latitude distribution.

ORIGIN OF SPECIES.—Bolli (1957a) proposed that *Globorotalia* (= *Morozovella*) *angulata* was derived from *Globorotalia* (= *Praemurica*) *uncinata*. He illustrated a form (pl. 17: figs. 10–12) that he considered transitional between *M. uncinata* and *M. angulata*. Blow (1979) accepted Bolli's proposed phylogeny and selected this specimen as a paratype to support his documentation of *M. praeangulata* as the stem form of the morozovellid lineage. The transition to *M. praeangulata* would have involved the development of a more pronounced conicotruncate test and concomitant change toward equidimensional (as opposed to tangentially elongate) chambers, as well as formation of a thicker (and ultimately) muricocarinate peripheral margin. This has been the traditional view of the origin of *Morozovella*. An alternate view, as noted in "Wall Texture, Classification, and Phylogeny," is that the wall texture of *M. praeangulata* developed with pustule buildup on a smooth "globorotaliid" surface in contrast to the praemuricate wall texture of *uncinata*. In this view *M. praeangulata* originated from a smooth-walled *Globanomalina*, such as *G. imitata*, which has pustules covering the walls of early formed anguloconical chambers (Plate 4: Figures 11–13, 16, Plate 36: Figures 8–12). These chambers are similar to those observed in the modern *Globorotalia scitula* (Plate 3: Figure 8), which was a stem form for several globorotaliid lineages in the Neogene. Thus, the initial step in the evolution of *M. praeangulata* would have involved the suppression of the later stages of ontogeny by speeding up the rate of maturation and the development of a more pustulose, conicotruncate adult test. This change in the timing of maturation would account for the small size of the early forms of *M. praeangulata*.

REPOSITORY.—Holotype (BP Cat. No. 38/15) and paratypes (BP Cat. Nos. 33/3, 33/9, 38/6, 38/14, 38/16, 41/54) deposited in the micropalentological collections at The Natural History Museum, London. Paratype (USNM P5074) deposited in the Cushman Collection, National Museum of Natural History. Paratype (USNM P5074) examined by WAB and RDN.

Morozovella subbotinae (Morozova, 1939)

FIGURE 24; PLATE 54: FIGURES 1–12

Globorotalia subbotinae Morozova, 1939:80, pl. 2: figs. 16, 17 [upper Paleocene, base of section at cemetary at Asankozha, left bank of Emba River, S part of Emba oil field, Kazakh S.S.R. (= Kazakhstan)].—Shutskaya, 1956:98, 99, pl. 4: fig. 4 [*Globorotalia subbotinae* Zone, Cherkessk Formation, Nal'chik, northern Caucasus] [in part, not pl. 4: fig. 3a,b; ? = *Acarinina wilcoxensis*].—Luterbacher, 1964:676, text-figs. 85a–86c, 89a–90c [*Globorotalia aequa* Zone, Gubbio section, central Apennines, Italy], text-fig. 88a–c [*Globorotalia formosa formosa*/*Globorotalia subbotinae* Zone, Gubbio section, central Apennines, Italy].—Shutskaya, 1970a:119, pl. 13: fig. 6a–c, pl. 14: fig. 6a–c [*Globorotalia subbotinae* Zone, Churuk-Su, Kacha River section, Bakchissarayan Stage, Bakhchissaray area, southwestern Crimea], pl. 38: fig. 9a–c [*Globorotalia subbotinae* Zone, Malyi Balkhan Ridge, middle Danian Fm., western Turkmenia].—Luterbacher, 1975a:732, pl. 2: fig. 2a,b [*Globorotalia formosa formosa* Zone, DSDP Site 305/12/CC; Shatsky Rise, northwestern Pacific Ocean]; 1975b:65, pl. 2: figs. 31–33 [*Globorotalia subbotinae* Zone, Possagno section, Trevisiano Province, Italy].

Globorotalia rex Martin, 1943:117, pl. 8: fig. 2a–c [Zone P6, Lodo Fm., Lodo Gulch, Fresno Co., California].—Bolli, 1957a:75, pl. 18: figs. 10–12 [*Globorotalia rex* Zone, upper Lizard Springs Fm., Trinidad].

Globorotalia (*Truncorotalia*) *aequa simulatilis* (Schwager).—Hillebrandt, 1962:134, 135, pl. 13: figs. 6a–c, 7, 8a–c [Zone G, Reichenhall-Salzburg Basin, Austro-German border]. [Not Schwager, 1883.]

Globorotalia bollii El-Naggar, 1966:202, pl. 22: fig. 5a–d [*Globorotalia wilcoxensis* Zone, Thebes Calcareous Shale, Gebel Aweina, Egypt] [in part, not pl. 22: fig. 6a–d (= *M. gracilis* (Bolli))].

Globorotalia nartanensis Shutskaya, 1970b:118–120, pl. 15: figs. 2a–c, 8a–c [*Globorotalia subbotinae* Zone, Churuk-Su, Kacha River section, Bakhchissarag region, Bakhchissarayan Stage, southwestern Crimea]. [Not *Globorotalia nartanensis* Shutskaya, 1956:96–98, pl. 54: fig. 2a–c (= *M. lensiformis* Subbotina, 1953).]

Globorotalia (*Morozovella*) *aequa rex* Martin.—Jenkins, 1971:101, 102, pl. 7: figs. 180–182 [*Globigerina wilcoxensis* Zone, Waipawan Stage, Middle Waipara River section, New Zealand].

Morozovella subbotinae (Morozova).—Berggren, 1971b:76, pl. 5: figs. 10, 11 [*Globorotalia subbotinae* Zone, DSDP Hole 20C/5/6: 100–102 cm; Brazil Basin, South Atlantic Ocean].—Snyder and Waters, 1985:442, 443, pl. 9: figs. 10–12 [DSDP Hole 548A/28/3: 70–74 cm; Goban Spur, northeastern Atlantic Ocean].—Toumarkine and Luterbacher, 1985:112, text-fig. 15:9a–c [reillustration of holotype of *Globorotalia rex* Martin, 1943], text-fig. 15:10a–c [reillustration of holotype of *Globorotalia subbotinae* Morozova, 1939], text-fig. 15:11a–c [reillustration of specimen from northwestern Crimea identified by Subbotina, 1953, pl. 17: fig. 13a–c as *Globorotalia crassata* Cushman].—Huber, 1991b:440, pl. 4: fig. 9 [Zone AP6A, ODP Hole 738C/10R: 277.78 mbsf; Kerguelen Plateau, southern Indian Ocean].—Lu and Keller, 1993:123, pl. 4: fig. 19 [their *Morozovella subbotinae* Subzone of Zone AP5A/*Planorotalites australiformis* Zone of Stott and Kennett, 1990; ODP Hole 738C/11/1R: 15–17 cm; Kerguelen Plateau, southern Indian Ocean]; 1995:102, pl. 1: figs. 11–13 [their Subzone P6bx, DSDP Site 577/9/6: 53–55 cm; Shatsky Rise, northwestern Pacific Ocean].

Globorotalia (*Morozovella*) *subbotinae subbotinae* (Morozova).—Blow, 1979:1018–1021, pl. 102: figs. 1–5, pl. 219: figs. 1–4 [Zone P6 of Blow, 1979; DSDP Hole 20C/6/3: 76–78 cm; Brazil Basin, South Atlantic Ocean], pl. 111: figs. 6–8 [Zone P7 of Blow, 1979, Sample KRE 83F, Moogli Mudstones, Kagua, Papua, New Guinea], pl. 115: figs. 3–5 [Zone P7 of Blow, 1979, Sample RS 80, Kilwa area, Tanzania; also pl. 115: fig. 6 as

Globorotalia (*Morozovella*) sp. specimen ex interc *G.* (*M.*) *aequa lacerti* Cushman and Renz and *G.* (*M.*) *subbotinae subbotinae* Morozova], pl. 119: figs. 4–10, pl. 219: figs. 5, 6, pl. 220: figs. 1–6, pl. 222: figs. 1–7 [Zone P7 of Blow, 1979, DSDP Hole 47.2/8/3: 82–85 cm], pl. 127: figs. 6, 7 [Zone P8a of Blow, 1979, DSDP Hole 47.2/8/2: 71–73 cm], pl. 123: fig. 8 [Zone P8b of Blow, 1979, DSDP Hole 47.2/8/1: 77–79 cm; Shatsky Rise, northwestern Pacific Ocean], pl. 103: figs. 2, 7, 9, pl. 223: figs. 1, 2 [Zone P6 of Blow, 1979, DSDP Hole 20C/6/3: 76–78 cm; Brazil Basin, South Atlantic Ocean].

ORIGINAL DESCRIPTION.—"Test lenticular, composed of 2–2$^1/_2$ spiral whorls. Peripheral margin acute, lobulate, with a keel and fine, irregular denticulations. Dorsal side slightly convex, ventral side conical, the side inclined at an angle of 25–30° to the dorsal side. Umbilicus narrow but deep. In the last whorl, there are 4–5 chambers rapidly increasing in size. Sutures deep near the umbilicus, becoming shallower toward the periphery. Wall thin, spinose. Aperture in the form of a narrow slit, extending from the umbilicus to the peripheral margin.

"Dimensions.—Diameter, 0.36 mm; thickness, 0.20 mm." (Morozova, 1939:80; translated from Russian.)

DIAGNOSTIC CHARACTERS.—Relatively large (to 0.5 mm maximum diameter), planoconvex to weakly biconvex test with moderately lobulate, strongly/thickly keeled periphery; 4–4$^1/_2$ chambers in last whorl, generally covered with muricae on umbilical side, spiral side relatively smooth; umbilical and spiral intercameral sutures weakly curved, tangential on spiral side yielding trapezoidal-shaped chambers; circumumbilical chamber tips weakly ornamented by muricae and surrounding deep, narrowly open umbilicus; aperture a low, umbilical-extraumbilical slit extending almost to periphery and bordered by weak lip.

DISCUSSION.—This robust species is a characteristic element of latest Paleocene and early Eocene planktonic assemblages. *Morozovella subbotinae* has had a convoluted taxonomic history. It is generally agreed by specialists that *Globorotalia subbotinae* Morozova, 1939, is a senior synonym of *Globorotalia rex* Martin, 1943 (see Berggren, 1977; Blow, 1979, for discussions). In the (former) Soviet Union this taxon was identified with (the middle Eocene) *Globorotalia crassata,* Cushman, 1925 (nomen non conservandum, fide Blow, 1979 = *Morozovella spinulosa* (Cushman, 1927b)) (see Subbotina, 1947, 1953).

Blow (1979) drew attention to the close similarities between *M. subbotinae* (Morozova), *M. marginodentata* (Subbotina), and *M. gracilis* (Bolli). In fact, he separated *M. gracilis* from *M. subbotinae* at the subspecies level based on the increase in chamber number (from 4$^1/_2$ in *subbotinae* to 5$^1/_2$–6 in *gracilis*), which is associated with the development of a somewhat more evolute coiling mode and more vorticiform spiral intercameral sutures in *M. gracilis,* and on the slightly different (shorter) stratigraphic range of *M. gracilis.* The development of a strongly dentate (fimbriate) muricocarina (*marginodentata*) on some morphotypes was regarded as an ecophenotypic variation within the *subbotinae* plexus of morphotypes. He considered this indicative of high productivity, and *M. marginodentata* was, accordingly, identified only as a variant of *M. subbotinae* (cf. Berggren, 1971b, who had suggested earlier that *M. marginodentata* might be synonymous, an ecophenotypic variant of *M. gracilis*).

STABLE ISOTOPES.—*Morozovella subbotinae* has $\delta^{13}C$ and $\delta^{18}O$ similar to *M. velascoensis* and *Acarinina nitida* and has more positive $\delta^{13}C$ and more negative $\delta^{18}O$ than *Subbotina triangularis* (D'Hondt et al., 1994). *Morozovella subbotinae* displays a pronounced increase in $\delta^{13}C$ with increased test size but little corresponding change in $\delta^{18}O$ (D'Hondt et al., 1994).

STRATIGRAPHIC RANGE.—Zone P5 to Zone P6b.

GLOBAL DISTRIBUTION.—*Morozovella subbotinae* is a geographically widespread morphospecies. It is recorded in (sub)tropical assemblages in Atlantic, Indo-Pacific, and typical Tethyan biogeographies and as far south as 60° in association with the early Eocene (Zone P6) extra-tropical excursion of carinate morozovellids on the Kerguelen Plateau (Huber, 1991b, ODP Site 738; Berggren, 1992, ODP Site 747) (Figure 24).

ORIGIN OF SPECIES.—*Morozovella subbotinae* evolved from *M. aequa* through the enhanced development of peripheral muricocarina, a heightened anguloconical umbilical side, and an increase in test size.

REPOSITORY.—Holotype (Slide No. 700) deposited in the micropaleontological collections at VNIGRI, St. Petersburg, Russia.

Morozovella velascoensis (Cushman, 1925)

FIGURE 25; PLATE 17: FIGURES 10–12; PLATE 55: FIGURES 1–15

Pulvinulina velascoensis Cushman, 1925:19, pl. 3: fig. 5a–c [Velasco Fm., San Luis Potosi, Tampico Embayment, eastern Mexico].

Globorotalia velascoensis (Cushman).—White, 1928:281, pl. 38: fig. 2a–c [Velasco Shale Fm., eastern Mexico].—Cushman and Renz, 1946:47, pl. 8: figs. 13, 14 [lower Lizard Springs Fm., Trinidad].—Subbotina, 1947:123, pl. 7: figs. 9–11 [*Globortalia velascoensis* Zone, Sunzha River section, northern Caucasus], pl. 9: figs. 21–23 [*Globorotalia velascoensis* Zone, Kuban River section, northern Caucasus].—Le Roy, 1953:33, pl. 3: figs. 1–3 [Maqfi section, Egypt].—Haque, 1956:181, pl. 24: fig. 2a–c [upper Paleocene, Nammal Gorge, Salt Range, Pakistan].—Bolli, 1957a:76, pl. 20: figs. 1–4 [*Globorotalia pseudomenardii* Zone, lower Lizard Springs Fm., Trinidad].—Loeblich and Tappan, 1957a:196, pl. 64: figs. 1a–2c [Zone P4, Velasco Fm., Tamaulipas, Mexico].—Bolli and Cita, 1960:391, pl. 35: fig. 7a–c [*Globorotalia pseudomenardii* Zone, Paderno d'Adda section, northern Italy].—Said and Kerdany, 1961:330, pl. 1: fig. 10a–c [lower Esna Shale Fm., Western Desert, Egypt].—Shutskaya, 1970b:118–120, pl. 23: fig. 3a–c, pl. 24: fig. 5a–c [*Acarinina tadjikistanensis djanensis* Subzone, Kachan Stage, Tarkhankut Peninsula, Crimea, Olenev Platform, Boring 210, 517–527 m], pl. 25: fig. 5a–c [same zone as above, but from boring 229, 637–641 m], pl. 27: fig. 12a–c [*Acarinina acarinata* Zone, Kachan Stage, Tarkhankut Peninsula, Crimea], pl. 29: fig. 8a–c [*Globorotalia aequa* Zone, Bakhchissarayan Stage, Tarkhankut Peninsula, Crimea].—Luterbacher, 1975a:726, pl. 1: fig. 8a,b [*Globorotalia pseudomenardii* Zone, DSDP Site 305/14/1: 135–138 cm; Shatsky Rise, northwestern Pacific Ocean].—Pujol, 1983:644, pl. 3: fig. 9 [Zone P5, DSDP Hole 516F/84/5: 13–15 cm; Rio Grande Rise, southwestern Atlantic Ocean].

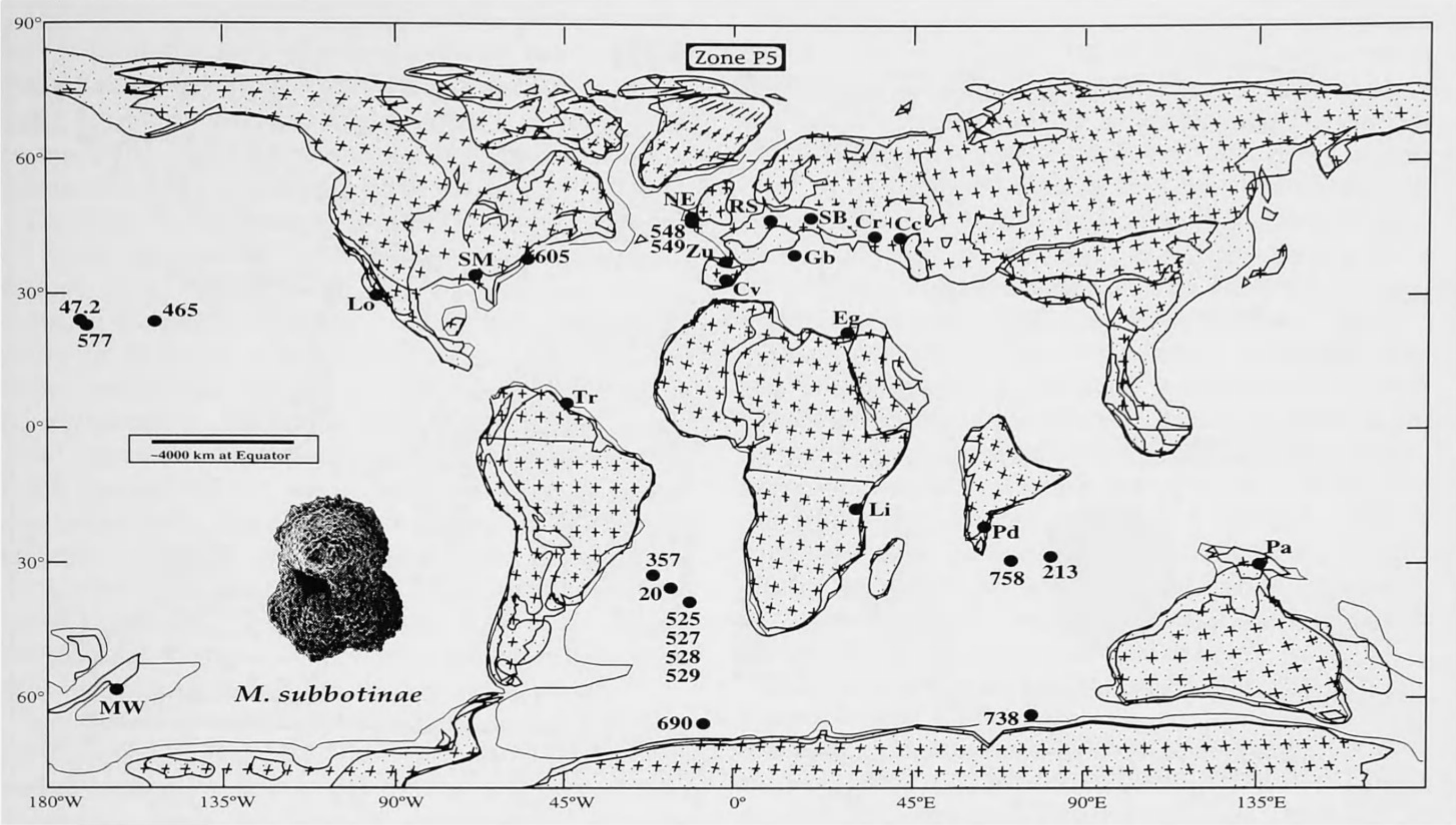

FIGURE 24.—Paleobiogeographic map showing distribution of *Morozovella subbotinae* (Morozova) in Zones P5 and P6.

Pseudogloborotalia velascoensis (Cushman).—Bermúdez, 1961:1349, pl. 16: fig. 11a,b [Velasco Station, Tampico-San Luis Potosi Railway, Mexico].

Globorotalia (*Truncorotalia*) *velascoensis velascoensis* (Cushman).—Hillebrandt, 1962:169, pl. 13: figs. 16–21 [Zone D = *Globorotalia pusilla pusilla* Zone (upper part), Reichenhall-Salzburg Basin, Austro-German border].

Truncorotaloides (*Morozovella*) *velascoensis* (Cushman).—McGowran, 1968:190, pl. 2: fig. 1 [Velasco Fm., Ebano, Mexico].

Globorotalia (*Morozovella*) *velascoensis velascoensis* (Cushman).—Jenkins, 1971:107, pl. 9: figs. 214–216 [*Globigerina triloculinoides* Zone, Waipawan Stage, Middle Waipara River section, New Zealand].—Blow, 1979:1029, pl. 92: fig. 7 [Zone P4, DSDP Hole 47.2/9/3: 70–72 cm; Shatsky Rise, northwestern Pacific Ocean], pl. 94: figs. 6–9, pl. 95: figs. 1, 2, pl. 216: figs. 1–8, pl. 217: figs. 1–6 [Zone P5, Samples FCRM. 1670, Lindi area, Tanzania], pl. 99: figs. 3, 4 [Zone P5, DSDP Hole 47.2/9/1: 64–66 cm; Shatsky Rise, northwestern Pacific Ocean].—Belford, 1984:10, pl. 1: fig. 2, pl. 19: figs. 1–12 [upper Paleocene, Wabag Sheet area, Papua, New Guinea].

Morozovella velascoensis (Cushman).—Toumarkine and Luterbacher, 1985:109, text-figs. 11, 12 [fig. 11: reillustration of Bolli, 1957a, pl. 20: figs. 1–3; fig. 12: reillustration of holotype from Cushman, 1925, pl. 3, fig. 5a–c].

ORIGINAL DESCRIPTION.—"Test plano-convex, the dorsal side flat or even slightly concave, ventral side very much produced, periphery carinate, subacute, the series of which surround a depressed umbilical area; about seven chambers in the last-formed coil; sutures distinct, on the dorsal side curved, marked by a series of small, bead-like processes, the periphery of each with a slightly raised carina which marks also the line of coiling in the central portion, ventral side with the sutures nearly radiate, straight, much depressed, surface roughened with very minute, low spinose processes which rather uniformly cover the entire test; aperture elongate, narrow, on the ventral side [of] the last-formed chamber extending from near the periphery almost to the umbilical area." (Cushman, 1925:19.)

DIAGNOSTIC CHARACTERS.—Relatively large (maximum diameter > 0.5 mm), robust, plano-convex, nearly circular, moderately lobulate test composed of about 15–16 chambers arranged in $2^1/_2$–3 whorls; last whorl with 6–7 (rarely 8) anguloconical chambers whose tips surround moderately open umbilicus; umbilicus surmounted by an "adumbilical" or circum-umbilical rim ("collar") of fused muricae; umbilical sutures radial, depressed, moderately to strongly curved, raised and beaded on spiral side; wall finely perforate, distinctly muricocarinate periphery, but spiral chamber surfaces often nearly free of muricae; aperture a low, interiomarginal, umbilical-extraumbilical arch.

DISCUSSION.—This is the type species of the genus *Morozovella* McGowran (in Luterbacher, 1964) and one of the most characteristic and easily recognized Paleocene morozovellids. It has been assigned to various genera and subgenera over the past half century but would appear to have found a suitable home in the genus *Morozovella* as defined by McGowran in Luterbacher (1964; see also McGowran, 1968).

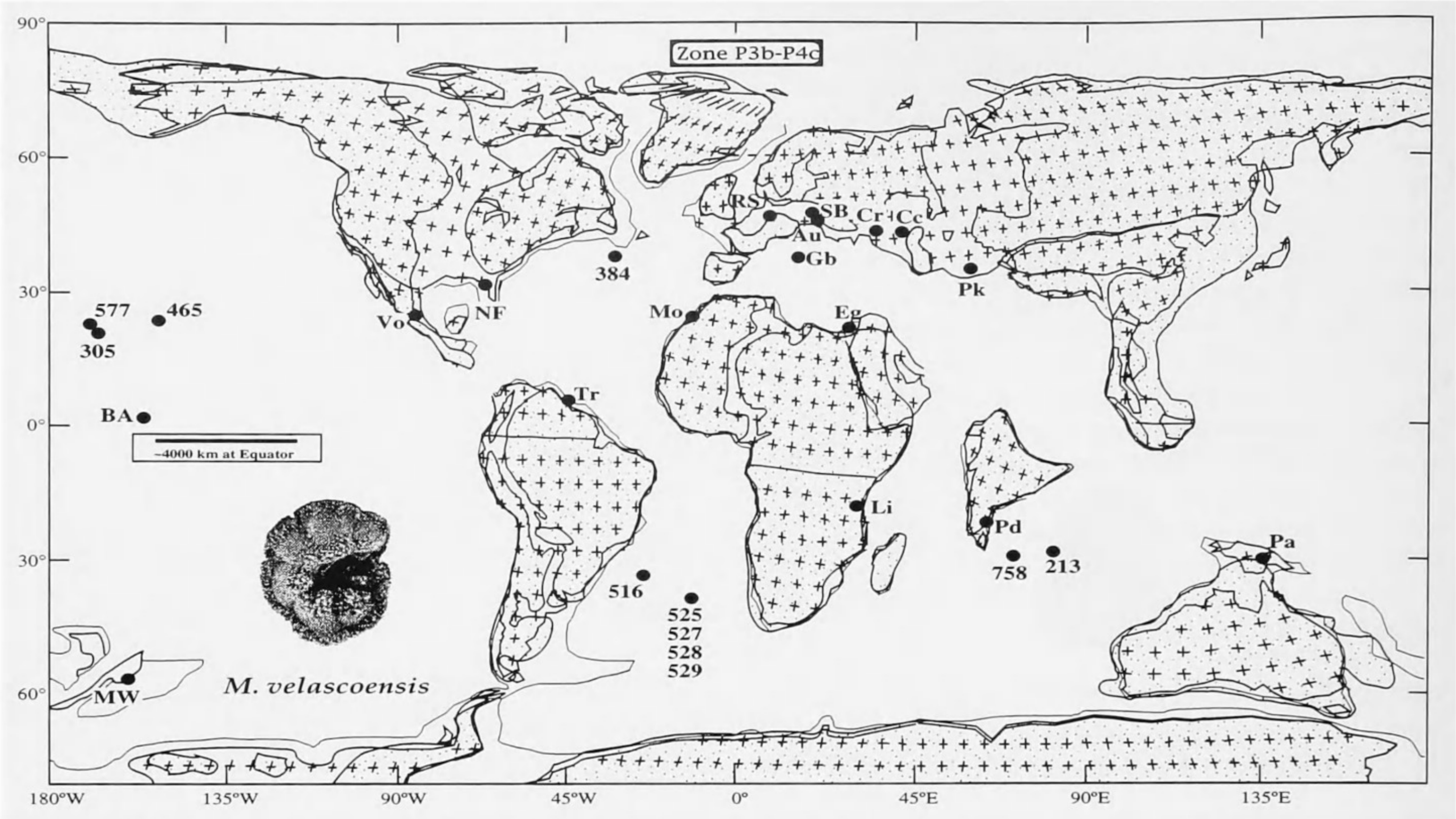

FIGURE 25.—Paleobiogeographic map showing distribution of *Morozovella velascoensis* (Cushman) in Zones P4 and P5.

This species has been confused with the heterochronously isomorphic form *M. caucasica* (Glaessner) (see Subbotina, 1953, pl. 19: figs. 1a–2c, who identified strongly muricocarinate and circumumbilically muricate forms from the lower Eocene zone of conical globorotaliids of the northern Caucasus as *G. velascoensis*; see also El-Naggar, 1966, who was equally confused by the distinctions between these two taxa, and Blow, 1979, for clarification of the problems associated with separation and recognition of these two forms).

STABLE ISOTOPES.—*Morozovella velascoensis* has $\delta^{13}C$ similar to coexisting species of *Morozovella* and *Acarinina* and more positive $\delta^{13}C$ and more negative $\delta^{18}O$ than *Subbotina* (Boersma and Premoli Silva, 1983; Shackleton et al., 1985; D'Hondt et al., 1994). *Morozovella velascoensis* displays a pronounced increase in $\delta^{13}C$ with increased test size but little corresponding change in $\delta^{18}O$ (D'Hondt et al., 1994). This species typically has more negative $\delta^{18}O$ than all other analyzed species of *Morozovella* (Berggren and Norris, 1997).

STRATIGRAPHIC RANGE.—Zone P3b to Zone P5 (top).

GLOBAL DISTRIBUTION.—*Morozovella velascoensis* has a wide geographic distribution but is a predominantly (sub)tropical to temperate form; it has not been recorded from high northern or southern (subantarctic) latitudes (> 45° N or S). The disappearance of this taxon is a distinct biostratigraphic event that is used to define the boundary between Zones P5 and P6, which occurs in mid-Chron C24r, and is closely correlative with the Paleocene/Eocene boundary as denoted in the Belgian and/or London–Hampshire Basin(s) of northwestern Europe (Berggren and Aubry, 1996) (Figure 25).

ORIGIN OF SPECIES.—This species evolved from *Morozovella conicotruncata* (Subbotina) within Subzone P3b by the acquisition of coarsely muricate adumbilical ridges, the complete loss of muricae on the spiral chamber surfaces and between the murcrocarina and umbilical collar, as well as the formation of a thick, coarsely muricate mucrocarina.

REPOSITORY.—Holotype (USNM CC4347) deposited in the Cushman Collection, National Museum of Natural History. Examined by WAB and RDN.

Genus *Igorina* Davidzon, 1976

TYPE SPECIES.—*Igorina tadjikistanensis* (Bykova, 1953).

ORIGINAL DESCRIPTION.—"Test free, bilaterally convex. Equatorial outline round, slightly undulate. Axial outline takes the form of a bilateral cone with variable vertex angles. Chambers on spiral side alate, on umbilical side triangular. Umbilicus small or absent. Aperture a slit at the base of the septal surface of the last chamber. Surface of chambers smooth or almost uniformly covered with small spines." (Davidzon, 1976:197; translated from Russian.)

DIAGNOSTIC CHARACTERS.—Test small, biconvex, may have a peripheral keel; chambers, ovoid or low conical in shape, 5-6 in final whorl; wall, coarsely cancellate, praemuricate, often with a thick, encrusted pustulose layer covering the praemuricate wall; aperture, interiomarginal, umbilical-extraumbilical, a low arch bordered by a thin lip.

DISCUSSION.—As Pearson (1993:212) observed, the group of "biconvex, muricate morozovellids" (see Boersma and Premoli Silva, 1983; Premoli Silva and Boersma, 1989)—including the *pusilla–laevigata, convexa,* and *broedermanni* plexus of forms—is probably distinct from *Acarinina* and mainstream morozovellids. He considered these forms inappropriately placed in *Igorina* Davidzon (Loeblich and Tappan, 1988), inasmuch as the type species of the latter, *Globorotalia tadjikistanensis* Bykova, was considered an enigmatic, biconvex morozovellid from the upper part of Zone P3a, and probably is related to *conicotruncata.* Recent examination and SEM reillustration of the holotypes of *Globorotalia tadjikistanensis* Bykova (pl. 11: figs. 4-6) and *Globorotalia convexa* Subbotina (pl. 11: figs. 1-3), however, have shown these forms to be synonymous, with *tadjikistanensis* having priority.

Igorinids are characterized by their small, coarsely cancellate tests, evolute coiling, and distinctive blunt, praemuricate surface texture. We believe that the Igorinids evolved from *Praemurica* about the time of appearance of the first morozovellids (*M. praeangulata, M. angulata*). Like many globigerininid groups, the igorinids show a trend toward chamber compression and development of a peripheral keel, but this trend is reversed in the Eocene with the evolution of the *I. broedermanni* group.

Igorina albeari (Cushman and Bermúdez, 1949)

FIGURE 26; PLATE 16: FIGURES 1-6; PLATE 56: FIGURES 1-16

Globorotalia albeari Cushman and Bermúdez, 1949:33, pl. 6: figs. 13-15 [holotype from stratigraphic level within subsequently described (1957) *Globorotalia pseudomenardii* Zone, Madruga Fm., Cuba].—Cifelli and Belford, 1977:100, pl. 1: figs. 4-6 [holotype reillustrated].

Globorotalia pusilla laevigata Bolli, 1957a:78, pl. 20: figs. 5-7 [*Globorotalia pseudomenardii* Zone, Lizard Springs Fm., Trinidad].—Bolli and Cita, 1960:27, pl. 32: fig. 6a-c [*Globorotalia pseudomenardii* Zone, Paderno d'Adda, northern Italy].—Hillebrandt, 1962:128, 129, pl. 11: fig. 17a-c [*Globorotalia pseudomenardii* Zone, Reichenhall-Salzburg Basin, Austro-German border].—McGowran, 1965:63, pl. 6: fig. 4 [upper Paleocene, stratigraphically equivalent to *Globorotalia pseudomenardii* Zone, Dilwyn Clay, Rivernook Mbr., Pebble Point, Australia].

Globorotalia pseudoscitula Glaessner.—Loeblich and Tappan, 1957a:193, pl. 46: fig. 4a-c [Zone P3, Coal Bluff Fm., Midway Group, Gulf Coast, Alabama], pl. 53: fig. 5a-c [Zone P4, Vincentown Fm., New Jersey], pl. 59: fig. 2a-c [Zone P4, Aquia Fm., Aquia Creek, Maryland/Virginia], pl. 63: fig. 6a-c [Zone P4, Velasco Fm., Tamaulipas, Mexico] [in part, not pl. 48: fig. 3a-c (= *Igorina pusilla* (Bolli))]. [Not Glaessner, 1937.]

Globorotalia (*Globorotalia*) *albeari* Cushman and Bermúdez.—Blow, 1979:883, pl. 92: figs. 4, 8, 9, pl. 93: figs. 1-4 [Zone P4, DSDP Hole 47.2/9/3: 70-72 cm; Shatsky Rise, northwestern Pacific Ocean].

ORIGINAL DESCRIPTION.—"Test very small for the genus, strongly biconvex, dorsal side showing all the coils and ventral side only the last-formed whorl, periphery somewhat rounded; chambers not very distinct, 9 to 10 in the last-formed whorl, only slightly inflated ventrally, increasing very gradually in size as added; sutures fairly distinct but only slightly depressed except in the last whorl on the ventral side, rather strongly recurved on the dorsal side; wall slightly spinose, coarsely perforate; aperture an elongate opening on the ventral side of the last-formed chamber extending from nearly the inner end to the periphery and with a distinct thin lip. Diameter 0.30-0.32 mm; thickness 0.20 mm." (Cushman and Bermúdez, 1949:33.)

DIAGNOSTIC CHARACTERS.—Moderately to strongly biconvex, essentially circular, cancellate, pustulose test with 6-8 chambers in final whorl; intercameral sutures on umbilical side radial to weakly recurved yielding triangular-shaped chambers; strongly recurved and exhibiting distinct limbation on the spiral side, particularly between the last 3-4 chambers, yielding trapezoidal-shaped chambers; peripheral margin distinctly carinate, particularly on last chambers of final whorl; aperture a low interiomarginal, umbilical-extraumbilical arch extending towards, but not to, the peripheral margin.

DISCUSSION.—Comparison of the type specimens (Plate 16: Figures 1-6) of *Globorotalia albeari* Cushman and Renz, 1946, and *G. pusilla laevigata* Bolli, 1957a, by Blow (1979) and Berggren (1960, 1965, 1968, 1969a, 1977) have confirmed the suspicions previously raised by Postuma (1971) of the synonymy of these two forms. Most notable is the presence of a distinct peripheral carina in this taxon that was not shown in the holotype illustration by Cushman and Renz (1946) nor, surprisingly, in the refiguration of the holotype by Cifelli and Belford (1977). We have observed a wide range of variation in the degree of convexity of the spiral side in this taxon and have tried to convey this variation in Plate 56: Figures 1-16. The umbilical side is generally less convex than the spiral side, and the final chamber is often flattened and smoother (less pustulose) than the remainder of the test.

STABLE ISOTOPES.—*Igorina albeari* has $\delta^{13}C$ more negative than *Acarinina* and *Morozovella* but more positive than *Subbotina* and *Globanomalina.* The $\delta^{18}O$ of *I. albeari* is more negative than *Subbotina* and *Globanomalina* but is more positive than *Morozovella* (Berggren and Norris, 1997).

STRATIGRAPHIC RANGE.—Zone P3a/P3b boundary to Zone P4.

GLOBAL DISTRIBUTION.—*Igorina albeari* is predominantly tropical to subtropical, low latitude, in distribution. It has not been recorded from high southern latitudes at appropriate stratigraphic levels (Stott and Kennett, 1990), although Huber (1991b) recorded/illustrated a form (pl. 3: figs. 18, 19) similar to *albeari* (as *pusilla*) from a biostratigraphic level (Zone AP5 near the Paleocene/Eocene boundary) in ODP Hole 738C (Kerguelen Plateau, southern Indian Ocean). From our experience with Russian literature and the comparative material in the collection at WHOI, it would appear that this taxon has not been recorded or is not present in the Caucasus-Crimean Paleocene (Figure 26).

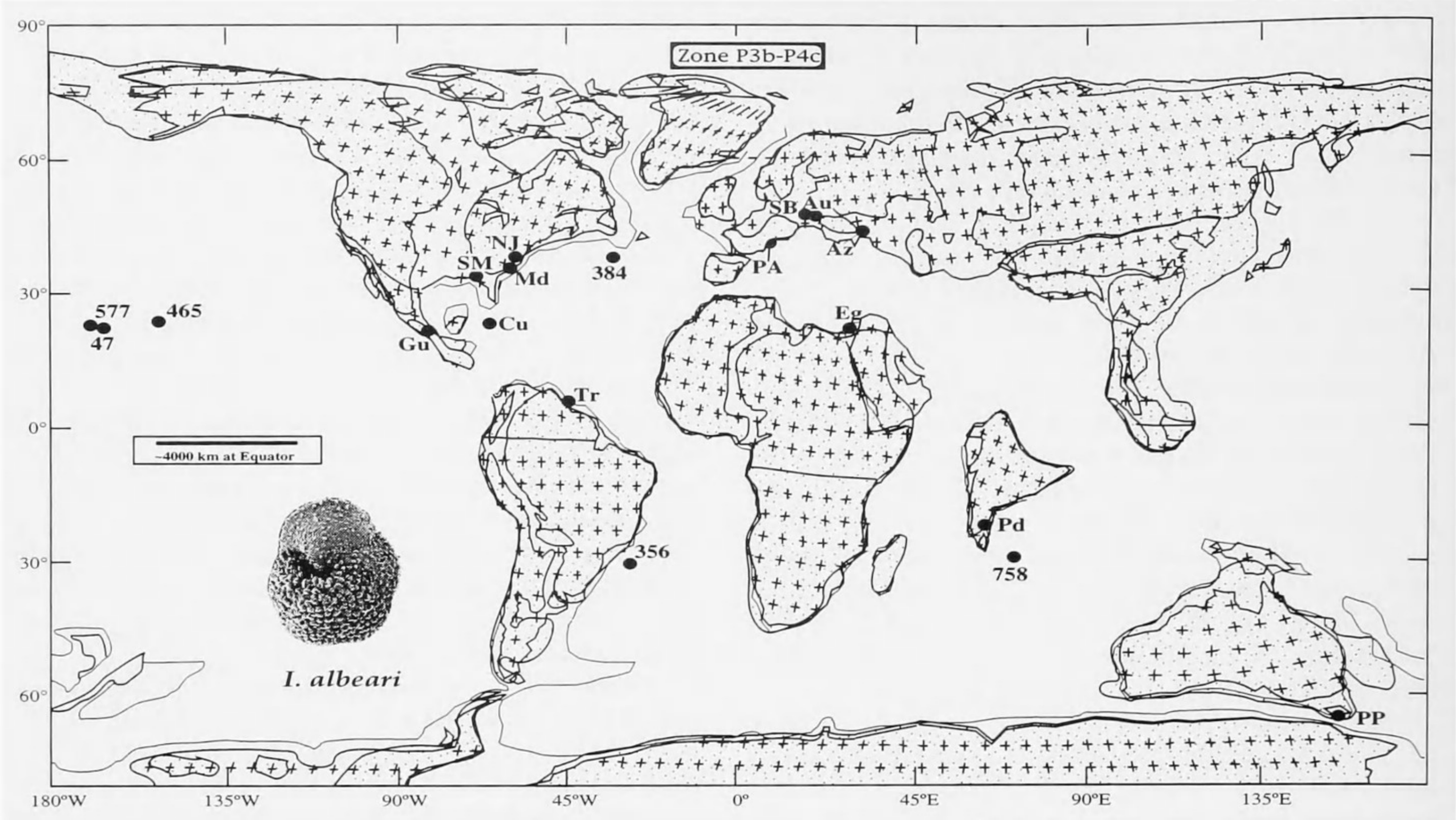

FIGURE 26.—Paleobiogeographic map showing distribution of *Igorina albeari* (Cushman and Bermúdez) in Zones P3 and P4.

ORIGIN OF SPECIES.—*Igorina albeari* is derived from *I. pusilla* by the development of compressed chambers and a keel on one or more chambers in the final whorl.

REPOSITORY.—Holotype (USNM CC47413) deposited in the Cushman Collection, National Museum of Natural History. Examined by WAB, RDN, and BTH.

Igorina pusilla (Bolli, 1957)

FIGURE 27; PLATE 16: FIGURES 7–9; PLATE 57: FIGURES 1–16

Globorotalia pusilla pusilla Bolli, 1957a:78, pl. 20: figs. 8–10 [*Globorotalia pusilla pusilla* Zone, Guayaguayare Well 159, Trinidad Leasholds, Ltd., Lizard Springs Fm., Trinidad].—Bolli and Cita, 1960:388, 389, pl. 34: fig. 4a–c [*Globorotalia pusilla pusilla* Zone, Paderno d'Adda, northern Italy].

Planorotalites tauricus Morozova, 1961:16, pl. 2: fig. 3 [*Acarinina indolensis* Subzone (Dn_2 III[1]), Michurino Substage, Urukh River, northern Caucasus].

Globorotalia (*Globorotalia* ?) *pusilla pusilla* Bolli.—Hillebrandt, 1962:128, pl. 11: fig. 18a,b [*Globorotalia pusilla pusilla* Zone, Reichenhall-Salzburg Basin, Austro-German border].

Globorotalia pusilla pusilla (?) Bolli.—Shutskaya, 1970b:218, pl. 22: fig. 3a–c [lower subzone of *Acarinina tadjikistanensis djanensis* Zone, lower Danatin Formation, Malyi Balkhan Ridge, western Turkmenia].

Globorotalia pusilla Bolli.—Pujol, 1983:652, pl. 2: figs. 12, 13 [*Globorotalia pusilla* Zone, DSDP Hole 516F/86/4: 6–9 cm; Rio Grande Rise, South Atlantic Ocean].

Morozovella pusilla pusilla (Bolli).—Snyder and Waters, 1985:446, 449, 460, pl. 8: figs. 15–17 [*Morovozella pusilla pusilla* Zone, DSDP Site 549/20/5: 18–20 cm; northeastern Atlantic Ocean].

Planorotalites pusilla pusilla (Bolli).—Toumarkine and Luterbacher, 1985:108, fig. 12:13a–c [holoype reillustrated], fig. 12:14a–c [Zone P3, DSDP Hole 144A/3/4: 120–122 cm; South Atlantic Ocean].

ORIGINAL DESCRIPTION.—"Shape of test low trochospiral, biconvex, compressed; equatorial periphery nearly circular, slightly lobate; axial periphery acute to subacute. Wall calcareous, perforate, surface smooth. Chambers compressed; 12–16, arranged in 2½–3 whorls, the 5–6 chambers of the last whorl increasing moderately in size. Sutures on spiral side strongly curved, slightly depressed; on umbilical side radial, depressed. Umbilicus narrow, open. Aperture a low arch, with narrow lip; interiomarginal, extraumbilical-umbilical. Coiling random. Largest diameter of holotype 0.24 mm." (Bolli, 1957a:78.)

DIAGNOSTIC CHARACTERS.—Relatively small (generally < 0.25 mm in diameter), essentially circular, biconvex, cancellate, pustulose test with 5–6 chambers in last whorl; intercameral sutures on umbilical side radial, depressed, on spiral side moderately to strongly curved, depressed/weakly incised; axial periphery subacute and non-carinate; umbilicus narrow, shallow, aperture an interiomarginal, umbilical-extraumbilical arch extending towards, but not reaching, the periphery.

DISCUSSION.—*Igorina pusilla* is the earliest representative of the biconvex, praemuricate igorinids. The small, biconvex

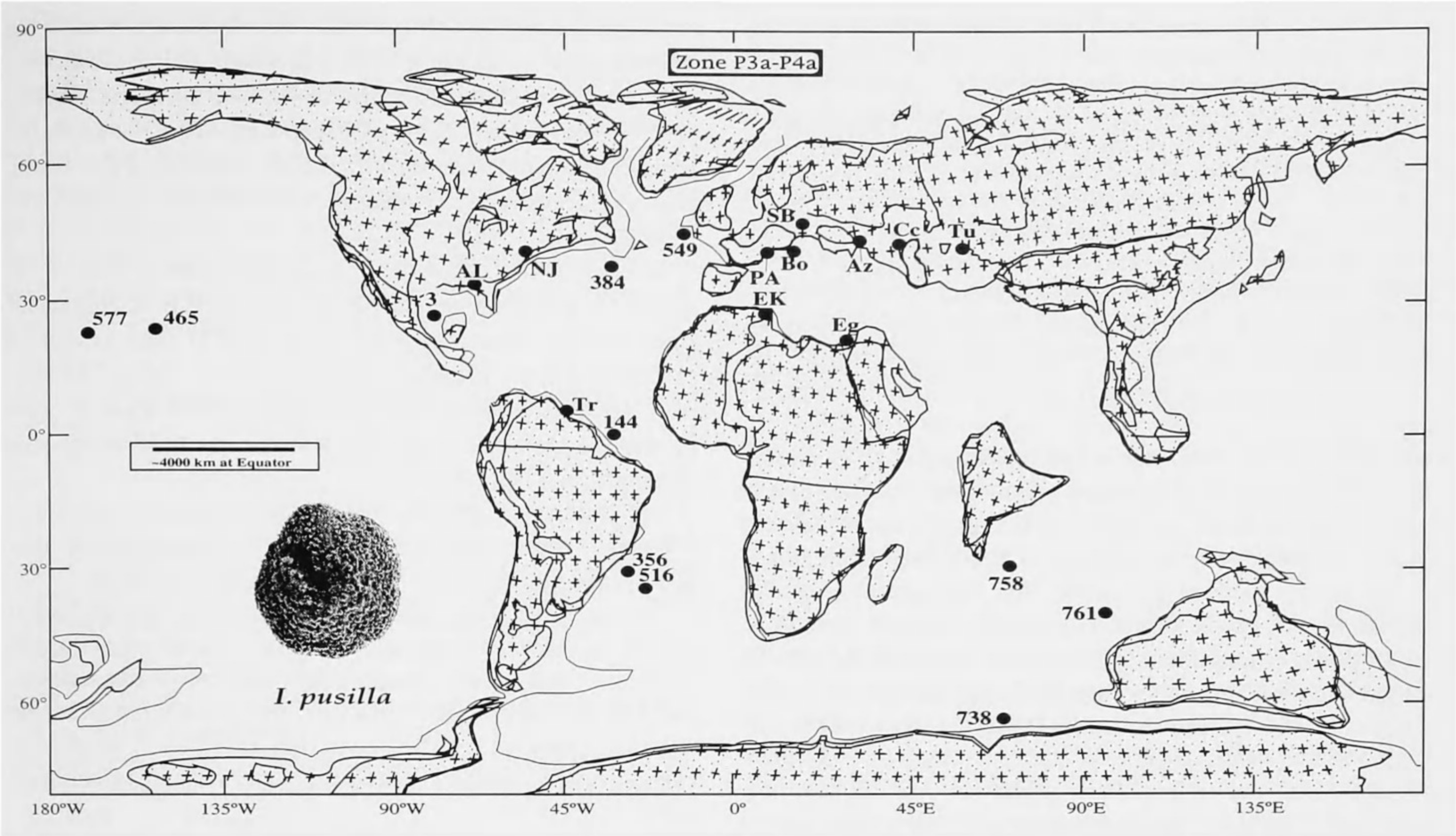

FIGURE 27.—Paleobiogeographic map showing distribution of *Igorina pusilla* (Bolli) in Zones P3 and P4.

test, deep funnel-shaped entrances to the pores, and distinctly praemuricate surface serves to differentiate this form (and its descendants) from the mainline morozovellids and suggests that *I. pusilla* represents the founding species of a separate lineage among early Paleogene planktonic foraminifera. There appears to be little confusion in the identification of this species. We note, however, that *Planorotalites tauricus* Morozova (1961) is a middle Paleocene igorinid species from the northern Caucacus that we regard as synonymous with *I. pusilla*.

STABLE ISOTOPES.—No data available.

STRATIGRAPHIC RANGE.—Zone P3a to Zone P3b (lower part).

GLOBAL DISTRIBUTION.—*Igorina pusilla* has been recorded from predominantly low latitude (sub)tropical locations (Figure 27).

ORIGIN OF SPECIES.—We believe that the igorinids are derived from the nonkeeled, praemuricate forms of the *inconstans-uncinata* plexus as previously suggested by Pearson (1993). Although the exact pattern of ancestry has not been worked out, *Igorina pusilla* is probably derived from forms similar to *P. inconstans* or *P. uncinata* by development of more involute coiling. This transformation may have occurred through the suppression of the later stages of ontogeny by speeding up the rate of maturation. This change in the timing of maturation would account for the small size of mature igorinids.

REPOSITORY.—Holotype (USNM P5064) deposited in the Cushman Collection, National Museum of Natural History. Examined by WAB, RDN, and BTH.

Igorina tadjikistanensis (Bykova, 1953)

PLATE 11: FIGURES 1–9; PLATE 58: FIGURES 1–12

Globorotalia tadjikistanensis Bykova, 1953:86, pl. 3: fig. 5a–c [*Globorotalia tadjikistanensis* Zone, Suzakian Stage, southern part of Tadzhik Basin, Ak-Tau, Kazakhstan; given as Eocene].—Leonov and Alimarina, 1960:53, pl. 7: figs. 1, 2, 7 [upper part *Globorotalia tadjikistanensis* Subzone, eastern facies, Khieu River section, northern Caucasus], figs. 3, 4, 7 [lower part *Globorotalia tadjikistanensis* Subzone, eastern facies, Khieu River section, northern Caucasus].—Luterbacher, 1964:52, text-fig. 52a–c [*Globorotalia pusilla pusilla* Zone, Gubbio section, central Apennines, Italy].

Globorotalia convexa Subbotina, 1953:209, pl. 17: fig. 2a–c [holotype], fig. 3a–c [zone of conical globorotaliids, Foraminiferal Layer, Series F1, Khieu River, Nal'chik, northern Caucasus].—Loeblich and Tappan, 1957a:188, pl. 48: fig. 4a–c [Zone P4, Vincentown Fm., New Jersey], pl. 50: fig. 7a–c [Zone P4, Hornerstown Fm., New Jersey], pl. 53: figs. 6a–8c [Zone P4, Aquia Fm., Maryland], pl. 57: figs. 5a–6c [Zone P4, Salt Mountain Limestone, Alabama], pl. 63: fig. 4a–c [Zone P4, Velasco Fm., Tamaulipas, Mexico].—Pujol, 1983:644, pl. 3: figs. 1, 2 [Zone P3, DSDP Hole 516F/88/2: 102–103 cm; Rio Grande Rise, South Atlantic Ocean].

Truncorotaloides (*Morozovella*) *convexus* (Subbotina).—McGowran, 1968:192, pl. 2: figs. 11–14 [*Truncorotaloides* (*Acarinina*) *mckannai* zonule, Boongerooda Greensand, Australia].

Globorotalia (*Acarinina*) *convexa* Subbotina.—Jenkins, 1971:81, pl. 3: figs. 79–83 [*Globigerina* (*Subbotina*) *triloculinoides* Zone, type Teurian, Te Uri Stream section, New Zealand].—Blow, 1979:920, pl. 85: figs. 2–7 [Zone P3, DSDP Hole 47.2/10/2: 80–82 cm], pl. 88: figs. 3, 4 [upper part of Zone P3, DSDP Hole 47.2/10/1: 72–74 cm], pl. 100: figs. 3, 5–9 [Zone P5, DSDP Hole 47.2/9/1: 64–66 cm; Shatsky Rise, northwestern Pacific Ocean].

Globorotalia (*Acarinina*) *convexa* cf. *convexa* Subbotina.—Blow, 1979:921, pl. 100: figs. 1, 2, 4 [Zone P5, DSDP Hole 47.2/9/1: 64–66 cm; Shatsky Rise, northwestern Pacific Ocean].

Globorotalia (*Morozovella*) *tadjikistanensis* Bykova.—Belford, 1984:10, pl. 18: figs. 18–23 [upper Paleocene, Wabag Sheet, Papua, New Guinea].

Morozovella convexa (Subbotina).—Stott and Kennett, 1990:560, pl. 3: figs. 5, 6 [Zone AP3, near AP3/4 boundary, ODP Hole 690B/19H/4: 36–40 cm; Maud Rise, Weddell Sea, Southern Ocean].

ORIGINAL DESCRIPTION.—"Test rounded in outline, biconvex, with a weakly sloping, convex evolute side, and an arched, cone-shaped, strongly convex ventral side. Peripheral margin weakly lobate. The spiral consists of about three whorls with six to eight chambers per whorl. On the ventral side, the umbilical ends of the chambers converge, usually forming a small, shallow umbilicus. The chambers on the dorsal side in the first one and one-half whorls are barely discernible; in the last one to one-half whorls they are rather low, flat, and curved. On the ventral side the chambers are triangularly curved, rather distinctly convex, and increase slightly in size as they are added. The septal sutures on the dorsal side are tapered. In the final one and one-half whorls they are slightly depressed. On the ventral side the sutures are depressed and curved. Apertural face not distinct. The aperture is not distinguishable. The wall is rough, covered with short, thin spines. Dimensions of holotype: large diameter 0.32 mm; small diameter 0.28 mm; thickness 0.20 mm." (Bykova, 1953:86; translated from Russian.)

DIAGNOSTIC CHARACTERS.—Relatively small (< 0.25 mm in diameter), nonspinose, biconvex, ovate to subcircular, moderately lobulate, densely and finely praemuricate test with 5-7 (rarely up to 9–10) chambers in last whorl; axial periphery subrounded to subacute, noncarinate; umbilical intercameral sutures curved, depressed, spiral sutures depressed, strongly recurved, tangential to inner whorl, often obscured by dense murical network; umbilicus small, shallow as a result of tight coiling mode, surrounded by an irregularly wavy umbilical shoulder formed by undulating periumbilical chamber apices; aperture a low, narrow interiomarginal, umbilical–extraumbilical slit bordered by a distinct lip and extending towards, but not reaching, the peripheral margin.

DISCUSSION.—This taxon is a distinct component of late Paleocene and earliest Eocene assemblages. Recent examination and SEM reillustration of the holotype specimen of the taxon *tadjikistanensis* (Plate 11: Figures 4–6) and *convexa* (Plate 11: Figures 1–3), described originally from the upper Paleocene of Kazakhstan (Bykova, 1953) and from the zone of conical globorotaliids (= Zones P6–P8) in the Kuban River section near Nal'chik, in the northern Caucasus (Subbotina, 1953), respectively, has shown the two forms to be conspecific, with the former having priority. We essentially follow the interpretation of Blow (1979), although unlike Blow we include certain forms illustrated by Loeblich and Tappan (1957a) from the synonymy of this species. We also include the multichambered variety identified as cf. *convexa* in this taxon, which presages its descendant *I. broedermanni* Cushman and Bermúdez.

STABLE ISOTOPES.—*Igorina tajikistanensis* has $\delta^{18}O$ slightly lighter than coexisting *M. velascoensis* at equivalent sizes and has distinctly more negative $\delta^{18}O$ than *Subbotina* (Shackleton et al., 1985; Berggren and Norris, 1997). The $\delta^{13}C$ of *I. tajikistanensis* displays a strong increase in $\delta^{13}C$ with increased size, which is similar to *Acarinina* and *Morozovella* (Berggren and Norris, 1997).

STRATIGRAPHIC RANGE.—Zone P3b to Zone P7.

GLOBAL DISTRIBUTION.—*Igorina tadjikistanensis* was broadly distributed in tropical and subtropical latitudes.

ORIGIN OF SPECIES.—This species probably evolved from *I. pusilla* in middle to upper Zone P3 by developing a more involute coiling mode, increasing the number of chambers in the final whorl, and developing a dense, finely praemuricate ornament. *Igorina tadjikistanensis* differs from *I. albeari* in being generally smaller, lower spired, and without a peripheral keel.

REPOSITORY.—Holotype (No. 2794-a) and paratype (No. 2794-a) deposited the micropaleontological collections at VNIGRI, St. Petersburg, Russia. Examined by FR.

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

TYPE SPECIES.—*Globigerina* (*Eoglobigerina*) *taurica* Morozova, 1961.

ORIGINAL DESCRIPTION.—"Test very low trochospiral with 10–15 chambers, and with 5–6, but occasionally more in the ultimate whorl. The chambers which are globular to slightly ovoid in shape increase very gradually in size. The arrangement of chambers in the coil is nearly planispiral although the last one or two chambers may be shifted slightly towards the umbilicus. The aperture is interiomarginal, umbilical to extraumbilical, a low to high arch which is bordered by a narrow lip that often is somewhat wider in the umbilical area. The umbilicus can vary from narrow and deep to fairly broad and wide but is open to the previous chambers. The wall is weakly to strongly cancellate and nonspinose." (Olsson, Hemleben, Berggren, and Liu, 1992:202.)

DIAGNOSTIC CHARACTERS.—Test very low trochospiral, 5-6, up to 8 in some species, globular to oval chambers in last whorl that increase slowly to moderately in size; periphery moderately to distinctly lobulate; nonspinose, cancellate wall texture weakly developed; aperture an interiomarginal, umbilical-extraumbilical low to high rounded arch, bordered by a thin lip.

DISCUSSION.—The wall texture of *Praemurica* (Plate 6: Figures 2–4) is similar to that observed in the modern *Neogloboquadrina dutertrei* (d'Orbigny) (Plate 5: Figures 9, 10). Elongate subparallel ridges, often with an orientation towards the aperture, are connected by shorter less well-developed ridges that are thicker and broader on one side. This gives the test a cancellate wall texture, which is herein termed praemuricate. It is the first distinctive nonspinose, pustulose wall texture to evolve in the phylogeny of the early Paleocene planktonic foraminifera.

Praemurica inconstans (Subbotina, 1953)

FIGURE 28; PLATE 10: FIGURES 4–8; PLATE 14: FIGURES 13, 14; PLATE 59: FIGURES 1–16

Globigerina inconstans Subbotina, 1953:58, pl. 3: figs. 1, 2 [holotype, fig. 1; both specimens from zone of rotaliform globorotaliids, Elburgan Fm., Kuban River, northern Caucasus = middle part of *Acarinina inconstans* Zone of Leonova and Alimarina, 1960].—Berggren, 1965:291, text-fig. 9:3, 4 [Zone P2, Mexia Clay member, Wills Point Fm., Midway Group, Mexia, Texas].

Globigerina schachdagica Khalilov, 1956:246, pl. 1: fig. 3 [holotype: Danian Stage, Zeid, northwestern Azerbaidzhan].

Acarinina praecursoria Morozova, 1957:1111, text-fig. 1 [Danian, Khokodze River, northern Caucasus].

Globorotalia trinidadensis Bolli, 1957a:73, pl. 16: figs. 19–21 [holotype], figs. 22, 23 [*Globorotalia trinidadensis* Zone, lower Lizard Springs Fm., Trinidad].

Transitional form between *Globorotalia pseudobulloides* (Plummer) and *Globorotalia uncinata* Bolli.—Bolli, 1957a:74, pl. 17: figs. 16–18 [*Globorotalia uncinata* Zone, lower Lizard Springs Fm., Trinidad].

Globorotalia (Acarinina) inconstans (Subbotina).—Leonov and Alimarina, 1960, pl. 3: figs. 1–3, 5–8 [*Globorotalia inconstans* Subzone: figs. 1, 7, Podkhoomok River section; figs. 2–6, Khieu River; fig. 8, Urukh River, northern Caucasus].

Globorotalia scabrosa Bermúdez, 1961:1196, 1197, pl. 5: fig. 5 [Petromex Well, 200 m, La Palma 56, Panuco, Veracruz, Mexico].

Globigerina scobinata Bermúdez 1961:1197, pl. 5: fig. 6 [Madruga Fm., Madruga, Havana Province, Cuba].

Globorotalia (Globorotalia) inconstans (Subbotina).—Hillebrandt, 1962:130, pl. 12: figs. 7, 8 [Zone B, Reichenhall-Salzburg Basin, Austro-German border].

Globorotalia inconstans (Subbotina).—Luterbacher, 1964:650: figs. 19–23 [figs. 19, 23, topotypes from zone of rotaliform globorotaliids, upper part of Elburgan Fm., Kuban River, northern Caucasus; figs. 20, 22, *Globorotalia trinidadensis* Zone, Gubbio section, central Apennines, Italy].

Globigerina arabica El-Naggar, 1966:157, 158, pl. 18: fig. 6 [holotype from Sample 30, Gebel Owaina, *Globorotalia compressa/Globigerina daubjergensis* Zone, upper Danian, Nile Valley, Egypt].

Acarinina inconstans inconstans (Subbotina).—Shutskaya, 1970b:108, pl. 6: figs. 4, 5 [middle part *Acarinina inconstans* Zone: fig. 4, western Turkmenia, Malyi Balkhan; fig. 5, Elburgan Fm., northern Caucasus].

Globorotalia (Turborotalia) inconstans (Subbotina).—Blow, 1979:1080, pl. 71: figs. 6, 7 [Zone P1, DSDP Hole 47.2/1/1: top], pl. 75: figs. 4–7 [Zone P1, Lindi area, Tanzania], pl. 76: figs. 3, 6, 7 [Zone P2, DSDP Hole 47.2/10/6: 69–71 cm], fig. 10 [Zone P2, Hole 47.2/10/5: 70–72 cm], pl. 77: fig. 1 [Zone P2, DSDP Hole 20C/6/4: 72–74 cm; Brazil Basin, South Atlantic Ocean], pl. 81: figs. 1, 2 [Zone P2, DSDP Hole 47.2/10/4: 83–85 cm; Shatsky Rise, northwestern Pacific Ocean], pl. 233: figs. 4, 5 [Zone P1, Lindi area, Tanzania].

Subbotina inconstans (Subbotina).—Stott and Kennett, 1990:559, pl. 2: figs. 5, 6 [Subzone AP1b, upper Danian, ODP Hole 690C/14X/2: 36–40 cm; Maud Rise, Weddell Sea, Southern Ocean].

Morozovella inconstans (Subbotina).—Berggren, 1992:564, pl. 1: figs. 12, 13 [Subzone P1c, ODP Hole 747A/19H/CC: Kerguelen Plateau, southern Indian Ocean].

ORIGINAL DESCRIPTION.—"Test with round or broadly oval outline consisting of 2–2½ whorls to the spiral. Peripheral margin rounded, weakly lobulate. The early whorls are disproportionately small relative to the last whorl. They (the whorls) are situated either on the same plane as the last whorl or even below it. The last whorl contains 5–6 chambers which increase gradually in size; the last chamber is often considerably larger than the others. However, there are some individuals in which the last three chambers are of equal size.

"Dorsal side very strongly compressed, ventral side convex, in certain forms conical. There is a well-defined, shallow umbilicus in the middle of the ventral side. Chambers spherical, closely packed together. The outline of the dorsal side of the chambers is rounded and that of the ventral side is either rounded or triangular.

"Sutures simple, curved in the form of an arc. On the ventral side they radiate from the umbilicus. Aperture slit-like, situated along the marginal suture. Walls smooth, often finely cancellate. Dimensions: diameter 0.35–0.45 mm, thickness 0.12–0.20 mm." (Subbotina, 1953:58; translated from Russian.)

DIAGNOSTIC CHARACTERS.—Nonspinose, subcircular to broadly elongate-oval, moderately lobulate, 5–7 chambered, cancellate test; peripheral margin rounded to weakly subangular, chambers in early whorls tightly coiled, rapidly expanding in final whorl; sutures radial, straight to weakly curved in early forms, more strongly curved and weakly incised in more advanced forms; aperture an interiomarginal, umbilical-extraumbilical slit with distinct, lipped rim.

DISCUSSION.—The extensive synonymy above reflects our current understanding and interpretation of this taxon. A variety of morphotypes have been ascribed to *inconstans–trinidadensis–praecursoria* over the past 40 years and assigned to the genera *Globigerina, Globorotalia, Acarinina, Subbotina,* and *Turborotalia.* We include this form in the genus *Praemurica* following the demonstration by Olsson et al. (1992) of a phylogenetically distinct and homogenous lower Paleocene cancellate, nonspinose lineage. One of us (WAB) has examined the type specimens of *inconstans, praecursoria, trinidadensis,* and *schachdagica* and the synonymic listing above is based to a large extent on those studies. The wide range of variation ascribed herein to this morphospecies unifies forms sharing the characteristics of a cancellate, nonspinose test intermediate between the *pseudoinconstans–taurica* morphology and the typically anguloconical, nonkeeled *uncinata* morphology.

STABLE ISOTOPES.—*Praemurica inconstans* has more positive $\delta^{13}C$ and more negative $\delta^{18}O$ than *Subbotina* and *Globanomalina* but has a similar isotopic signature to *P. taurica* (Boersma and Premoli Silva, 1983; Berggren and Norris, 1997). There is a pronounced increase in $\delta^{13}C$ with increased size in *P. inconstans* (Kelley et al., 1996).

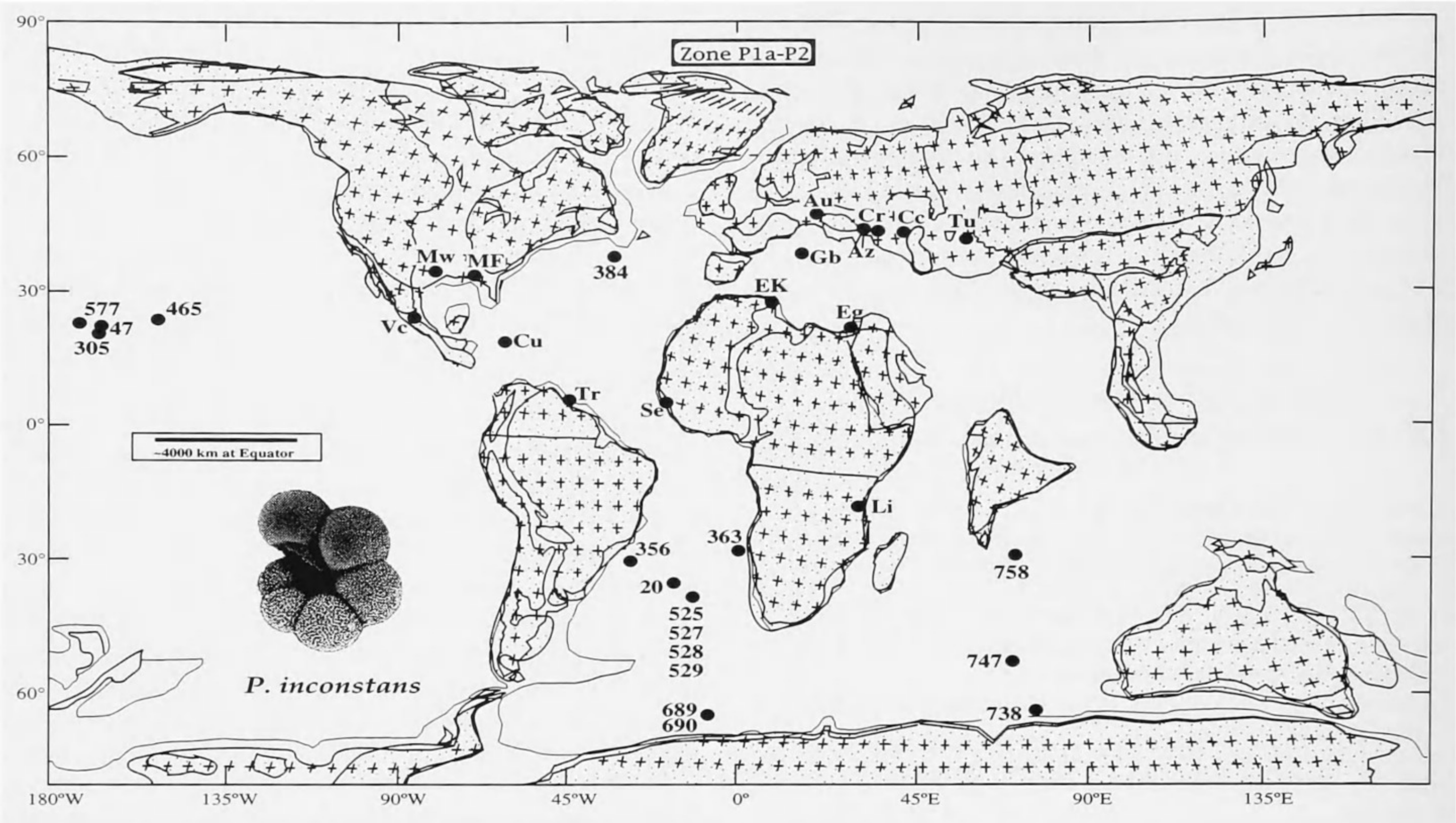

FIGURE 28.—Paleobiogeographic map showing distribution of *Praemurica inconstans* (Subbotina) in Zone P2.

STRATIGRAPHIC RANGE.—Zone P1c to lower Zone P3.

GLOBAL DISTRIBUTION.—A cosmopolitan species in northern and southern hemisphere sections (Figure 28).

ORIGIN OF SPECIES.—This morphospecies evolved from *Praemurica pseudoinconstans* by the development of umbilical-conical chambers in morphologically advanced forms, development of incised umbilical sutures, and an increase in the number of chambers in the final whorl.

REPOSITORY.—Holotype (No. 3992) and paratype (No. 3993) deposited in the micropaleontological collections at VNIGRI, St. Petersburg, Russia. Examined by WAB.

Praemurica pseudoinconstans (Blow, 1979)

PLATE 60: FIGURES 1–13

Globorotalia pseudobulloides (Plummer).—Loeblich and Tappan, 1957a:192, pl. 40: fig. 9a–c [paratype, Pine Barren Mbr., Clayton Fm., Alabama] [in part]. [Not Plummer, 1926.]

Globorotalia (*Turborotalia*) *pseudoinconstans* Blow, 1979:1105, pl. 67: fig. 4 [holotype: Zone Pα, DSDP Hole 47.2/11/3: 148–150 cm], pl. 67: fig. 3 [paratypes: Zone Pα, DSDP Hole 47.2/11/3: 148–150 cm], pl. 69: fig. 4 [paratypes: Zone P1, DSDP Hole 47.2/11/3: 0–5 cm; Shatsky Rise, northwestern Pacific Ocean].

"*Morozovella*" *inconstans* (Subbotina).—Huber, 1991c:461, pl. 3: figs. 11, 12 [Zone AP1b, ODP Hole 738C/19R: 365.22 mbsf; Kerguelen Plateau, southern Indian Ocean]. [Not Subbotina, 1953.]

Praemurica pseudoinconstans (Blow).—Olsson, Hemleben, Berggren, and Liu, 1992:202, pl. 6: figs. 1, 4 [Zone Pα, Clayton Basal Sands, Millers Ferry, Alabama]: figs. 2, 3, 5–8 [Zone P1a, Pine Barren Mbr., Clayton Fm., Millers Ferry, Alabama].

ORIGINAL DESCRIPTION.—"The comparatively small test is coiled in a low, fairly lax, trochospire with 6 complete chambers visible in the last convolution of the test together with a small part of a seventh chamber and about 12–14 chambers comprising the spire. In dorsal aspect, the chambers are sensibly equidimensional, inflated and subglobular, with quite distinctly incised dorsal intercameral sutures; these intercameral sutures are radially disposed. In ventral aspect, the chambers are inflated, subglobular, but are slightly more embracing and appressed than as seen in dorsal aspect. The chambers increase evenly, but only slowly, in size as added in the progression of the trochospire. The umbilicus is widely open, moderately deep and clearly delimited by the umbilical shoulders of the last convolution of chambers. The primary aperture is slit-like near the umbilicus but widens to become highly arched at, or near to, the peripheral margin of the test; the aperture is bordered by a strongly developed flap-like lip proximally, which extends into the umbilical depression. Distally, the lip of the aperture is more rim-like and is less broad than seen proximally. Within the umbilicus, relict apertures are present for chambers prior to the last and their apertural lips are confluent with the lip of the ultimate chamber. The equatorial profile is subcircular to slightly elongate in the direction of the diameter which bisects the final chamber; the equatorial profile is also moderately lobulate. The axial-apertural profile shows an equally biconvex test with rounded peripheral margins. The wall texture of the test is finely and densely perforate and, over the earlier chambers of the last whorl, the mural-pores open into small pore-pits. The inter-pore ridges show a meandriform pattern which is characteristic. Maximum diameter of holotype 0.328 mm. as measured by electron beam sensor." (Blow, 1979:1105.)

DIAGNOSTIC CHARACTERS.—Ultimate whorl with 5–5½ chambers of which first few increasing in size gradually, final few increasing in size more rapidly; last chamber slightly offset toward umbilicus in some specimens. Aperture a high rounded arch, bordered by a narrow lip broadening toward umbilicus; aperture not as pronounced as *P. taurica*. Cancellate wall texture weakly developed, difficult to view with light microscope, especially in poorly preserved specimens. Pores about 1 μm in diameter at narrowest point, positioned at bases of cancellate ridges. Walls about 4 μm thick, overall test size up to 300 μm across.

DISCUSSION.—*Praemurica pseudoinconstans* is a fairly common species that may be confused with the less common *Parasubbotina pseudobulloides* (Plummer). Indeed, Blow (1979) carefully distinguished the two species and selected as a paratype a specimen from the Clayton Formation, Alabama, previously identified by Loeblich and Tappan (1957a) as *P. pseudobulloides*. The chambers in *P. pseudobulloides* increase more rapidly in size and are more inflated than in *P. pseudoinconstans*. *Parasubbotina pseudobulloides* is spinose in contrast to *P. pseudoinconstans*, which is nonspinose. The meandriform pattern of the interpore ridges noted by Blow (1979) is due to the *Neogloboquadrina dutertrei*-like wall texture observed in this species under SEM. In this type of wall texture, the pores are often not isolated from one another by interpore ridges as in *P. pseudobulloides*. Except for their general appearance, the two wall textures are fundamentally different.

STABLE ISOTOPES.—No data available.

STRATIGRAPHIC RANGE.—Zone Pα to Zone P2.

GLOBAL DISTRIBUTION.—Originally described from DSDP Site 47, Shatsky Rise, northwestern Pacific Ocean. It also occurs in Alabama and in the South Atlantic Ocean at DSDP Site 356.

ORIGIN OF SPECIES.—Evolved from *Praemurica taurica* in middle Biochron Pα by increasing the rate of expansion of the last few chambers in the ultimate whorl.

REPOSITORY.—Holotype (BP Cat. No. 37/134) and paratypes (BP Cat. No. 37/135, 40/7) deposited in the micropaleontological collections at The Natural History Museum, London. Paratype (USNM P5724) deposited in the Cushman Collection, National Museum of Natural History. Paratype (USNM P5724) examined by WAB and RKO.

Praemurica taurica (Morozova, 1961)

FIGURE 29; PLATE 10: FIGURES 1–3; PLATE 61: FIGURES 1–15

Globigerina (*Eoglobigerina*) *taurica* Morozova, 1961:10, pl. 1: fig. 5a–c [lower Danian Stage (Uylin Substage), Dn1 I Zone, *Globigerina* (*Eoglobigerina*) *taurica* Zone, Tarkhankut Peninsula, Crimea].

Morozovella taurica (Morozova).—Berggren, 1992:564, pl. 1: figs. 9–11 [Danian, ODP Hole 747C/3H/2: 22–24 cm; Kerguelen Plateau, southern Indian Ocean].

Praemurica taurica (Morozova).—Olsson, Hemleben, Berggren, and Liu, 1992:202, pl. 5: figs. 1–8 [Zone P1a, Pine Barren Mbr., Clayton Fm., Millers Ferry, Alabama].

ORIGINAL DESCRIPTION.—"Test with a subpolygonal lateral outline, strongly compressed along the growth axis. Spire consists of three whorls. Early whorls lie on one level with the surface of the last whorl or rise up slightly above it. In each whorl there are five to six inflated subspherical chambers, rapidly and uniformly increasing in size and arranged freely. Peripherally on the chambers a small papillate projection, directed toward the subsequent chamber, is frequently observed. Last chamber asymmetrical, flattened at the apertural face and slightly shifted toward the umbilical surface. Equatorial outer margin scalloped. Axial outer margin weakly asymmetric, broadly rounded. Sutures deep, straight. Umbilicus narrow. Aperture a semicircular slit located between the umbilicus and the outer margin. Sometimes it is surrounded by a very narrow lip, the width of which is uniform over its whole length. Wall smooth, finely perforate. Surface lustrous or matte.

"Dimensions of holotype (fig. 5a–c): greatest diameter 0.45, least diameter 0.32, height 0.21 mm.

"*Variability*: The form of the test, changing from oval to rounded, and the number of chambers in a whorl are not constant. Tests are predominant in which the last whorl there are five to six chambers, but are encountered with four and a half, seven, or eight chambers to a whorl.

"*Comparison*: From the near species *Globigerina cretacea* d'Orbigny, 1840, and *G. edita* Subbotina, 1949, this species differs by its flatter, low test, the often oval outlines, more flattened spiral side, greater number (5–6) of chambers in the last whorl, the asymmetrical shape of the last chamber, which stands above the umbilicus, and the small umbilical aperture." (Morozova, 1961:10; translated from Russian.)

DIAGNOSTIC CHARACTERS.—Characterized by a very low trochospiral test with 5–6, occasionally more, chambers in ultimate whorl. Globular to slightly ovoid chambers increase very gradually in size with last one or two occasionally slightly shifted towards umbilicus. Umbilical-extraumbilical aperture a low to high arch bordered by narrow lip broadening towards umbilicus and becoming somewhat triangular in shape. In well-preserved specimens, lips from previous chambers project as small flaps into fairly wide, broad umbilicus having a deep depression. Cancellate structure weakly developed.

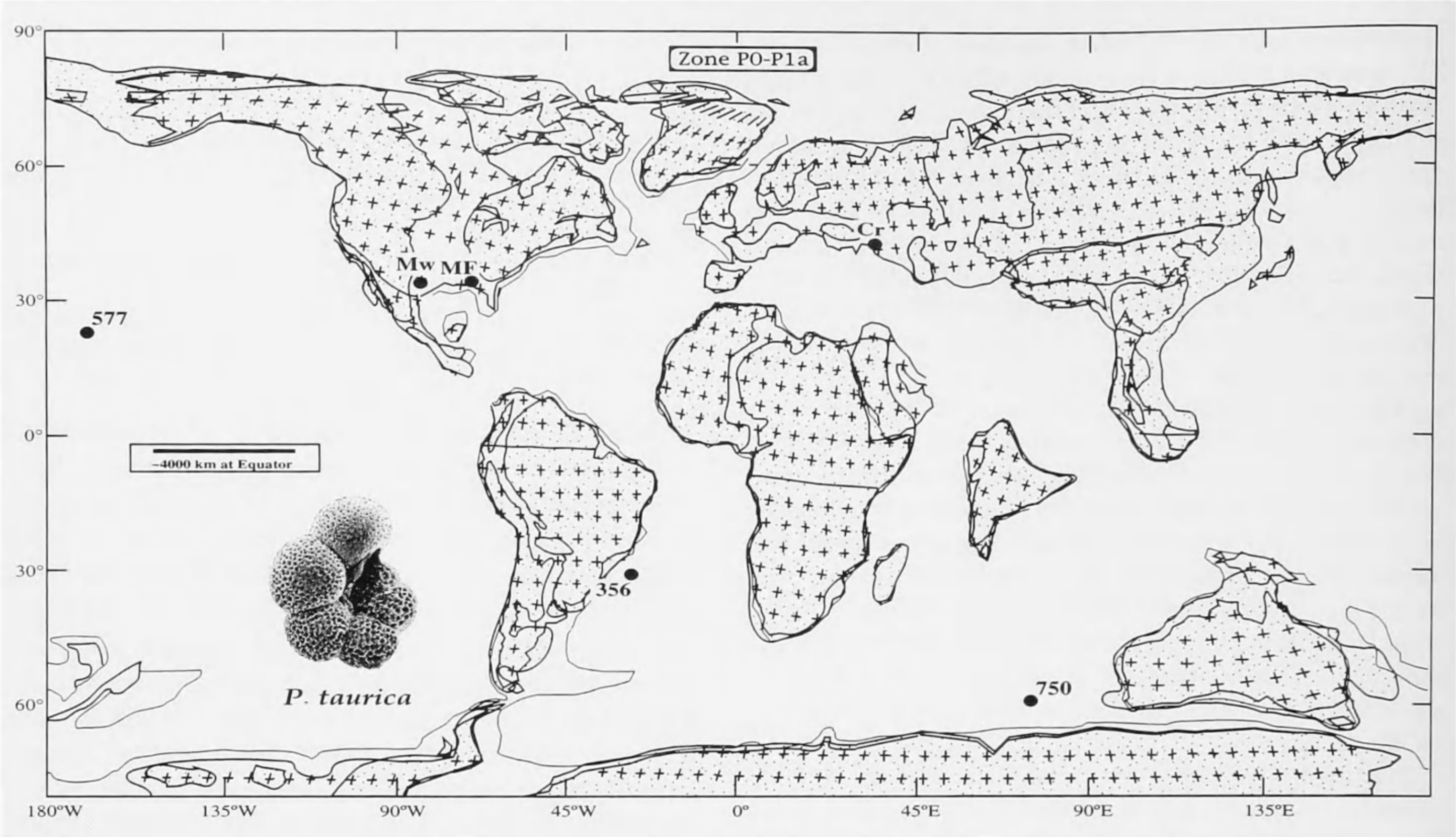

FIGURE 29.—Paleobiogeographic map showing distribution of *Praemurica taurica* (Morozova) in Zone P1.

DISCUSSION.—This is the first species of *Praemurica* to evolve from *Hedbergella monmouthensis* in the basal Danian. It is fairly commmon in Zone Pα. Although the cancellate wall texture is weakly developed, it is distinctive under SEM, being nearly identical to the living species *Neogloboquadrina dutertrei*. *Praemurica taurica* is a stem form of an important lineage leading to *P. uncinata*.

STABLE ISOTOPES.—*Praemurica taurica* has more positive $\delta^{13}C$ and more negative $\delta^{18}O$ than *Subbotina* and *Globanomalina* in the late Danian, but all these taxa have similar isotopic signatures in the earliest Danian (Berggren and Norris, 1997). There is a pronounced increase in $\delta^{13}C$ with increased size in *P. taurica* among small specimens (up to ~200 µm; D'Hondt and Zachos, 1993) but a weak trend above this size (Norris, 1996).

STRATIGRAPHIC RANGE.—Upper Zone P0 to Zone P1b; ? P1c.

GLOBAL DISTRIBUTION.—Worldwide in the high to low latitudes (Figure 29).

ORIGIN OF SPECIES.—This species evolved from *Hedbergella monmouthensis* in late Biochron P0. It is the stem form of the praemuricate *pseudoinconstans–inconstans–uncinata* lineage of the lower Paleocene (Danian) Zones P1 and P2.

REPOSITORY.—Holotype (No. 3510/1) deposited at GAN, Moscow. Examined by FR.

Praemurica uncinata (Bolli, 1957)

FIGURE 30; PLATE 10: FIGURES 9–11; PLATE 14: FIGURES 9–11; PLATE 62: FIGURES 1–16

Globorotalia uncinata Bolli, 1957a:74, pl. 17: figs. 13–15 [*Globorotalia uncinata* Zone, lower Lizard Springs Fm., Trinidad].—Luterbacher, 1964:655, 657, fig. 30a–c [*Globorotalia uncinata* Zone, level G-85, Gubbio section, central Apennines, Italy], fig. 31a–c [topotype, Trinidad].—Said and Sabry, 1964:385, 386, pl. 1: fig. 12a–c [*Globorotalia uncinata* Zone, Esna Shale, Gebel Aweina, Egypt].—Berggren, 1965:294, text-fig. 9 (5a–c) [*Globorotalia uncinata* Zone, Mexia Clay Mbr., Wills Point Fm., Mexia, Texas].—Toumarkine, 1978:692, 693, pl. 1: fig. 16 [*Globorotalia uncinata* Zone, DSDP Site 363/17/1: 87–89 cm; Walvis Ridge, South Atlantic Ocean].—Pujol, 1983:645, 652, pl. 2: fig. 1 [*Globorotalia uncinata* Zone, DSDP Hole 516F/87/7: 39–40 cm; Rio Grande Rise, South Atlantic Ocean].

Acarinina indolensis Morozova, 1959:1116, text-fig. 1 [Danian, *Globoconusa daubjergensis*/*Acarinina indolensis* Zone, northwestern Crimea].

Globorotalia uncinata uncinata Bolli.—El-Naggar, 1966:240, pl. 18: fig. 1a–c, pl. 19: fig. 2a–c [samples S.34 and S.36, respectively, both *Globorotalia uncinata* Zone, lower Esna Shale, Gebel Oweina, Egypt].

Acarinina inconstans uncinata (Bolli).—Shutskaya, 1970a:110, pl. 6: fig. 1a–c [holotype refigured], fig. 2a–c [middle part of *Acarinina inconstans* Zone, Elburgan Fm., Kuban River, northern Caucasus], fig. 3a–c [lower part of *Globigerina trivialis–Globoconusa daubjergensis–Globorotalia compressa* Zone, northern Osetiya, Urukh River, northern Caucasus]; 1970b:118–120, pl. 19: figs. 7a–c, 10a–c [*Acarinina inconstans* Zone, Elburgan Fm., Kuban River, Cherkessk region, northern Caucasus].

Globorotalia (*Acarinina*) *praecursoria praecursoria* (Morozova).—Blow, 1979:944–947, pl. 76: figs. 4, 8, 9, pl. 81: fig. 3 [Zone P2, DSDP Hole

47.2/10/5: 70–72 cm], pl. 77: figs. 2–5 [Zone P2, DSDP Hole 20C/6/4: 72–74 cm; Brazil Basin, South Atlantic Ocean], pl. 82: figs. 1–3 [Zone P2, recollection of *Globorotalia uncinata* type locality, Trinidad], pl. 84: fig. 2, pl. 85: fig. 9 [Zone P3, DSDP Hole 47.2/10/2: 80–82 cm; Shatsky Rise, northwestern Pacific Ocean]. [Not Morozova, 1961.]

Morozovella uncinata (Bolli).—Snyder and Waters, 1985:448, 449, pl. 10: figs. 1, 2 [*Globorotalia uncinata* Zone, DSDP Site 550/37/5: 59–61 cm; Porcupine Abyssal Plain, northeastern Atlantic Ocean].

ORIGINAL DESCRIPTION.—"Shape of test low trochospiral, spiral side almost flat or slightly convex, umbilical side distinctly convex; equatorial periphery distinctly lobate; axial periphery rounded to subangular. Wall calcareous, perforate, surface finely spinose. Chambers subangular, inflated, laterally compressed; 12–15, arranged in about 2½ whorls, the 5–6 chambers of last whorl increasing moderately in size. Sutures on spiral side strongly curved, depressed; on umbilical side radial, depressed. Umbilicus fairly narrow, deep, open. Aperture a low arch; interiomarginal, extraumbilical-umbilical. Coiling random. Largest diameter of holotype 0.35 mm." (Bolli, 1957a:74.)

DIAGNOSTIC CHARACTERS.—Nonspinose, weakly cancellate, elongate-oval, plano-convex to moderately high spired, moderately lobulate test with 5–8 chambers in last whorl; chambers occasionally so loosely coiled as to form secondary spiral apertures between them; sutures on umbilical side radial, depressed, on spiral side incised and strongly recurved yielding typically trapezoidal-shaped chambers; axial periphery subangular, noncarinate but with rugose muricae often situated along peripheral margin of early chambers of last whorl; umbilicus typically narrow, deep, bordered by weakly developed circumumbilical shoulder formed by raised periumbilical chamber extensions; aperture a narrow interiomarginal, umbilical-extraumbilical arch extending to peripheral margin.

DISCUSSION.—Blow (1979) argued the case for including *uncinata* Bolli, 1957a, as a junior synonym of *praecursoria* Morozova, 1957. Our examination of the holotypes of both of these forms leads us to reject this interpretation. Rather, we interpret *praecursoria* as an advanced, atypically large end-member of *inconstans* that is characterized by rounded chambers and an axial periphery, and we reserve for *uncinata* those forms exhibiting the typical anguloconical (but noncarinate) test with distinctly incised and recurved spiral intercameral sutures. *Acarinina indolensis* Morozova (1959) is a small form of *P. uncinata* with five chambers in the final whorl but, nevertheless, exhibits the characteristic morphology of this species.

STABLE ISOTOPES.—*Praemurica uncinata* has more positive $\delta^{13}C$ and more negative $\delta^{18}O$ than *Subbotina* and *Globanomalina* and has an isotopic signature similar to that of *Morozovella praeangulata* (Shackleton et al., 1985; Berggren and Norris, 1997). There is a pronounced increase in $\delta^{13}C$ with increased size in *P. uncinata* (Kelly et al., 1996; Norris, 1996).

STRATIGRAPHIC RANGE.—Zone P2 to lower Zone P3.

GLOBAL DISTRIBUTION.—This taxon has been widely reported in the literature from predominantly low latitude (sub)tropical localities. Shutskaya (1970a, 1970b) recorded it from several localities in the northern Caucasus. This species does not appear to occur in high southern latitudes (Stott and Kennett, 1990; Huber, 1991b), and we have not found it in our examination of material from the southern part of the Indian Ocean (Figure 30).

ORIGIN OF SPECIES.—This species evolved from *Praemurica inconstans* at the base of Zone P2 by extension of the umbilically conical chambers into most of the final whorl, and by the formation of blunt pustules around the umbilicus and on the initial chambers of the final whorl.

REPOSITORY.—Holotype (USNM P5048) deposited in the Cushman Collection, National Museum of Natural History. Examined by WAB and RDN.

Family GUEMBELITRIIDAE Montanaro Gallitelli, 1957

(by S. D'Hondt, C. Liu, and R.K. Olsson)

Guembelitriinae Montanaro Gallitelli, 1957:136 [subfamily].
Guembelitriidae El-Naggar, 1971:431 [nomen translatum ex subfamily].

ORIGINAL DESCRIPTION.—"Test triserial; chambers globular; aperture basal, arched, simple." (Montanaro Gallitelli, 1957:136.)

DIAGNOSTIC CHARACTERS.—Original description of foraminiferal tests assignable to subfamily Guembelitriinae does not apply to all members of family Guembelitriidae. Tests of guembelitriid foraminifera either triserial (*Guembelitria* spp.), trochospiral (*Parvularugoglobigerina* spp., *Globoconusa* spp.), or nearly triserial in initial whorl and approximately biserial in later whorls (*Woodringina* spp.). Chambers usually globular or subglobular, increasing gradually in size. Aperture usually a loop-shaped arch, often slightly infolded on one side, marked by a fine lip. Surface texture microperforate, smooth to pustulous; when present, pustules or small mounds generally perforated by one or more pores ("pore-mounds") (*Guembelitria, Parvularugoglobigerina, Woodringina*) or peripherally associated with pores (*Globoconusa*).

DISCUSSION.—Montanaro Gallitelli (1957) emended the family Heterohelicidae Cushman, 1927a, by creating the subfamily Guembelitriinae for the triserial genera *Guembelitria* Cushman, 1933, and *Guembelitriella* Tappan, 1940. Loeblich and Tappan (1957a) assigned *Woodringina* Loeblich and Tappan, 1957, to the Guembelitriinae, implicitly modifying the definition of the Guembelitriinae to include forms that are triserial in the first whorl and biserial in later whorls. El-Naggar (1971) raised the Guembelitriidae to family status, and Blow (1979) explicitly broadened its definition to include morphotypes with biserial and trochospiral stages.

The assignment of biserial *Woodringina* species to the Guembelitriidae rests on the hypothesis that *Woodringina* species were derived from *Guembelitria cretacea* Cushman, 1933. This phylogenetic hypothesis is a subset of the broader

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.

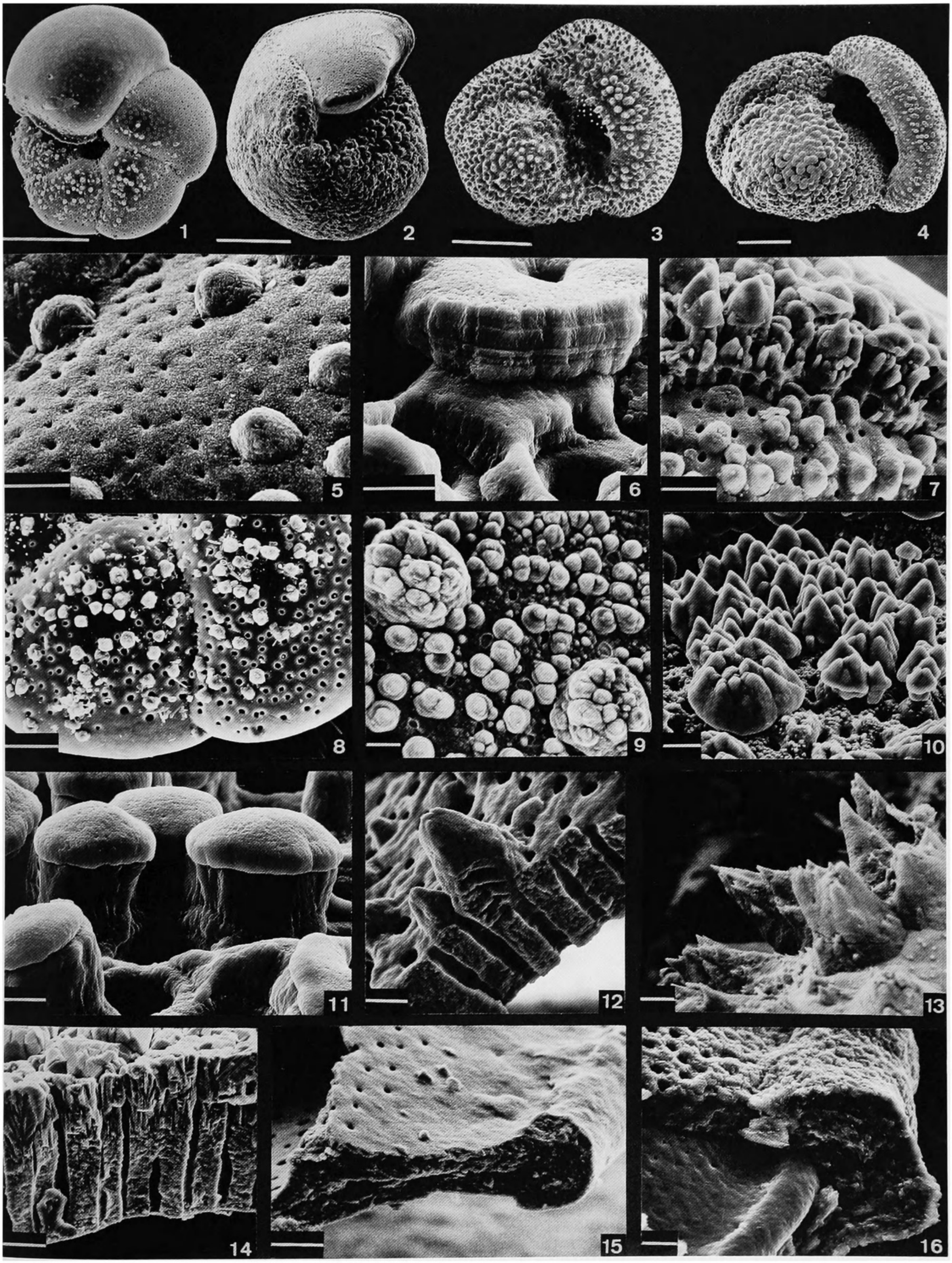
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PLATE 4

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.

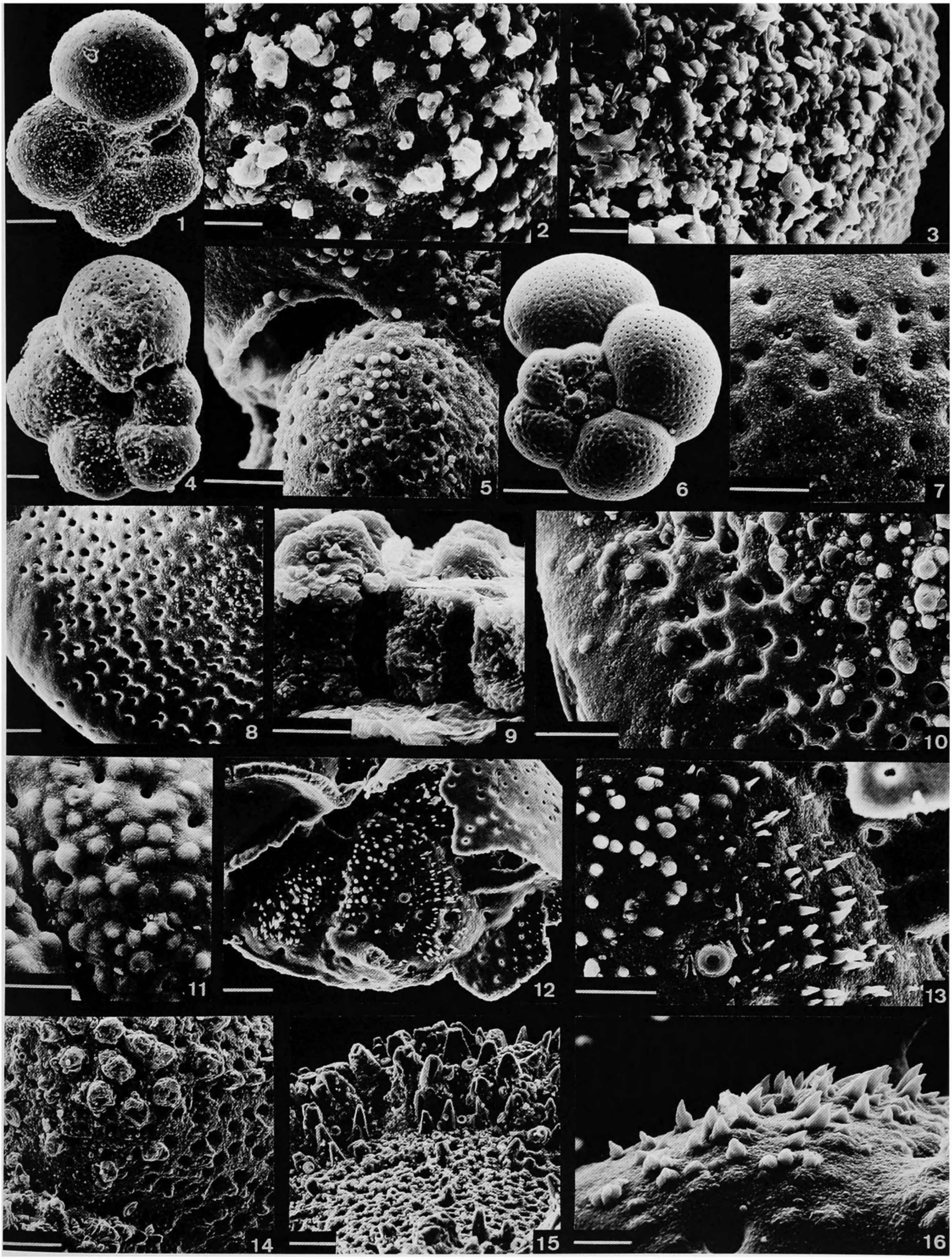
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PLATE 5

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.

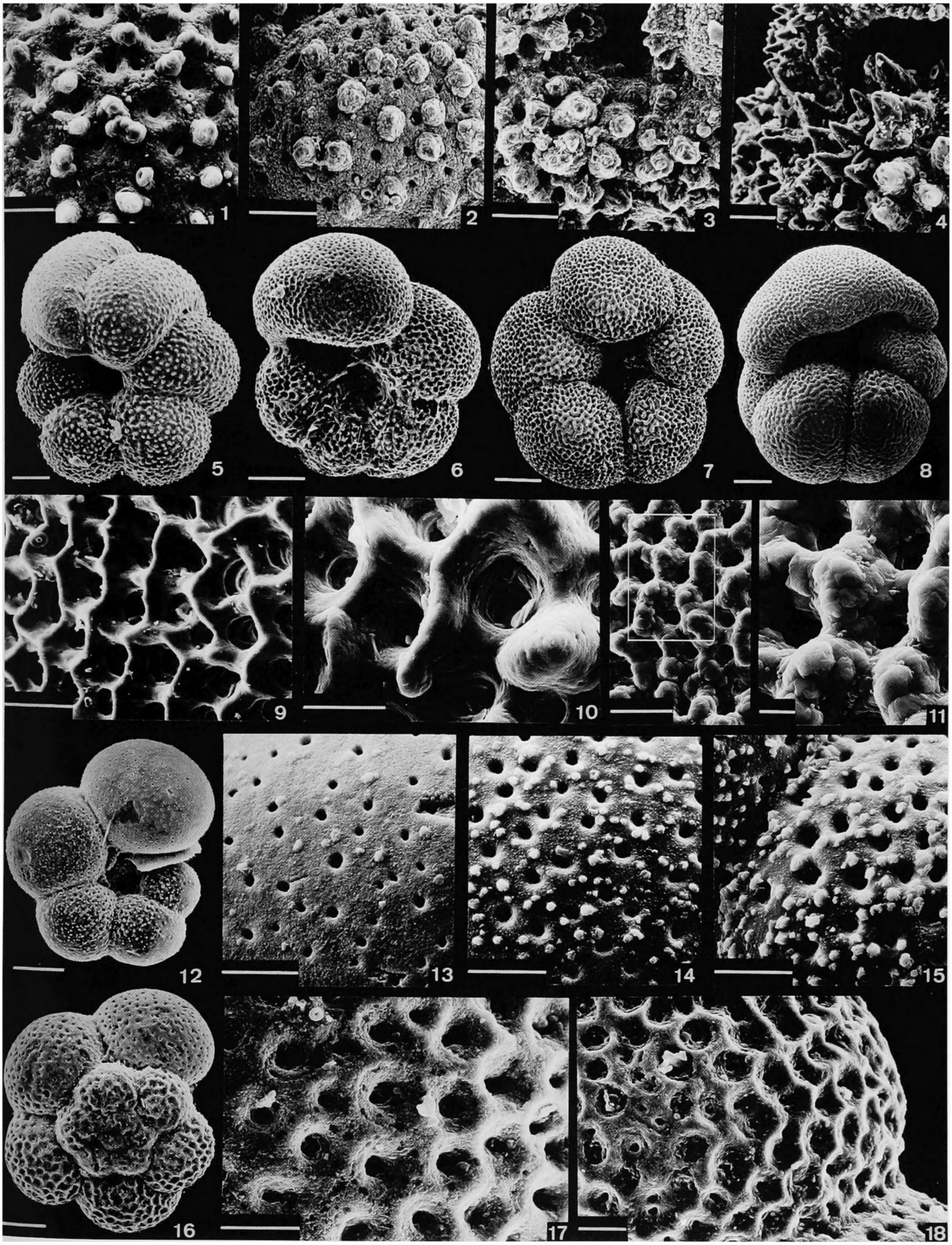
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PLATE 6

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.

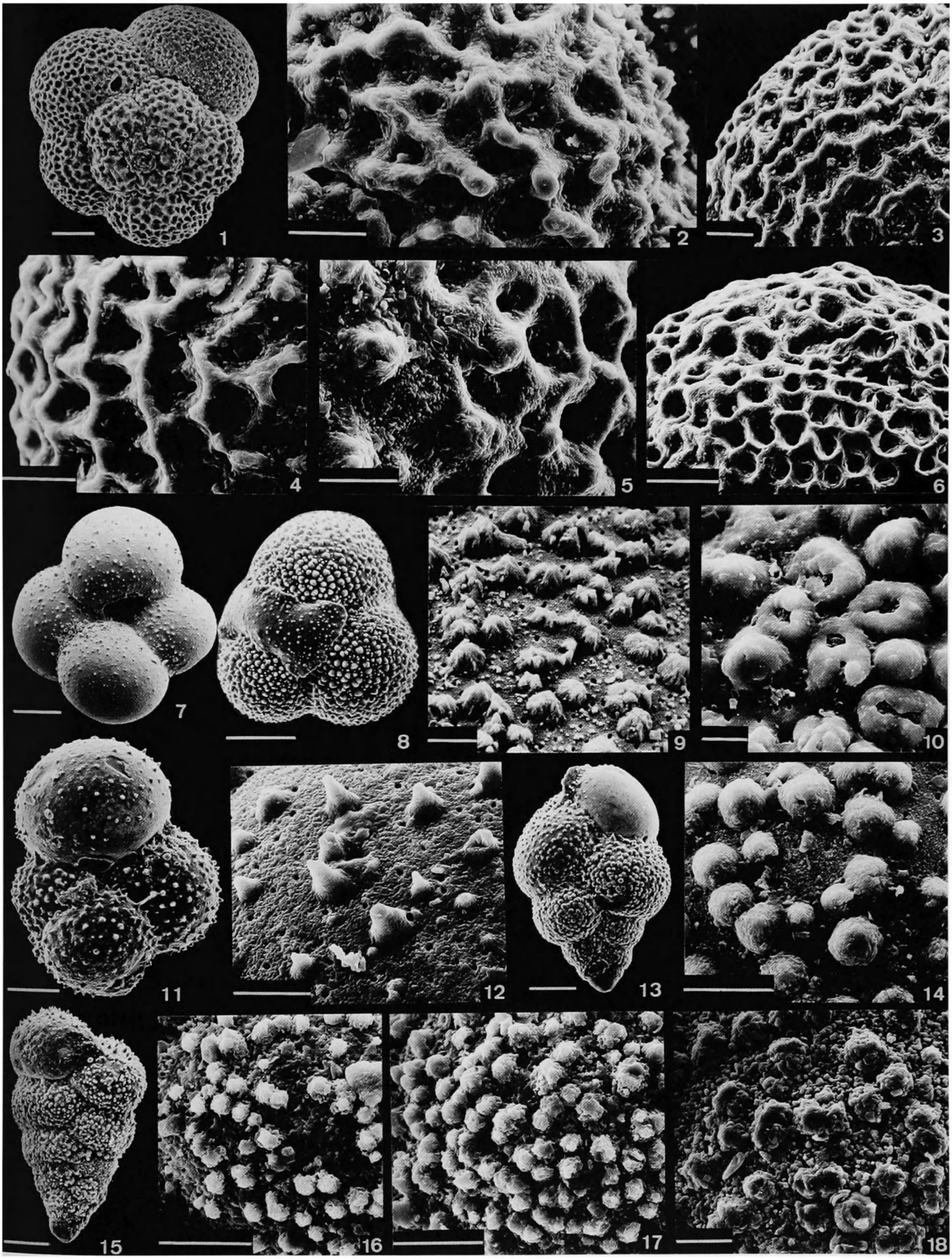
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PLATE 10

Russian Primary Type Specimens

(bars = 100 μm)

FIGURES 1–3.—*Globigerina* (*Eoglobigerina*) *taurica* Morozova, 1961:10, pl. 1: fig. 5, holotype no. 3510/1, Moscow GAN; Danian, Tarkhankut Peninsula, Crimea. See *Praemurica taurica.*

FIGURES 4–6.—*Globigerina inconstans* Subbotina, 1953:58, pl. 3: fig. 1, holotype no. 3992, St. Petersburg VNIGRI (378/18); zone of rotaliform globorotaliids, Elburgan Fm., Kuban River, northern Caucasus. See *Praemurica inconstans*.

FIGURES 7, 8.—*Acarinina praecursoria* Morozova, 1957:1111, text-fig. 1, holotype no. 3507/1, Moscow GAN; Danian, Khokhodz' River, northern Caucasus. See "Discussion" for *Praemurica inconstans* and for *Praemurica uncinata.*

FIGURES 9–11.—*Acarinina indolensis* Morozova, 1959:1116, text-fig. 1, holotype no. 3508/2, Moscow GAN; Danian, Tarkhankut Peninsula, Crimea. See "Discussion" for *Praemurica uncinata.*

FIGURES 12–14.—*Globorotalia imitata* Subbotina, 1953:206, pl. 16: fig. 14a–c, holotype no. 4073, St. Petersburg VNIGRI (378/112); zone of rotaliform globorotaliids (Danian?), Elburganian horizon, Kuban River, northern Caucasus. See *Globanomalina imitata.*

FIGURES 15–17.—*Globorotalia planoconica* Subbotina, 1953:210, pl. 17: fig. 4a–c, holotype no. 4081, St. Petersburg VNIGRI (378/118); zone of conical globorotaliids, lower to middle Eocene (probably lower Eocene), Series F1, Khieu River, Caucasus. See *Globanomalina planoconica.*

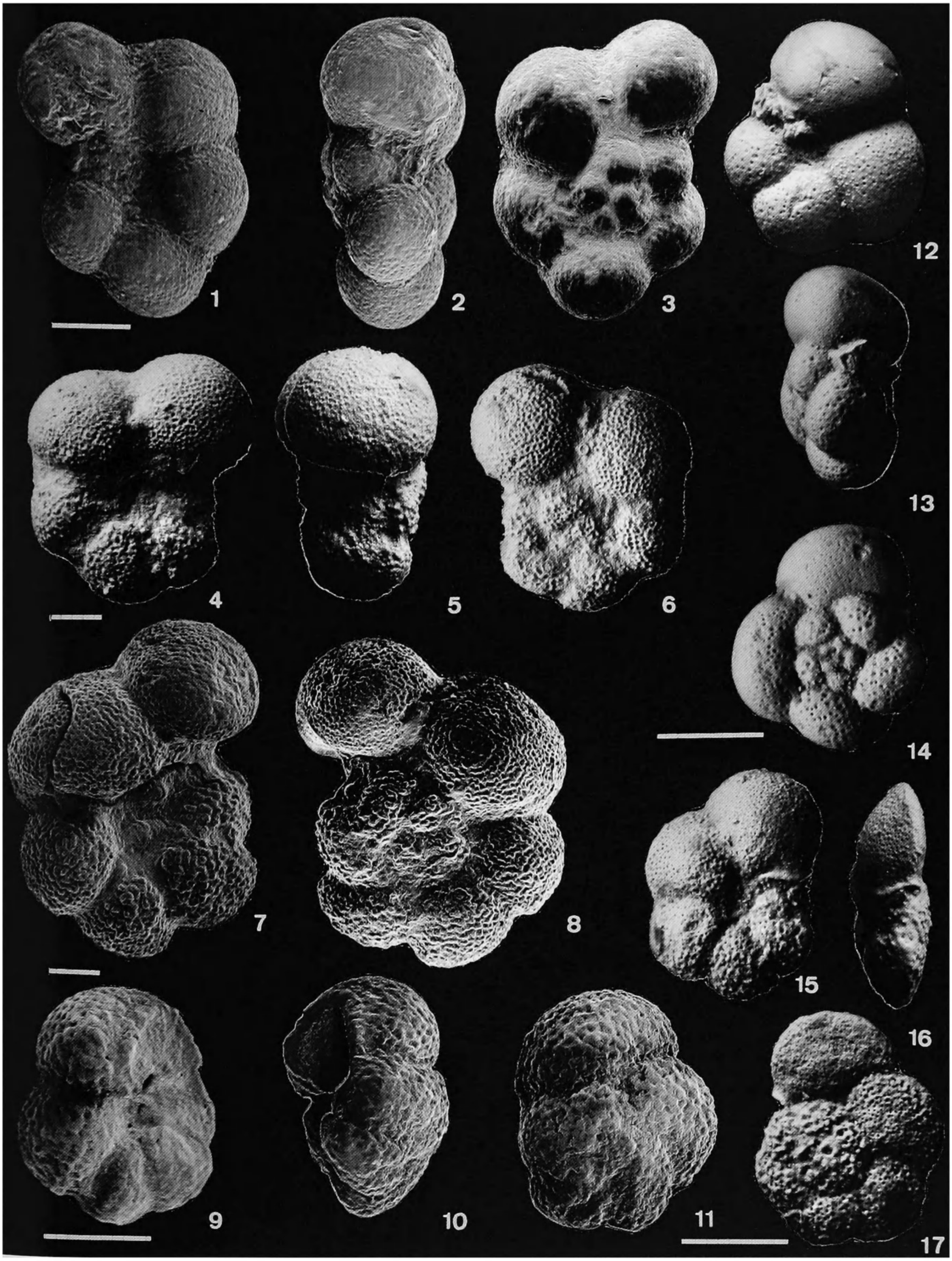
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PLATE 11

Russian Primary Type Specimens

(bars = 100 μm)

FIGURES 1–3.—*Globorotalia convexa* Subbotina, 1953:209, pl. 17: fig. 2a–c, holotype no. 4079, St. Petersburg VNIGRI (378/116); zone of conical globorotaliids, lower to middle Eocene (probably lower Eocene), Series F1, Khieu River, Caucasus. See "Discussion" for *Igorina tadjikistanensis.*

FIGURES 4–6.—*Globorotalia tadjikistanensis* Bykova, 1953:86, pl. 3: fig. 5a–c, holotype no. 2794-a (upper specimen), St. Petersburg VNIGRI (350/10); Suzakian Stage (middle Paleocene), Ak-Tau, southern part of Tadzhik Basin, Kazakhstan. See "Discussion" for *Igorina tadjikistanensis.*

FIGURES 7–9.—*Globorotalia tadjikistanensis* Bykova, 1953:86, paratype no. 2794-a (middle specimen), St. Petersburg VNIGRI (350/10); Suzakian Stage (middle Paleocene), Ak-Tau, southern part of Tadzhik Basin, Kazakhstan. See *Igorina tadjikistanensis.*

FIGURES 10–15.—*Globorotalia angulata* (White) var. *kubanensis* Shutskaya, 1956, specimens from remaining collections of Shutskaya (no. 645-32), St. Petersburg VNIGRI; zone of *Acarinina conicotruncata,* PC1 (middle Paleocene), Khieu River, Caucasus. Holotype in Moscow is lost, hence the identity of this taxon cannot be determined. Further confusing the taxonomic status of this taxon is the specimen represented by Figures 10–12, which is probably referable to *Morozovella apanthesma* (Loeblich and Tappan), and the specimen represented by Figures 13–15, which is probably referable to *Morozovella acutispira* (Bolli and Cita). The holotype figure, in contrast, resembles *Morozovella conicotruncata* (Subbotina).

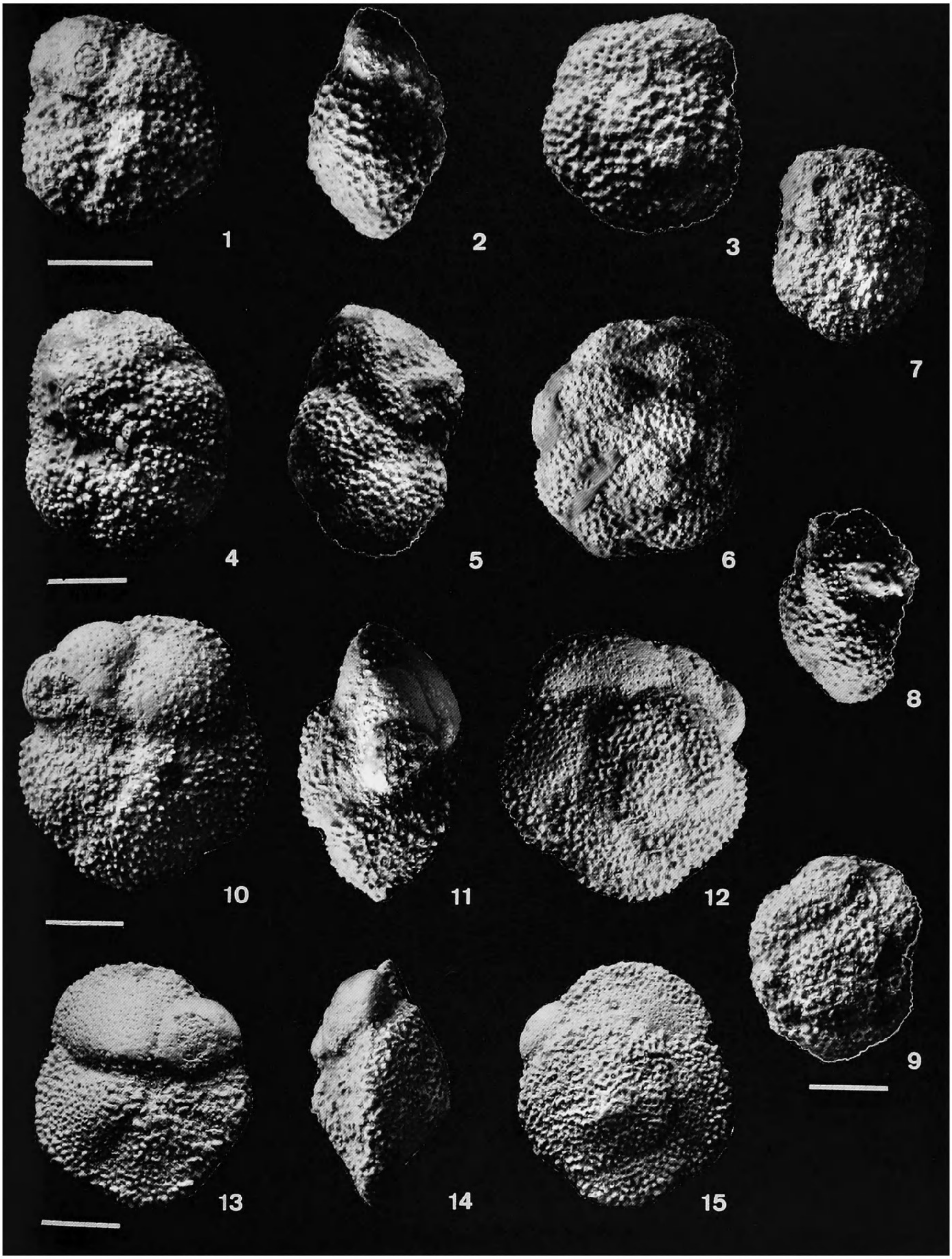
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PLATE 12

Russian Primary Type Specimens

(bars = 100 μm)

FIGURES 1–3.—*Acarinina acarinata* Subbotina, 1953:229, pl. 22: fig. 5, paratype no. 4129, St. Petersburg VNIGRI (378/160); zone of compressed globorotaliids, Paleocene–lower Eocene, Series F1, Khieu River, Caucasus. See "Discussion" for *Acarinina nitida.*

FIGURES 4–6.—*Acarinina intermedia* Subbotina, 1953:227, pl. 20: fig. 15, holotype no. 4095, St. Petersburg VNIGRI (378/124); zone of compressed globorotaliids, Paleocene?, Goryache Klynch horizon, Kuban River, Caucasus. See "Discussion" for *Acarinina nitida.*

FIGURES 7–9.—*Guembelitria dammula* Voloshina, 1961, hypotype; Paleocene, P0, Bjala (K/T section no. 2b, 1–2 cm above boundary), Bulgaria. See "Discussion" for *Guembelitria cretacea.*

FIGURES 10–12.—*Globanomalina imitata* (Subbotina, 1953), hypotype; Paleocene, P1b/c, Bjala (K/T section no. 2b, sample Sum 24/12), Bulgaria. See *Globanomalina imitata.*

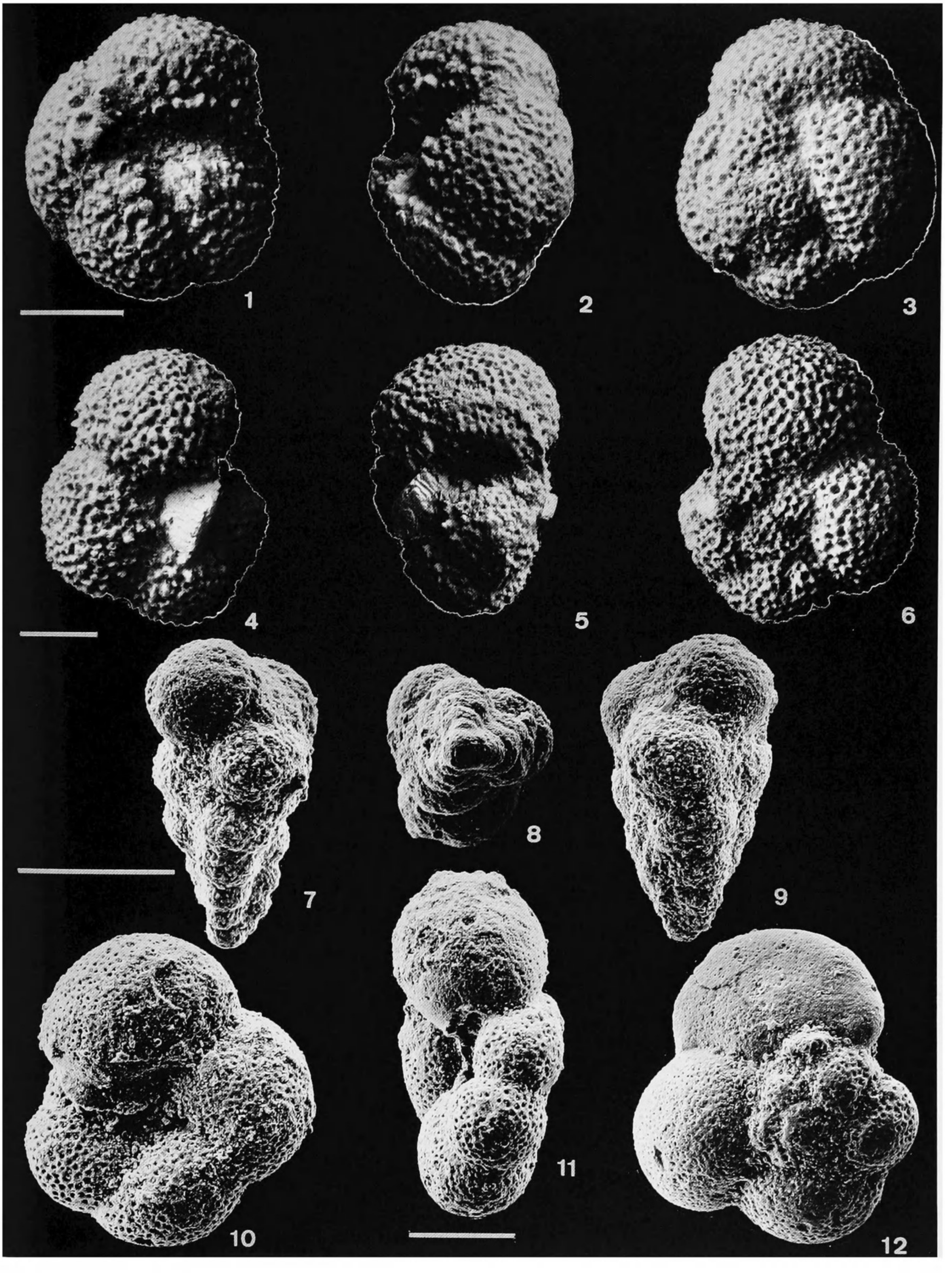
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PLATE 14

USNM Primary Type Specimens

(bars = 50 μm)

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

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

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

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

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

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

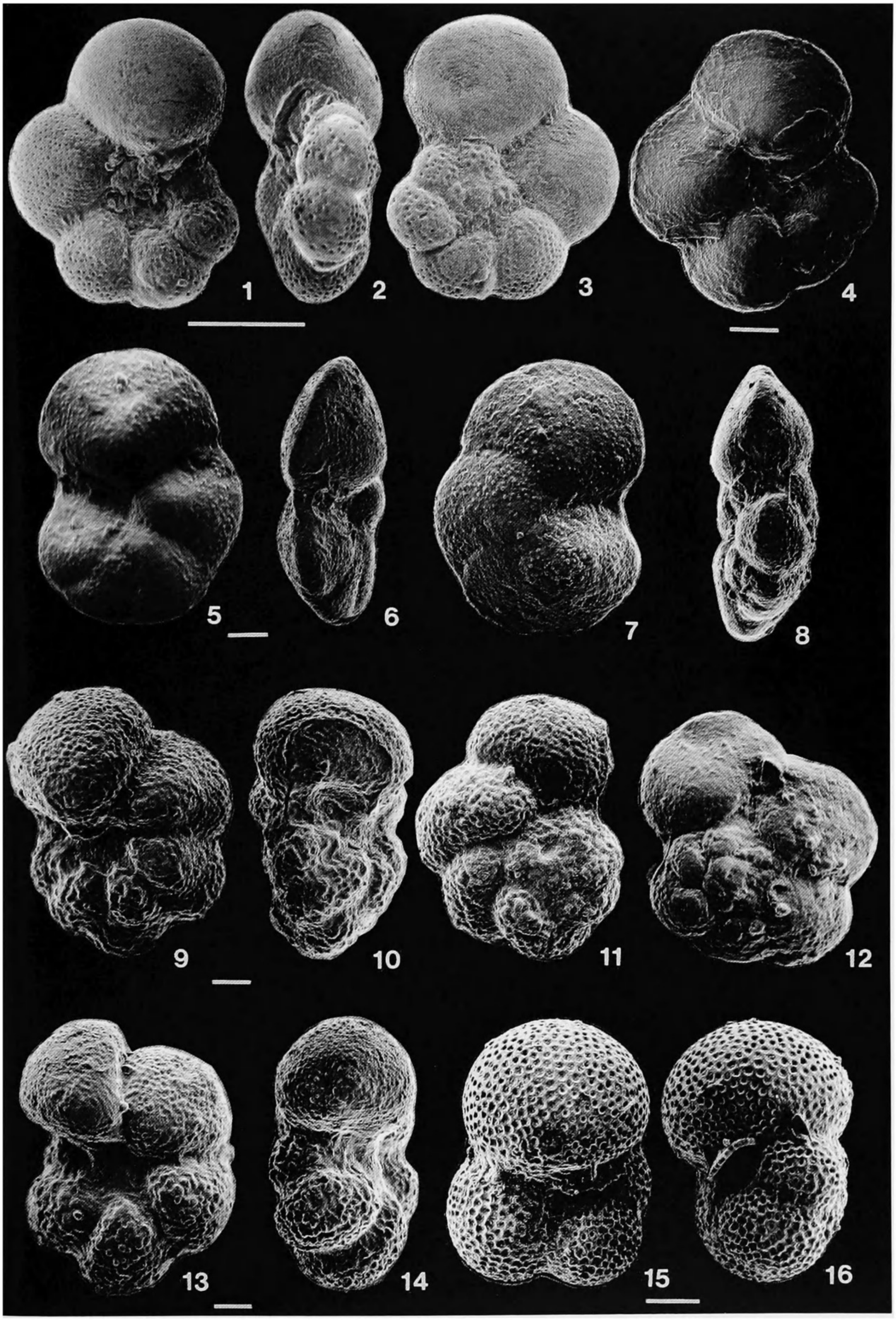
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PLATE 15

USNM Primary Type Specimens

(bars = 50 μm)

FIGURES 1–3.—*Globorotalia strabocella* Loeblich and Tappan, 1957, holotype, USNM P5879; Nanafalia Fm., Alabama.

FIGURES 4, 7, 8.—*Globigerina soldadoensis* Brönnimann, 1952, holotype, USNM 370085; Lizard Springs Fm., Trinidad; type locality of *Globorotalia velascoensis* Zone of Bolli, 1957a = Zone P5.

FIGURES 5, 6.—*Globigerina aquiensis* Loeblich and Tappan, holotype, USNM P5839; Aquia Fm., Aquia Creek, Virginia.

FIGURES 9, 10.—*Globigerina chascanona* Loeblich and Tappan, 1957 (= *Acarinina subsphaerica* (Subbotina)), holotype, USNM P5842; Zone P4, uppermost Hornerstown Fm., New Jersey.

FIGURES 11, 12, 15.—*Globorotalia crassata* (Cushman) var. *aequa* Cushman and Renz, 1942, holotype, USNM CC38210; near base of *Globorotalia subbotinae* Zone, Soldado Fm., Trinidad.

FIGURES 13, 14.—*Globigerina daubjergensis* Brönnimann, 1953, holotype, USNM CC64879; Danian, Daubjerg Quarry, Denmark.

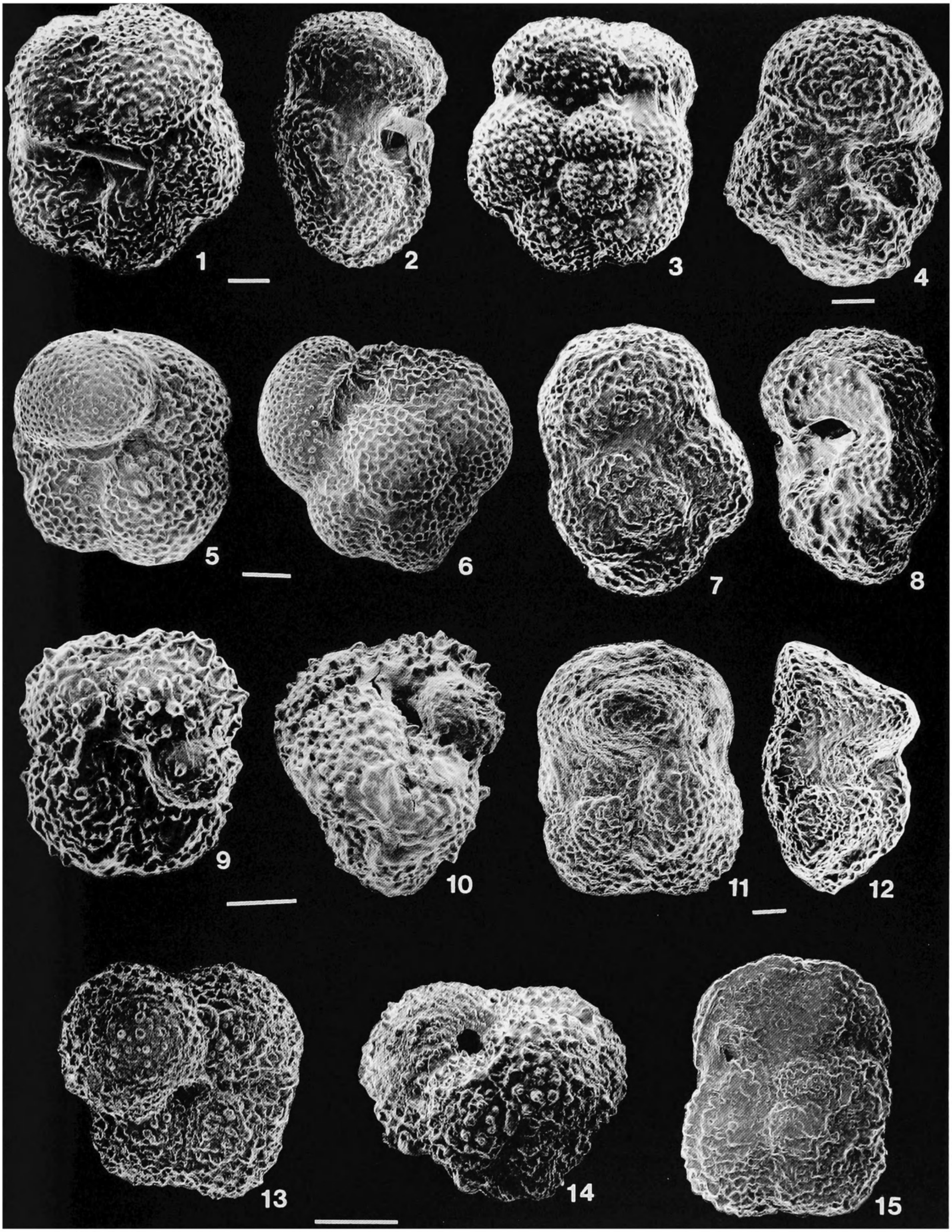
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PLATE 16

USNM Primary Type Specimens

(bars = 50 μm)

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

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

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

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


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PLATE 17

USNM Primary Type Specimens

(bars = 50 μm)

FIGURES 1–3.—*Globorotalia apanthesma* Loeblich and Tappan, 1957, holotype, USNM P5860; Zone P4, Aquia Fm., Virginia.

FIGURES 4–6.—*Globorotalia occlusa* Loeblich and Tappan, 1957, holotype, USNM P5874; Zone P4, Velasco Shale, Tamaulipas, Mexico.

FIGURES 7–9.—*Pseudogloborotalia pasionensis* Bermúdez, 1961, holotype, USNM 639063; sample G-58, Rio de Pasion, El Petén, Guatemala.

FIGURES 10–12.—*Pulvinulina velascoensis* Cushman, 1925, holotype, USNM CC4347; Velasco Fm., San Luis Potosi, Tampico Embayment, eastern Mexico.

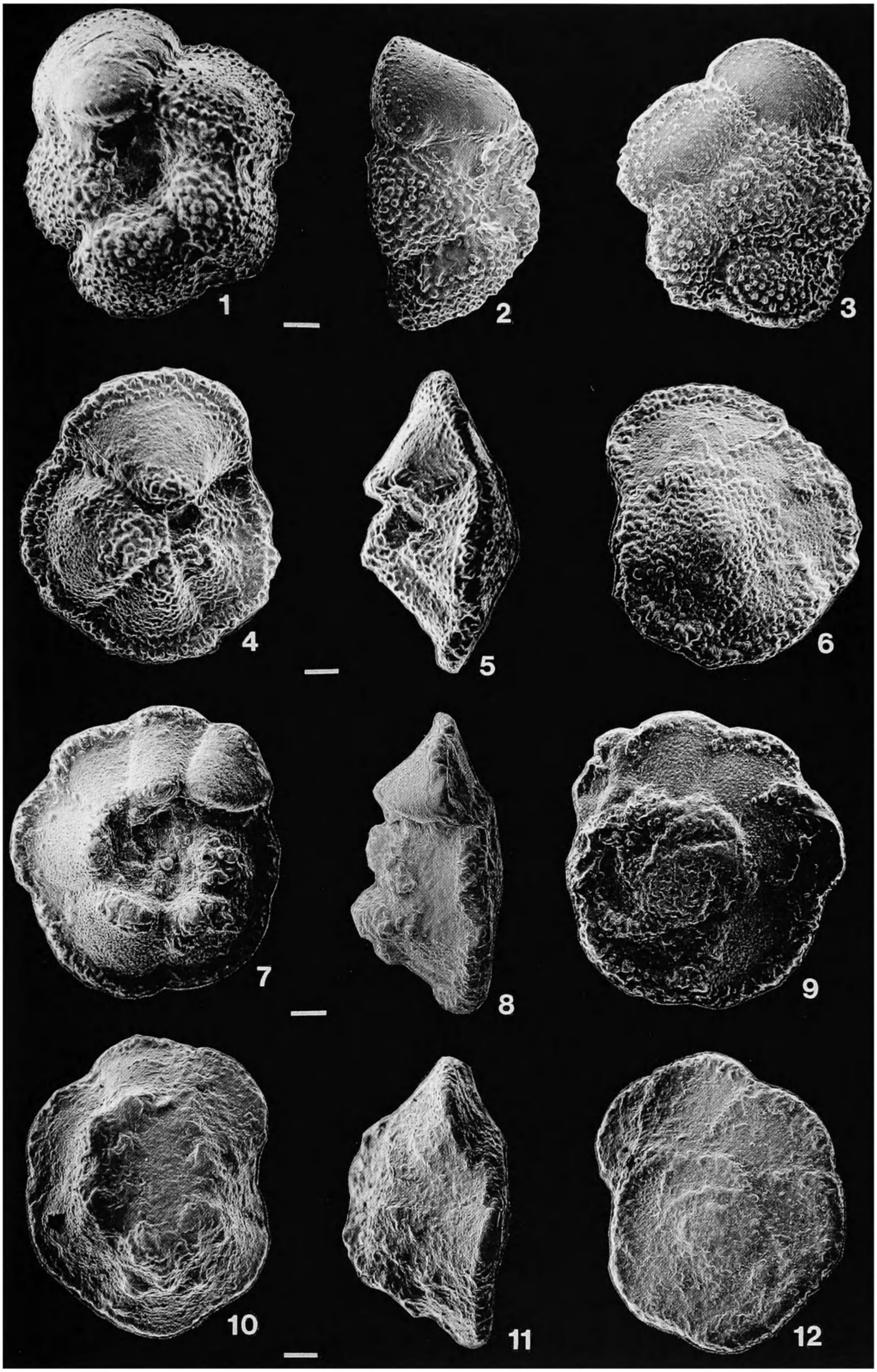
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PLATE 36

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.

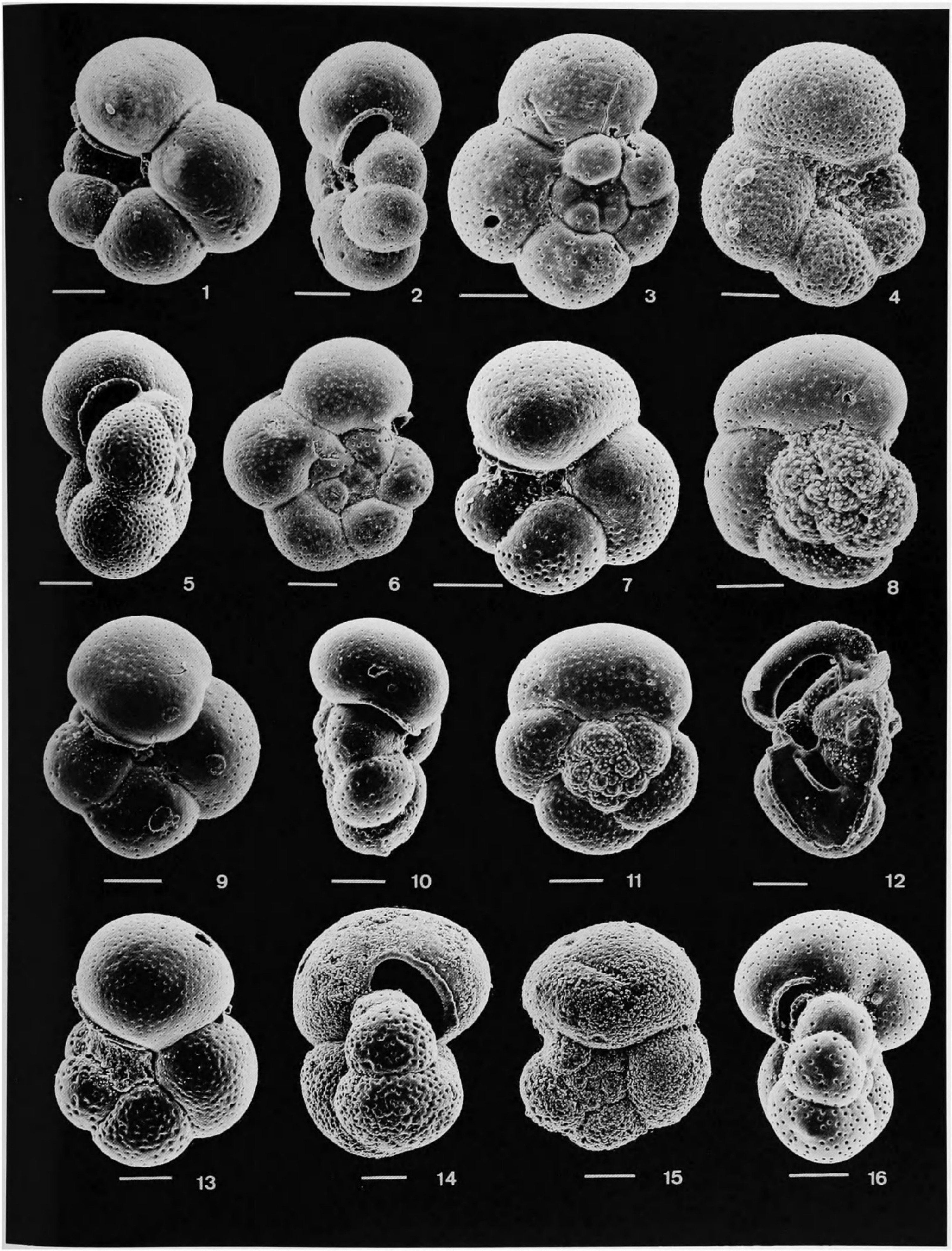
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PLATE 39

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.

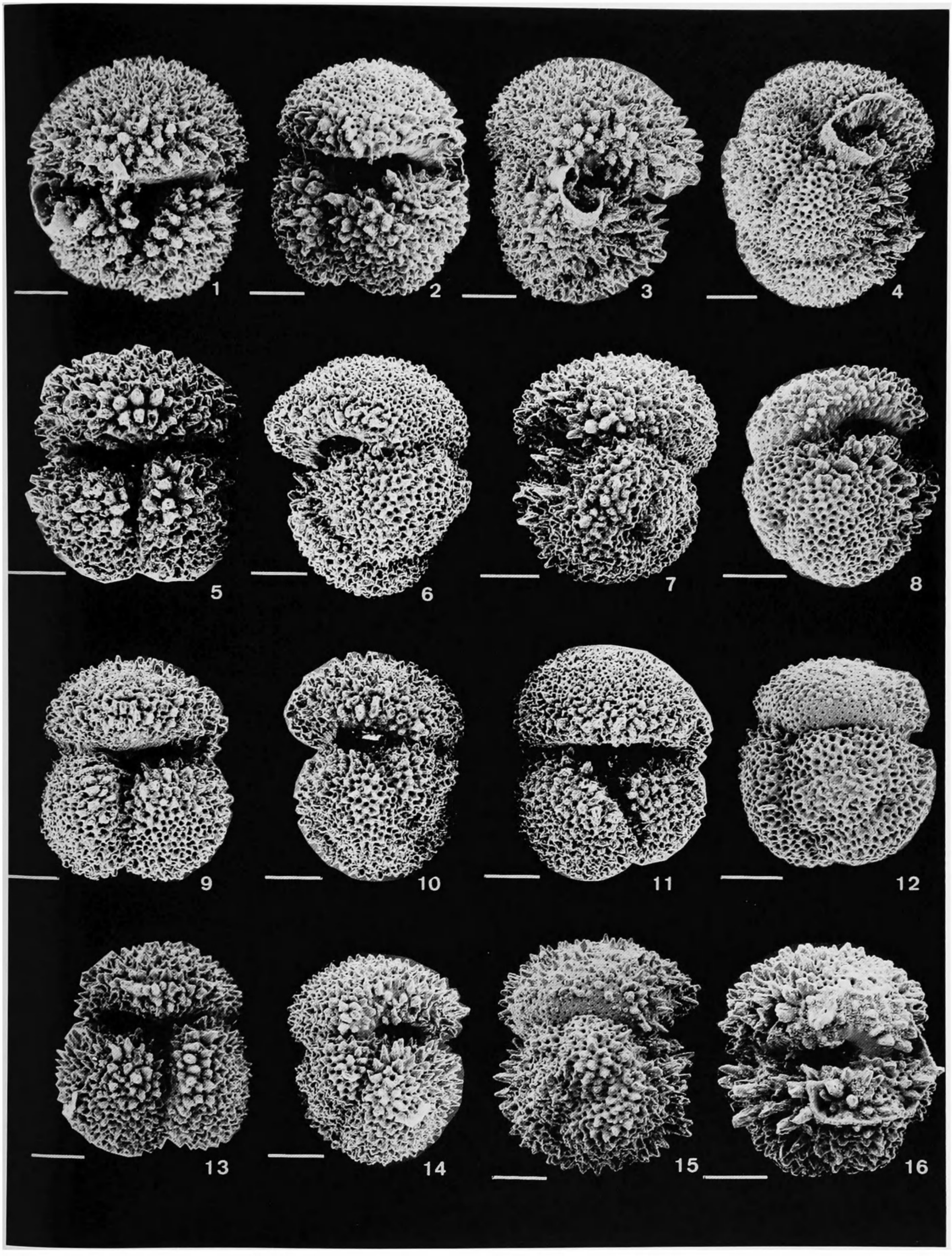
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PLATE 40

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.

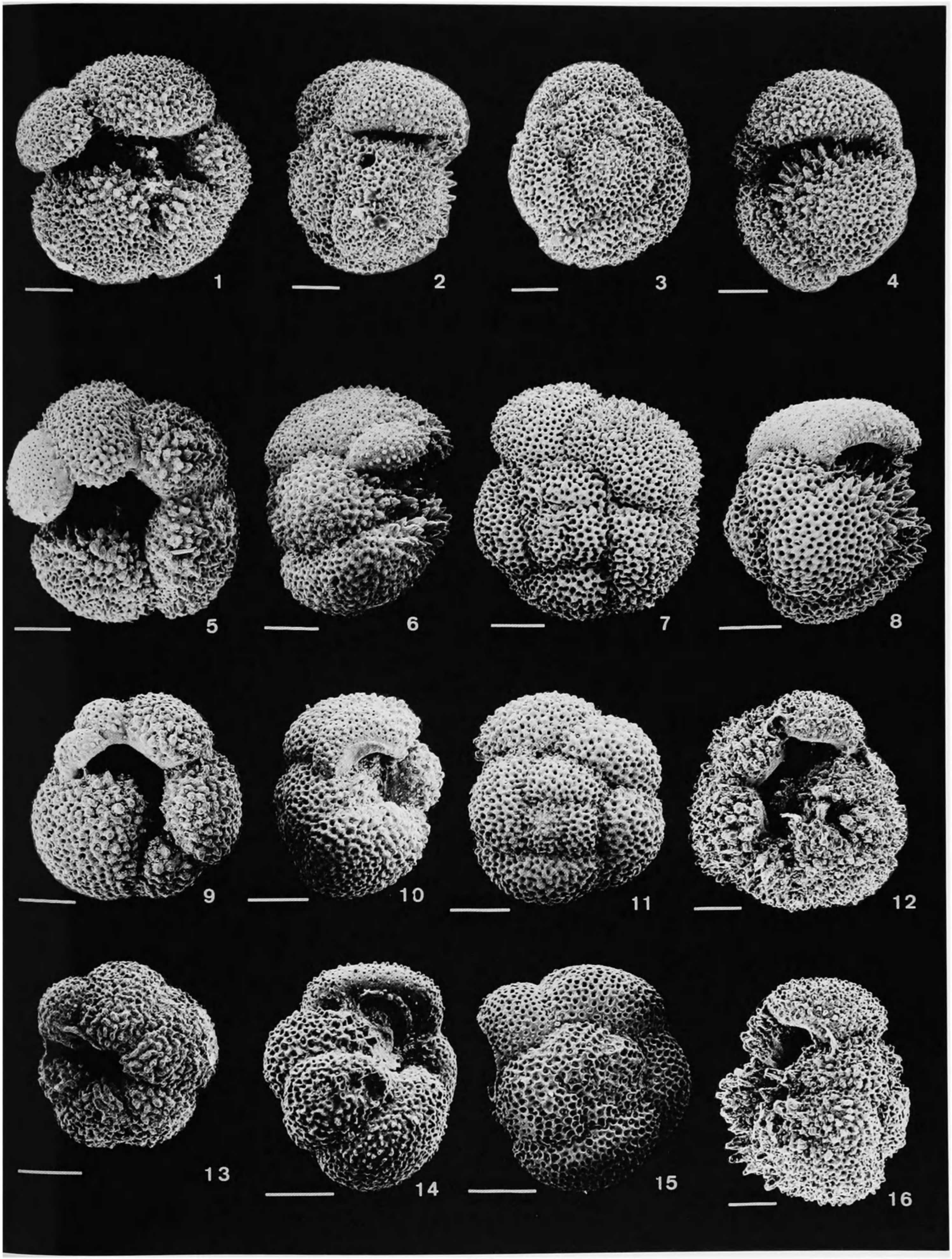
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PLATE 41

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.

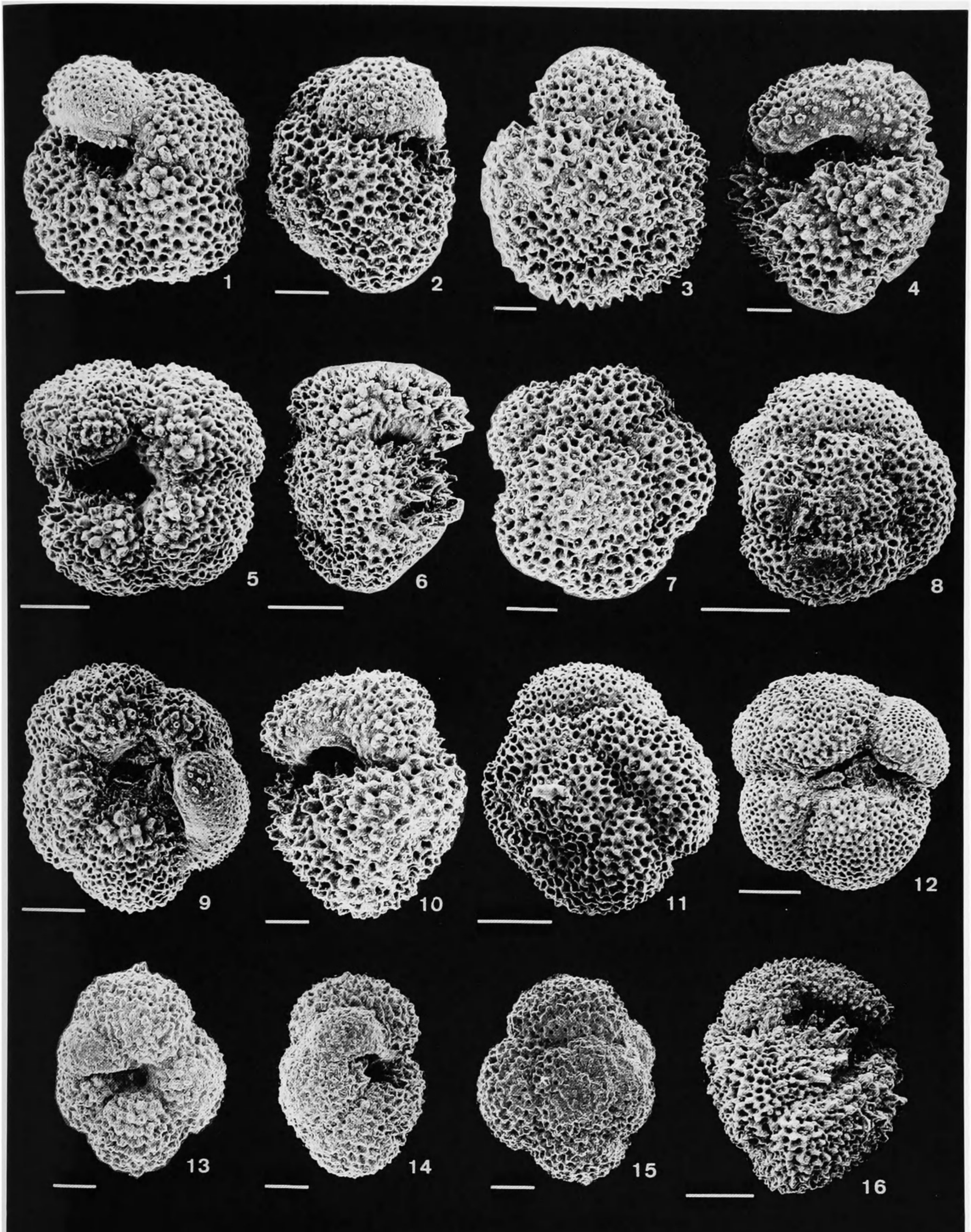
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PLATE 42

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.

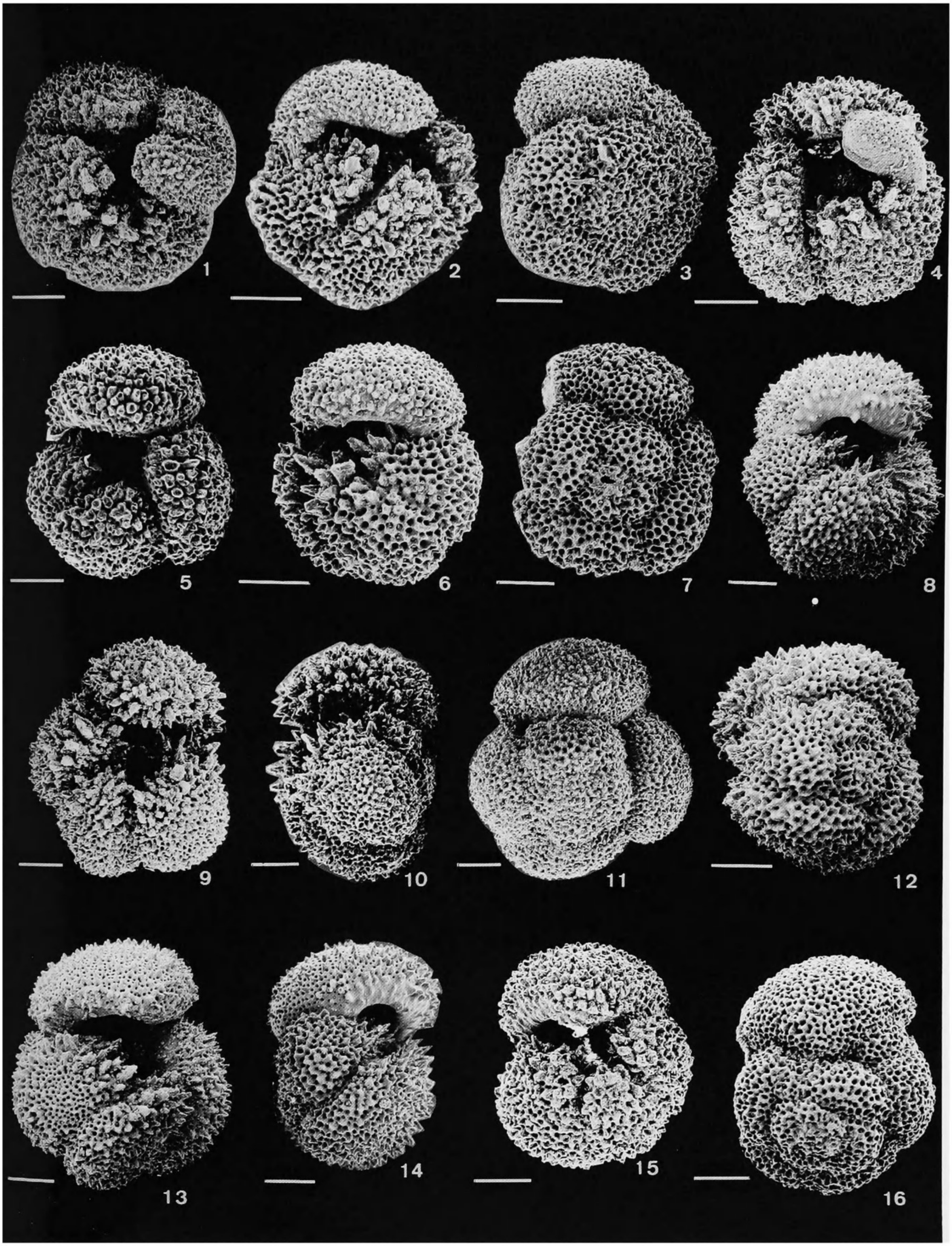
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PLATE 43

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.

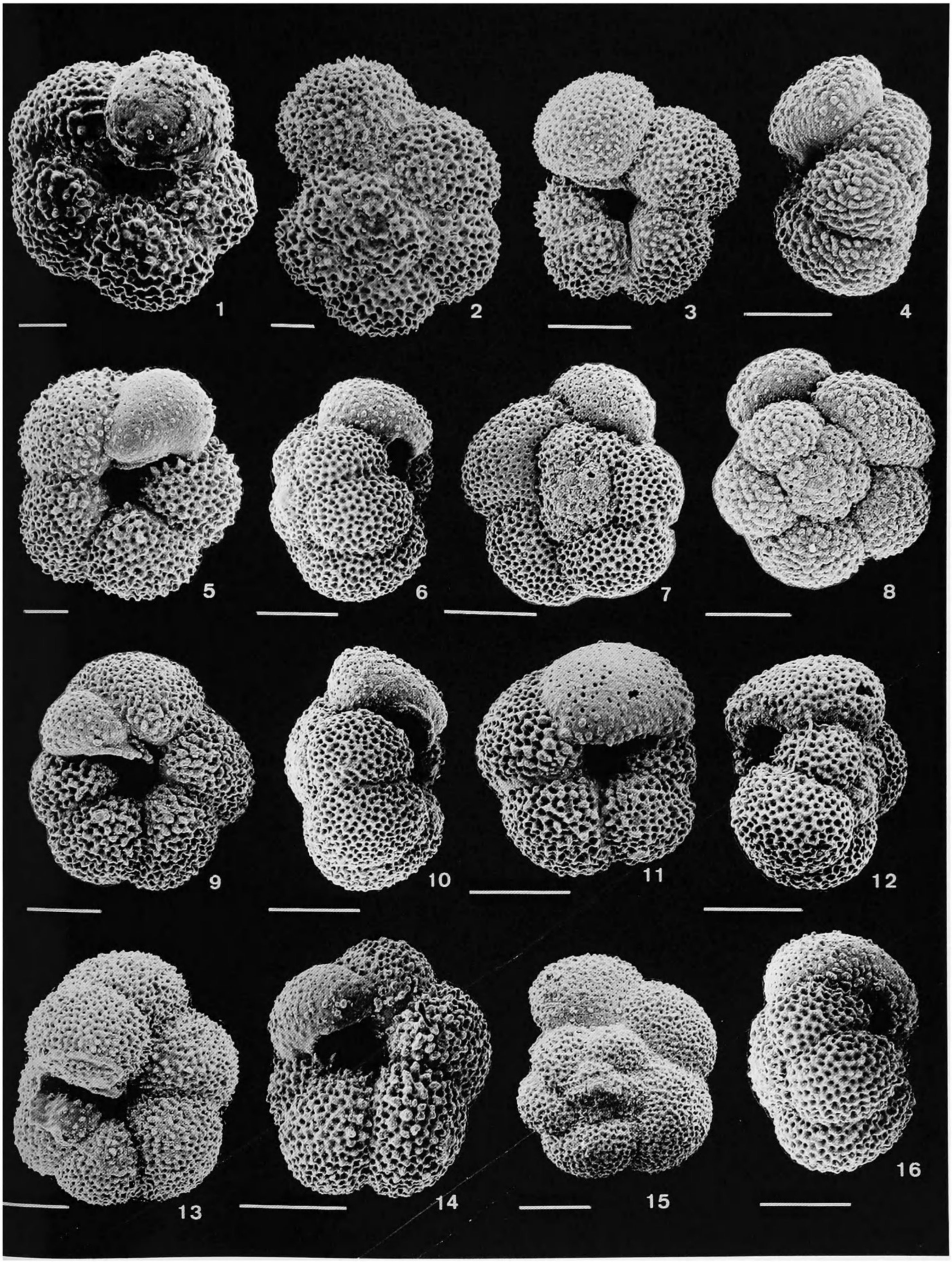
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PLATE 44

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.

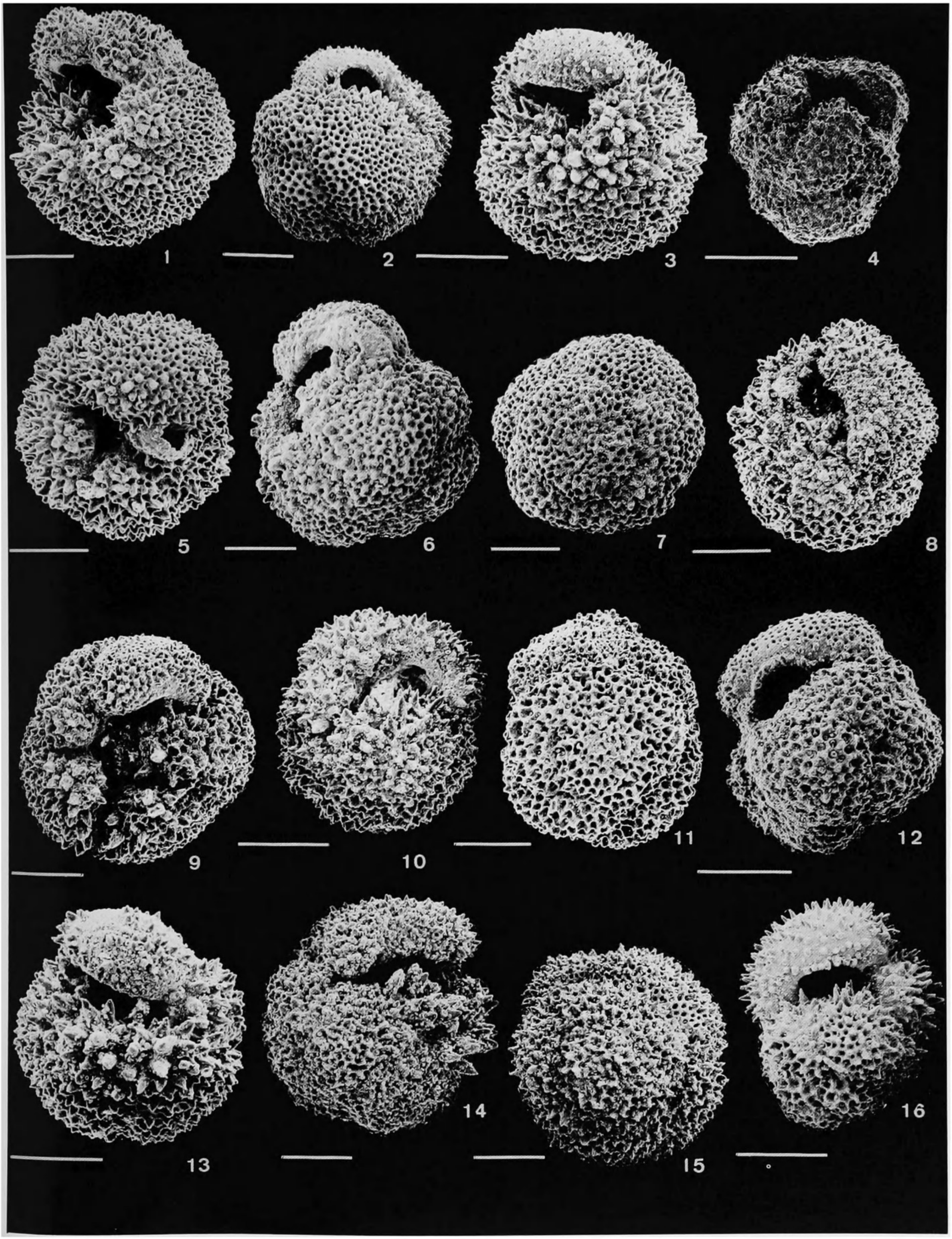
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PLATE 45

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.

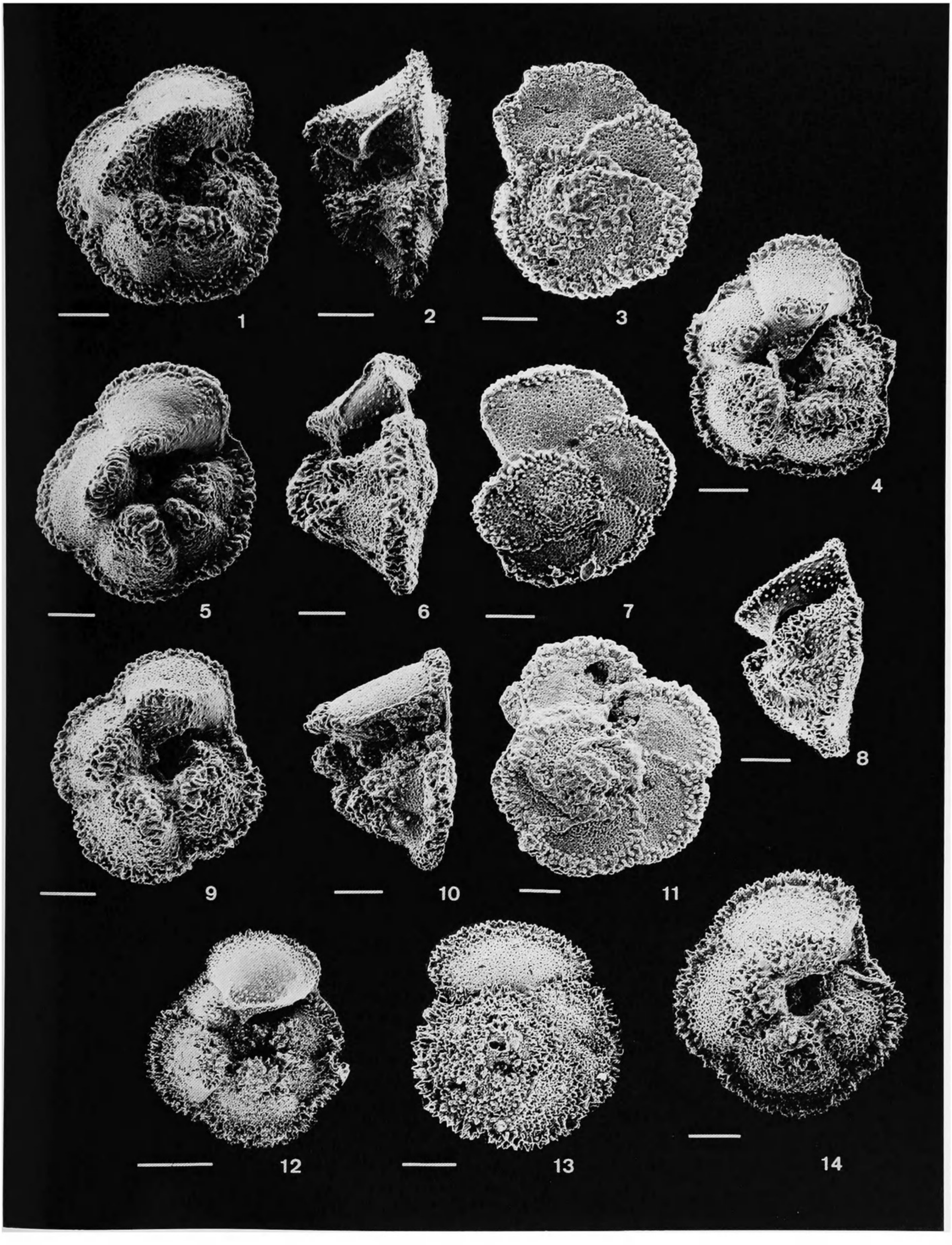
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PLATE 46

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.

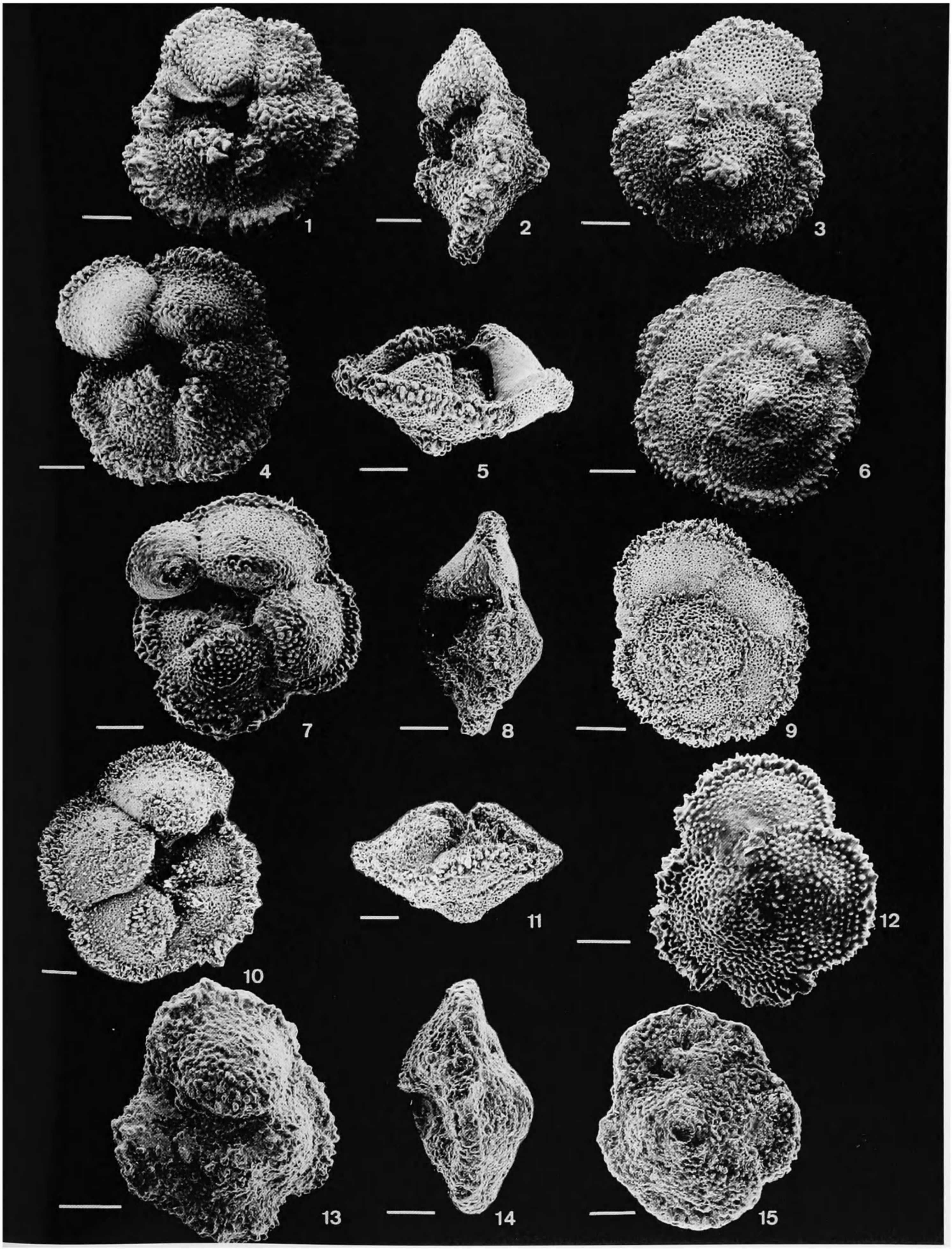
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PLATE 47

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.

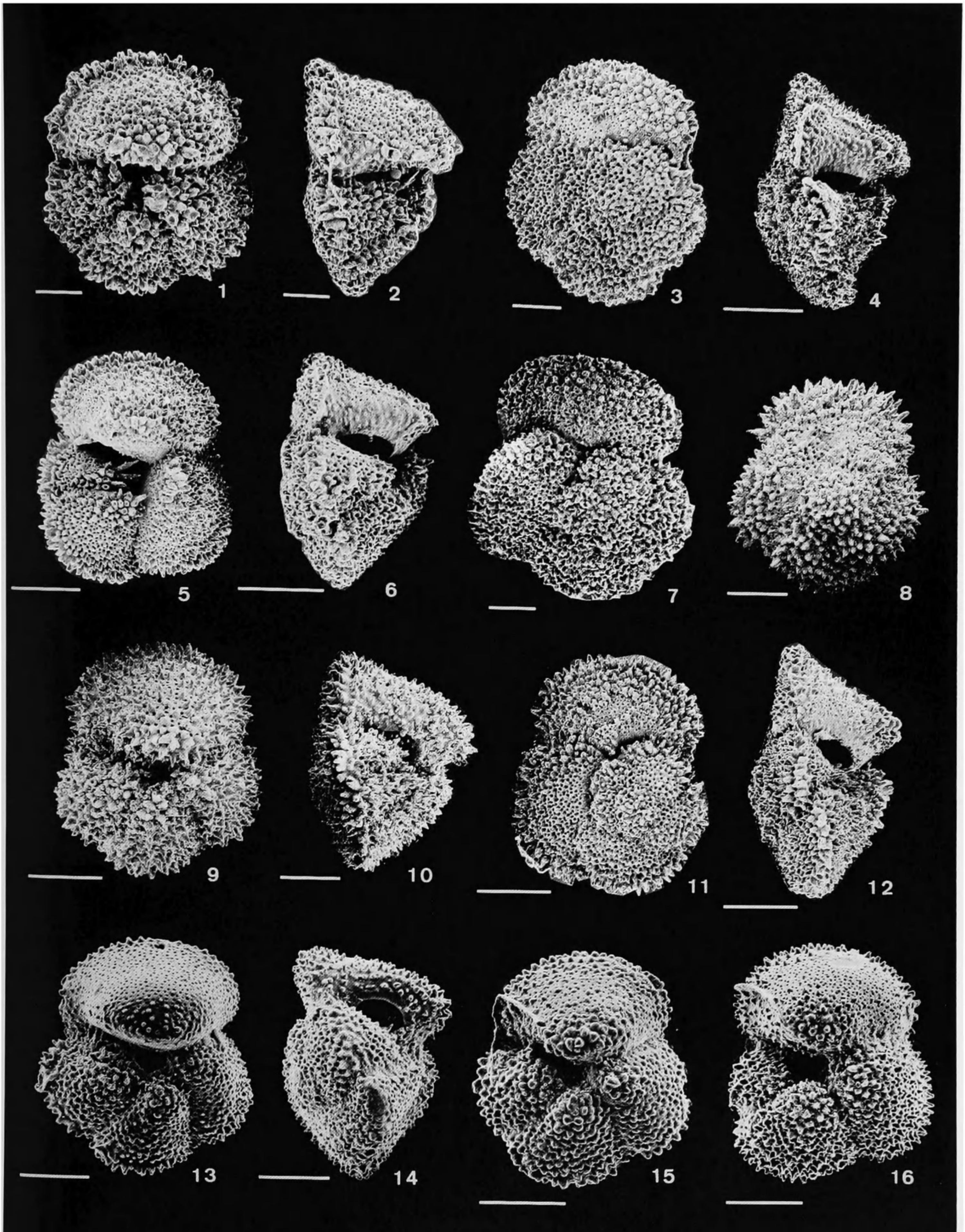
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PLATE 48

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.

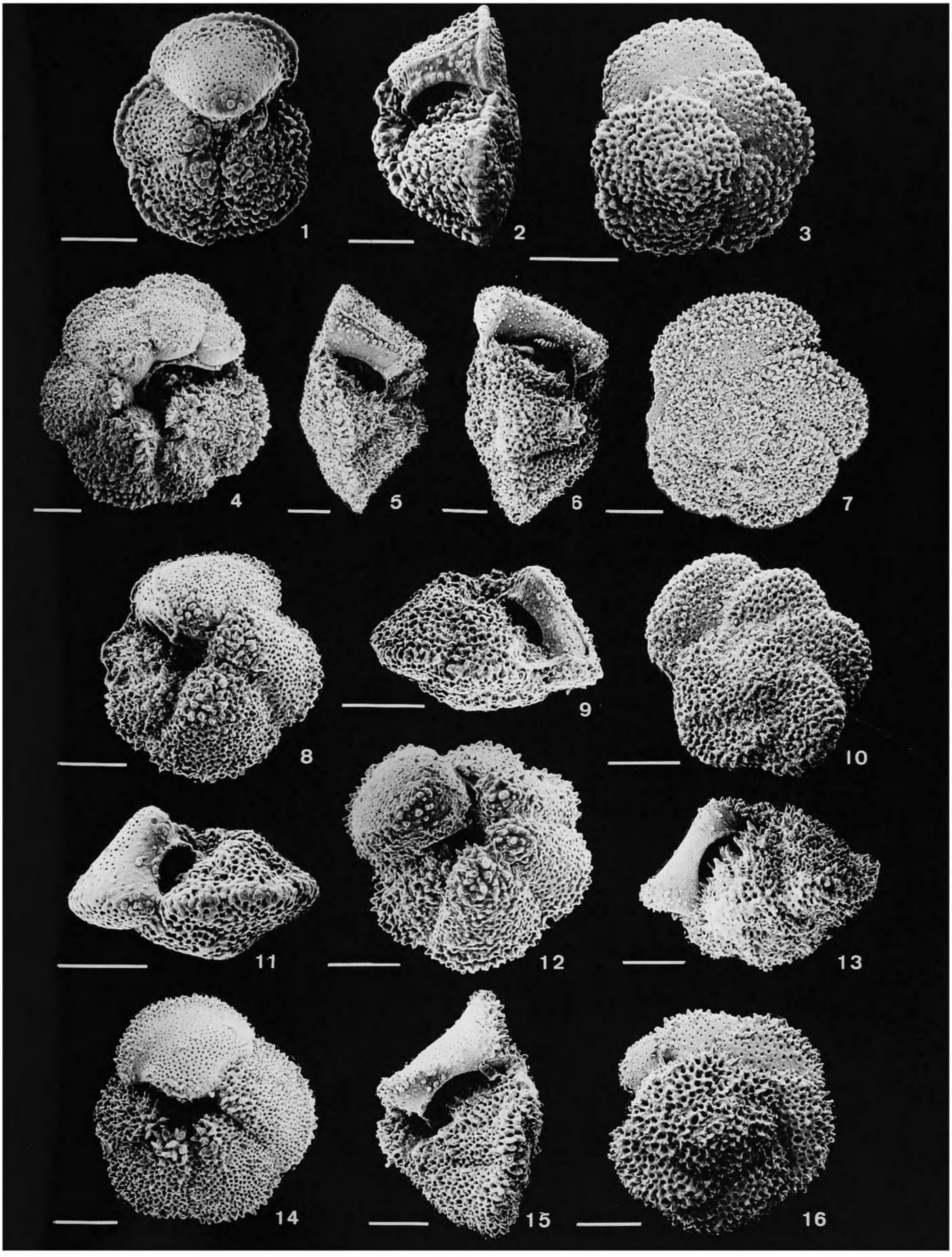
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PLATE 49

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.

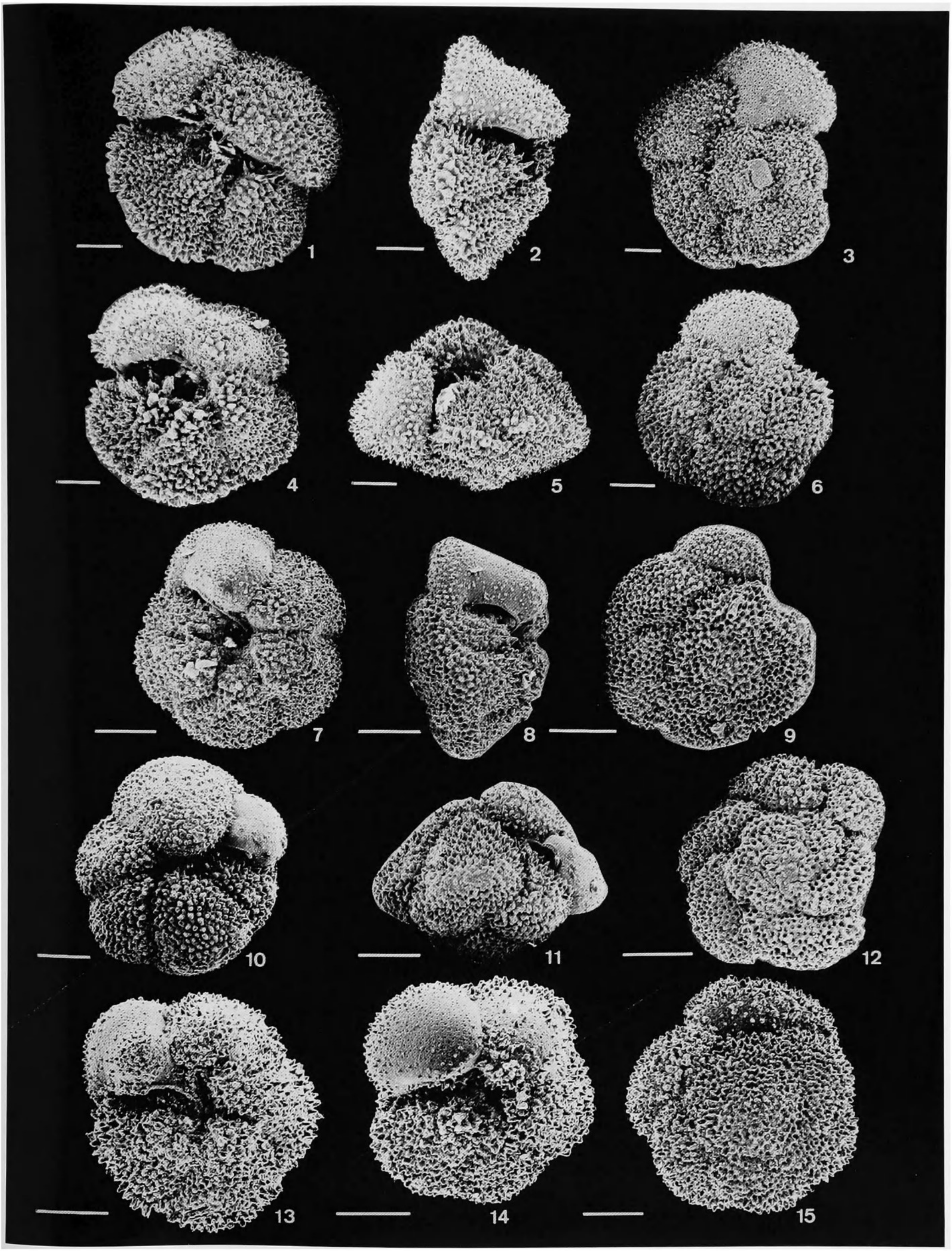
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PLATE 50

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.

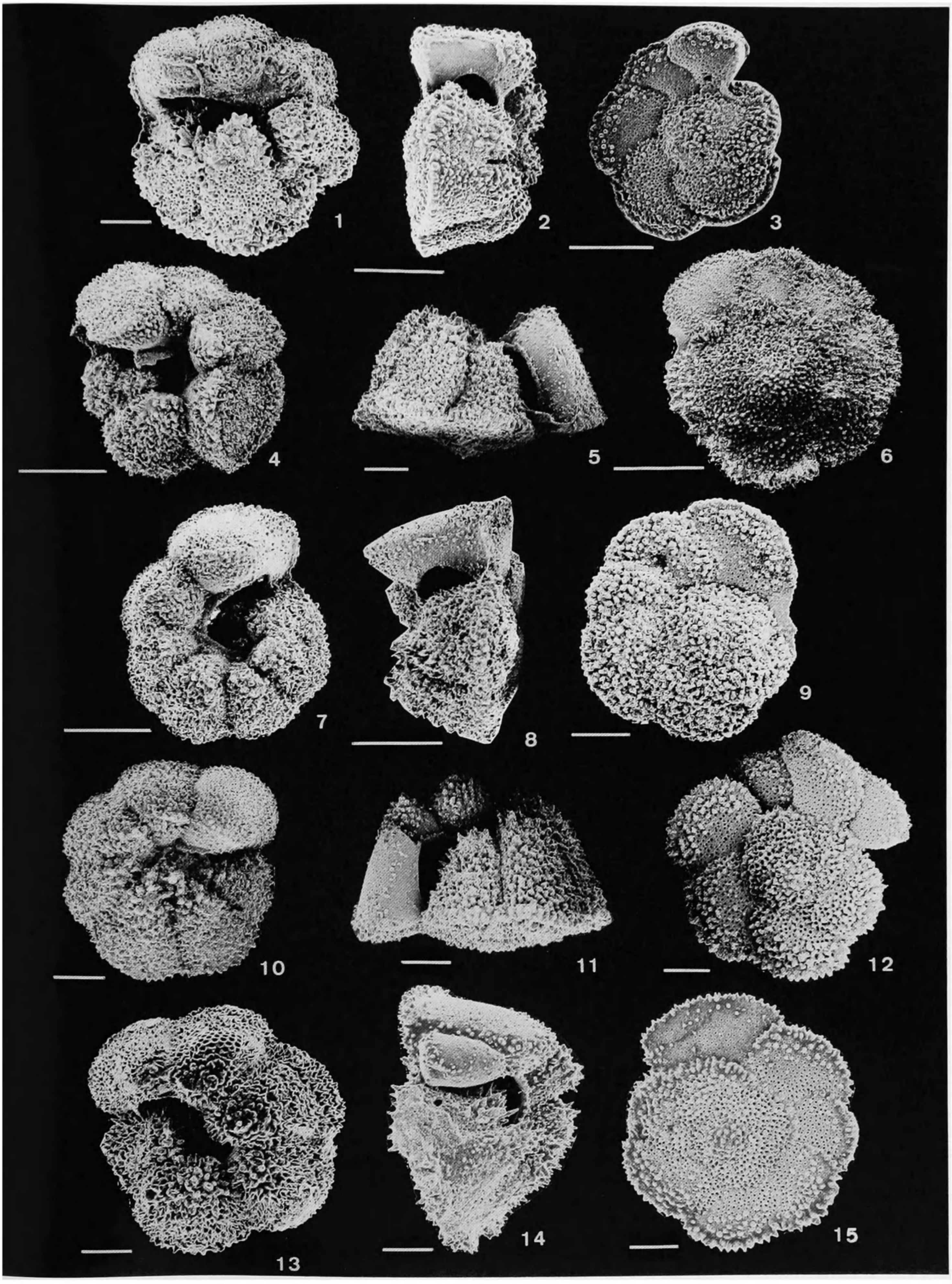
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PLATE 51

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.

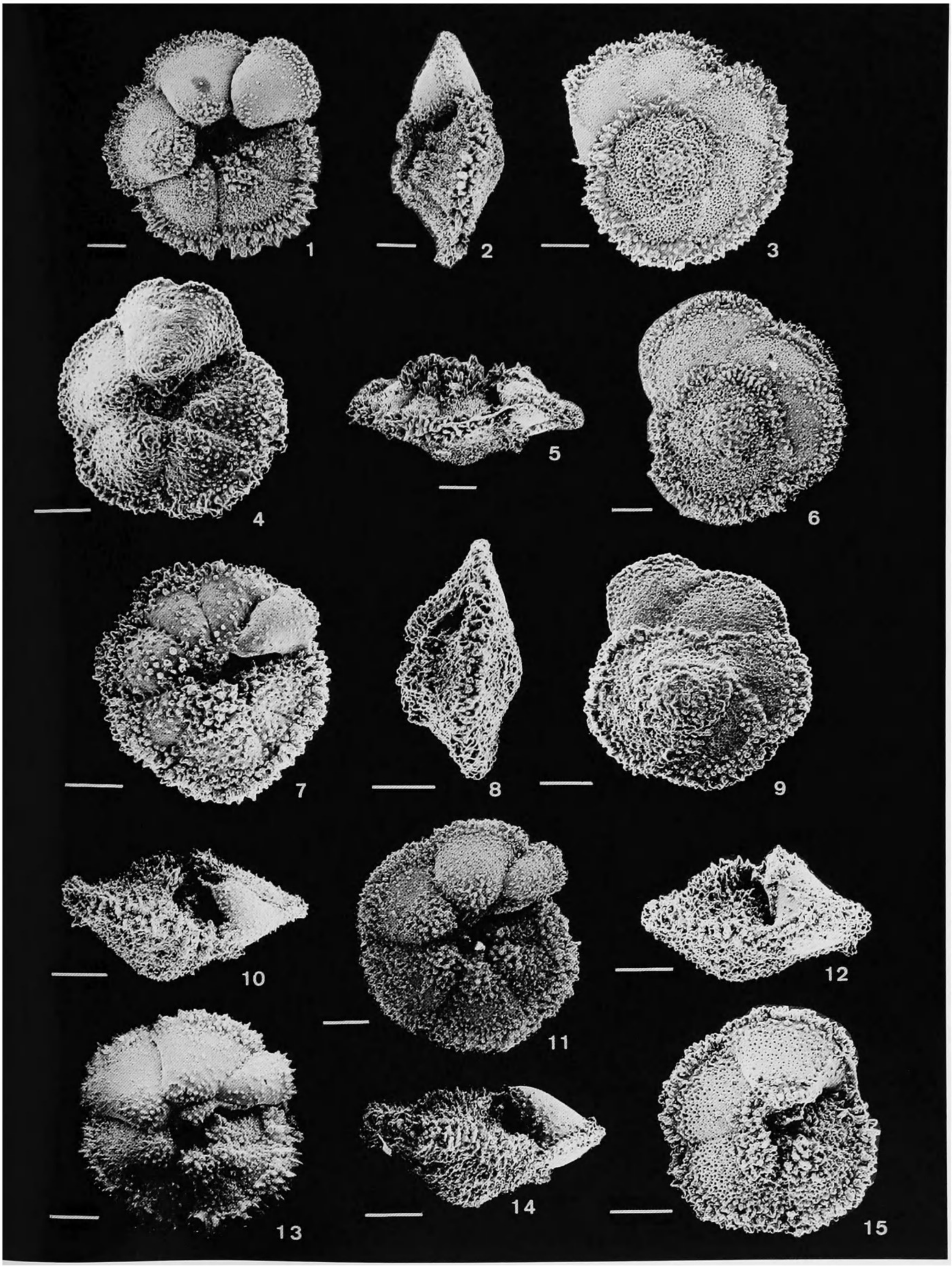
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PLATE 52

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.

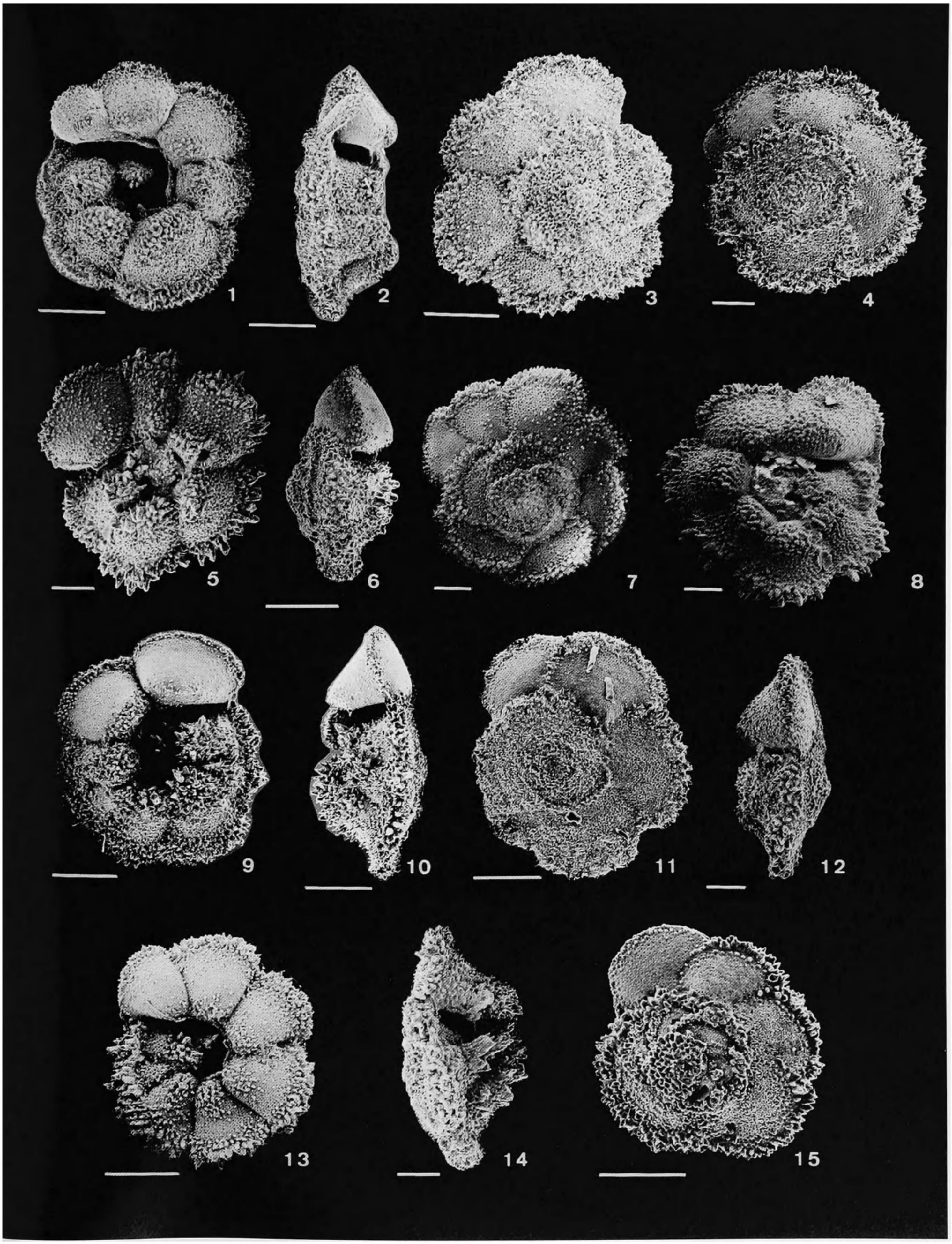
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PLATE 53

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.

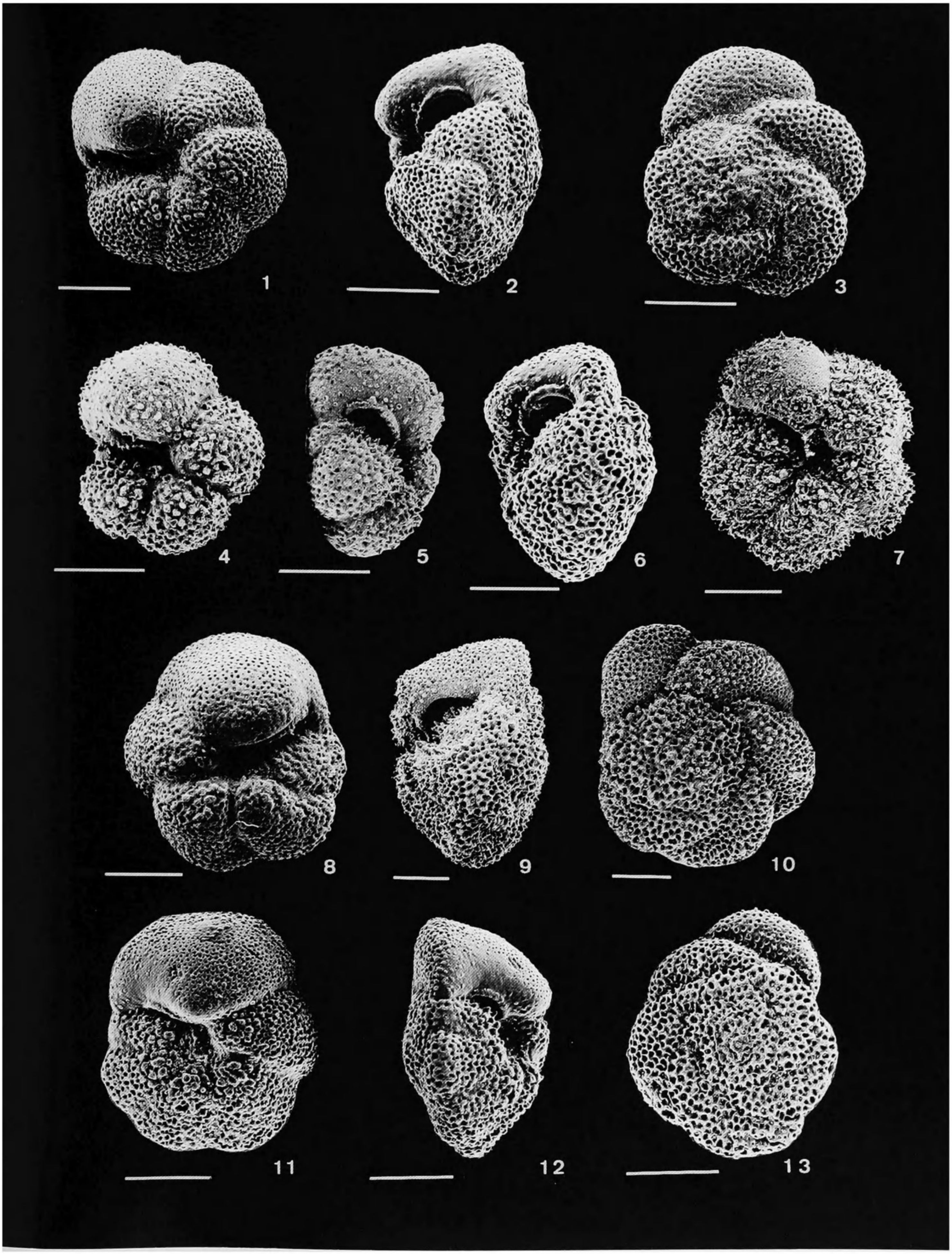
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PLATE 54

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.

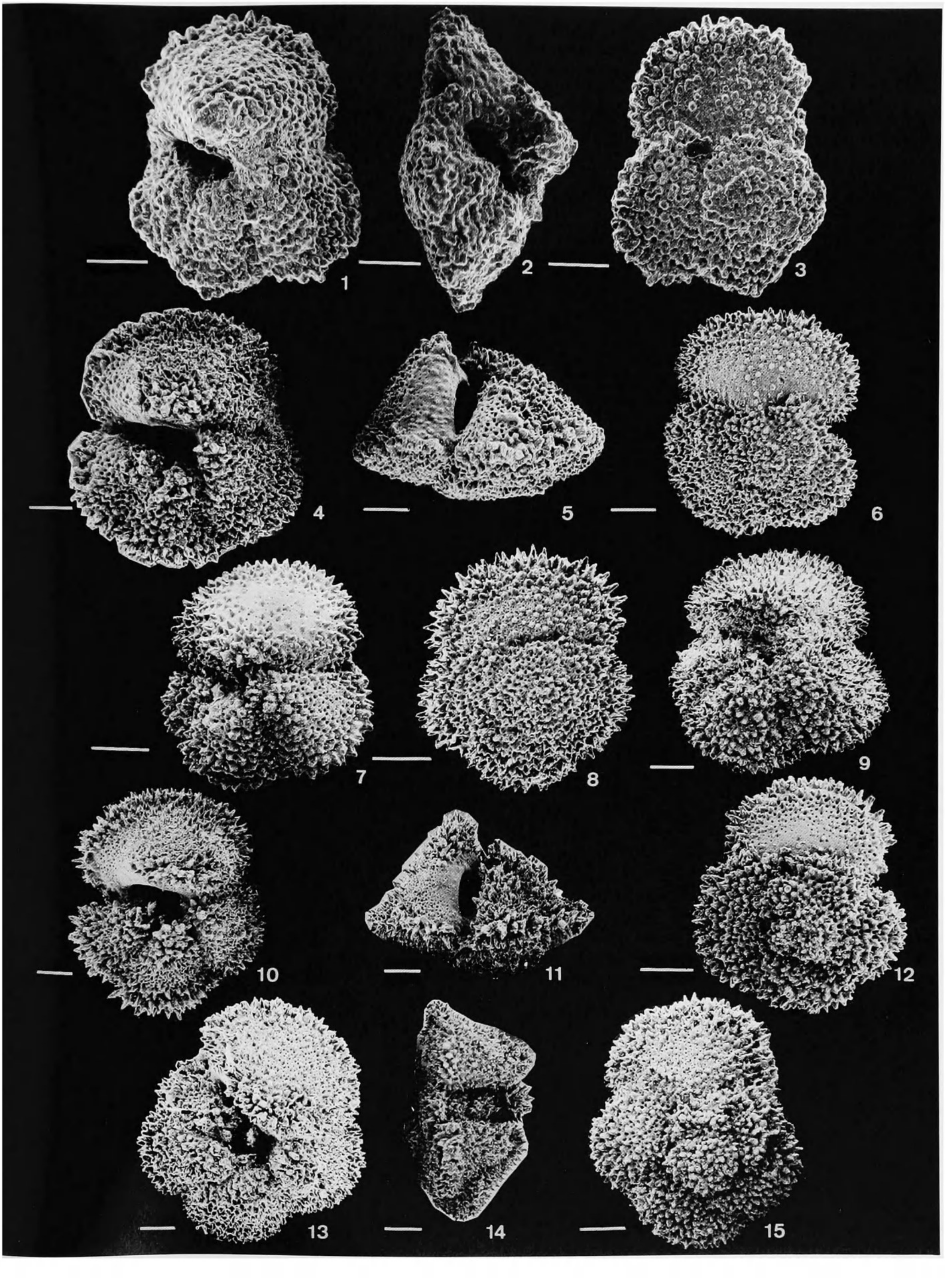
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PLATE 55

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.

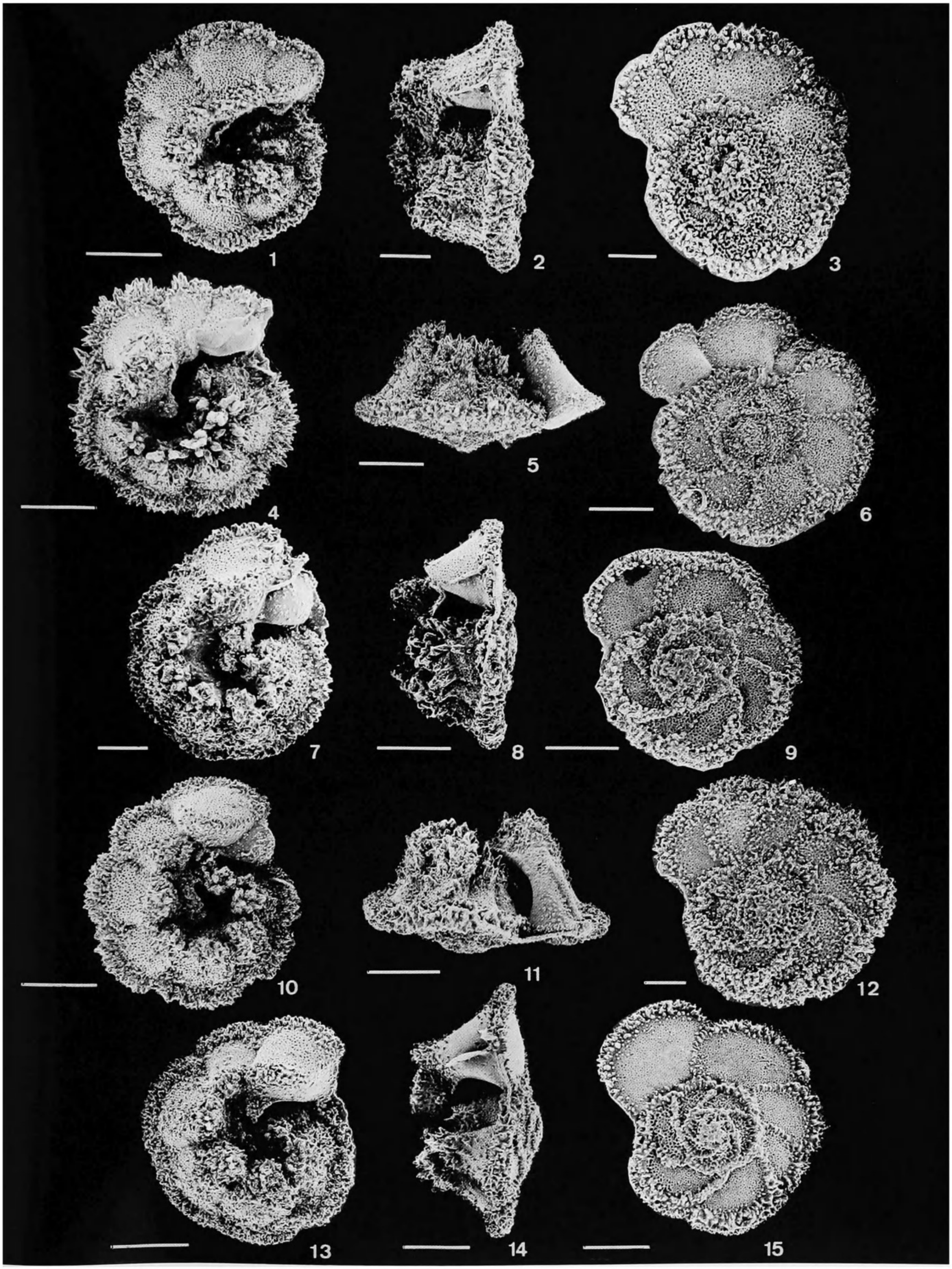
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PLATE 56

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.

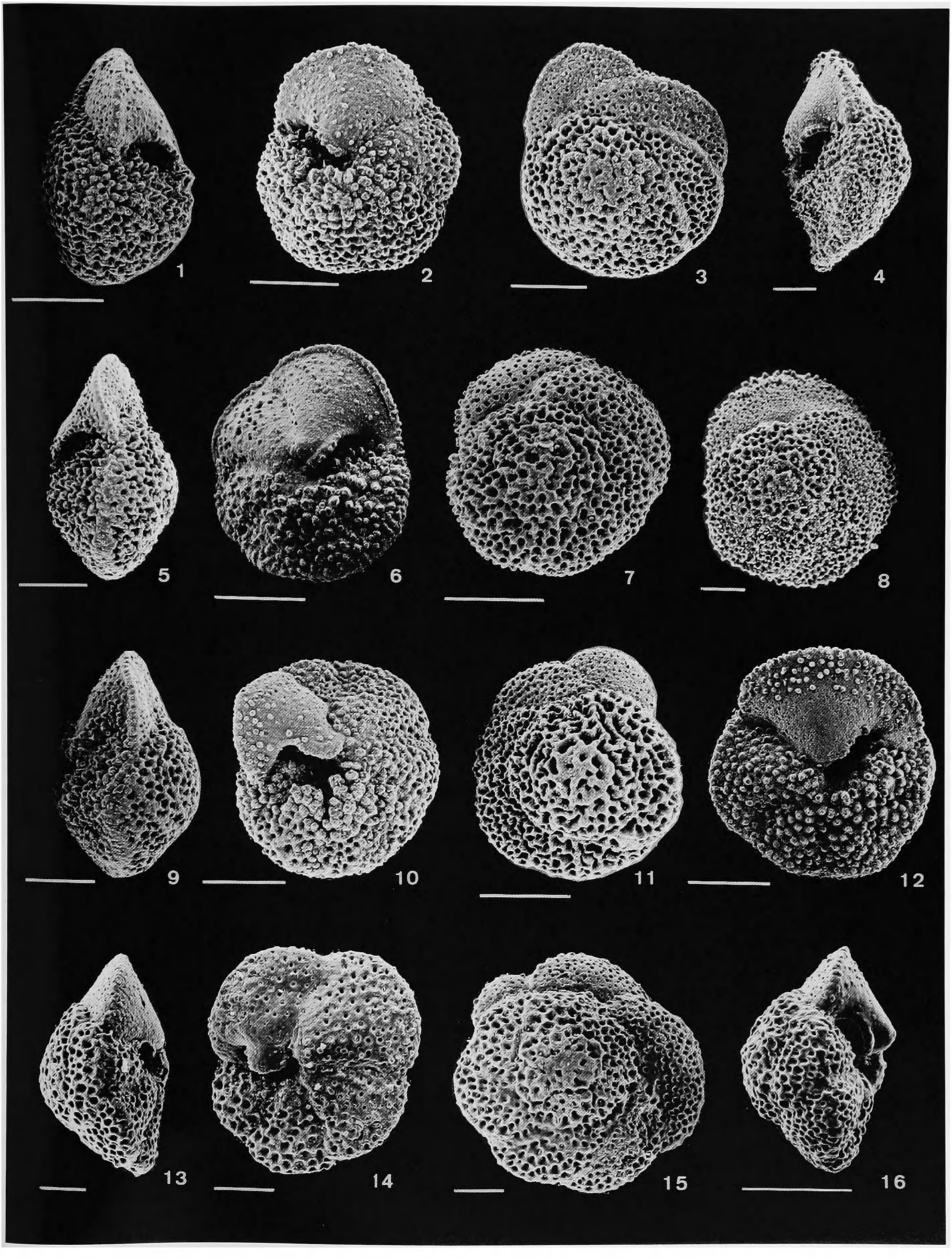
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PLATE 57

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.

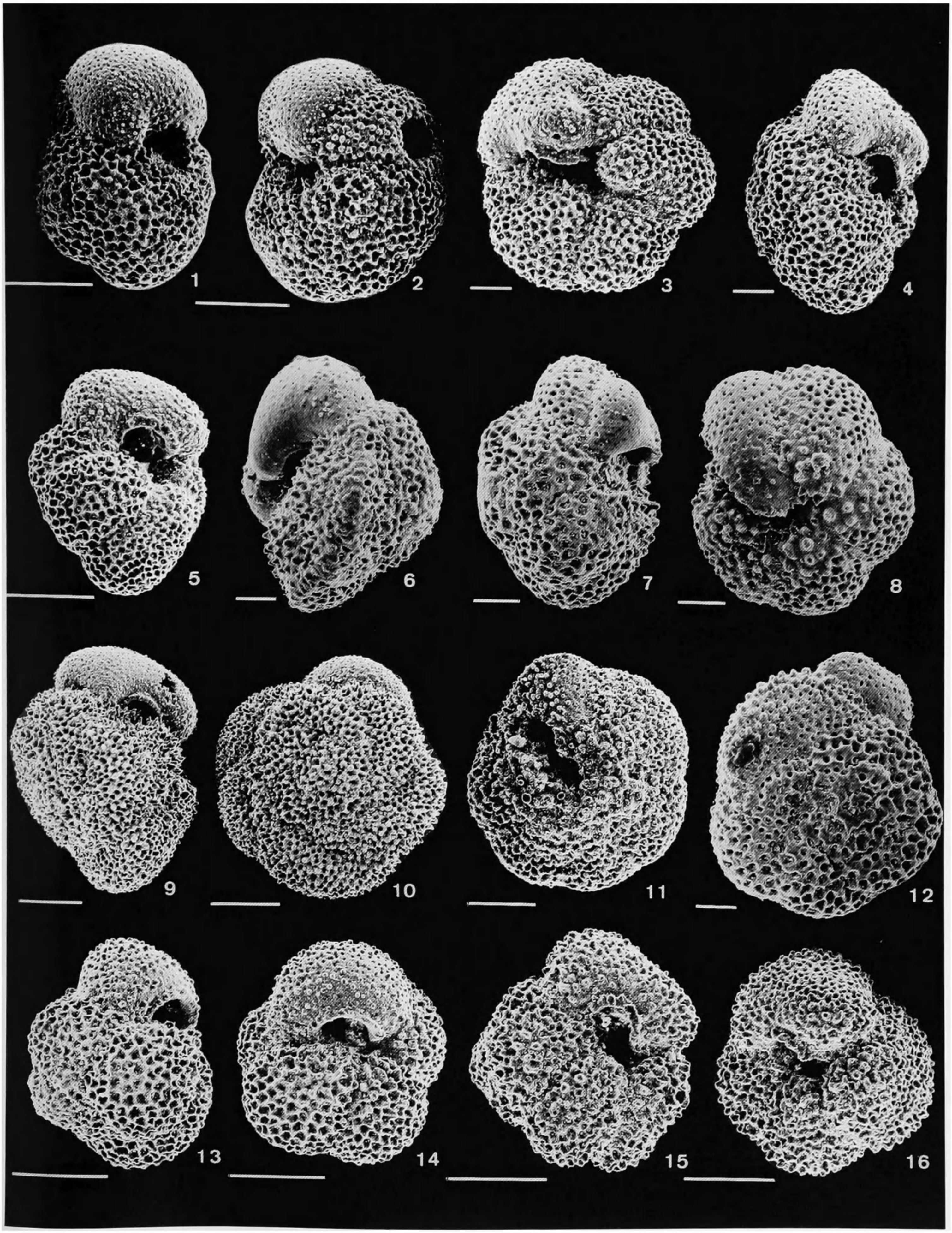
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PLATE 58

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.

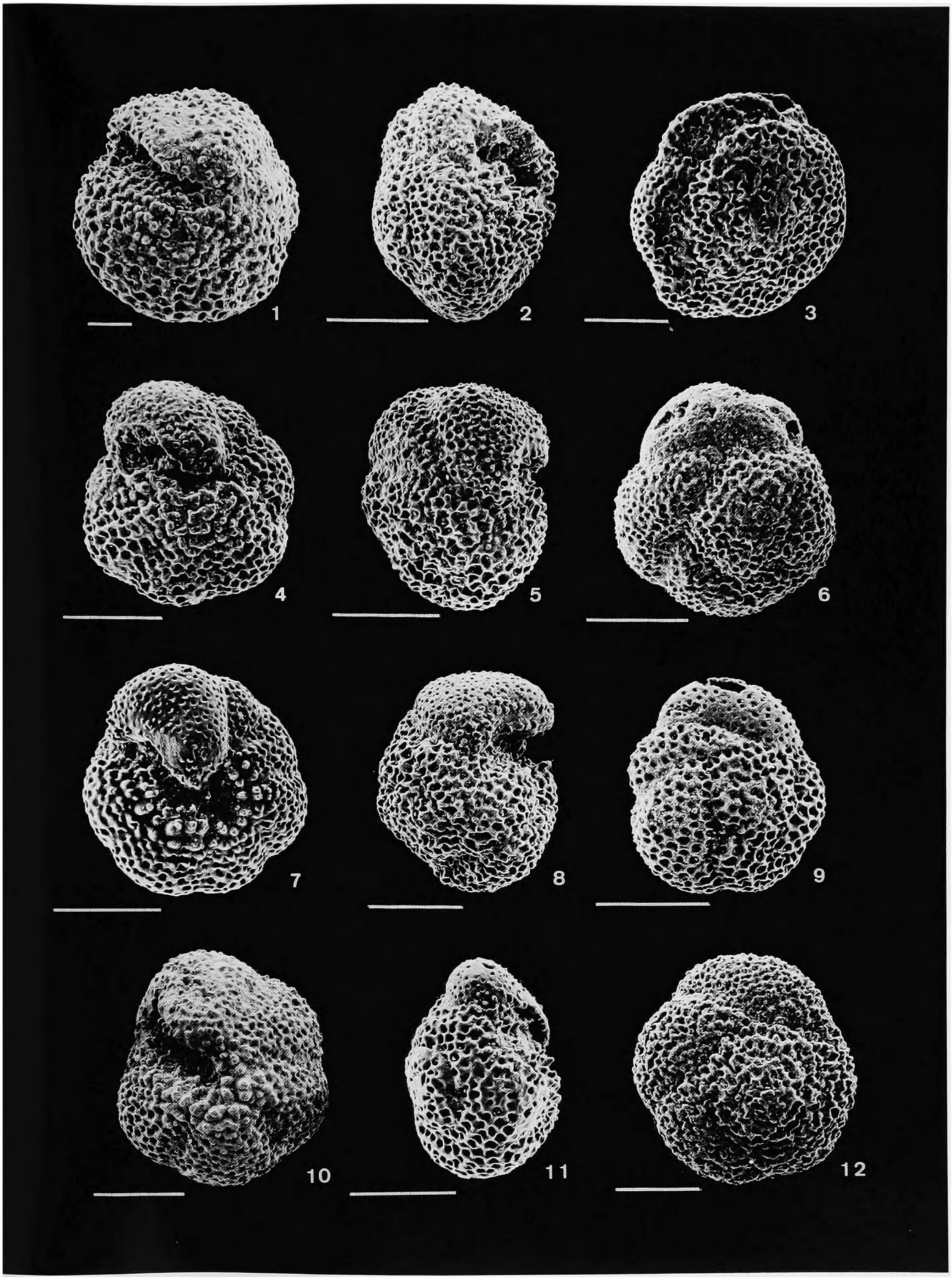
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PLATE 59

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.

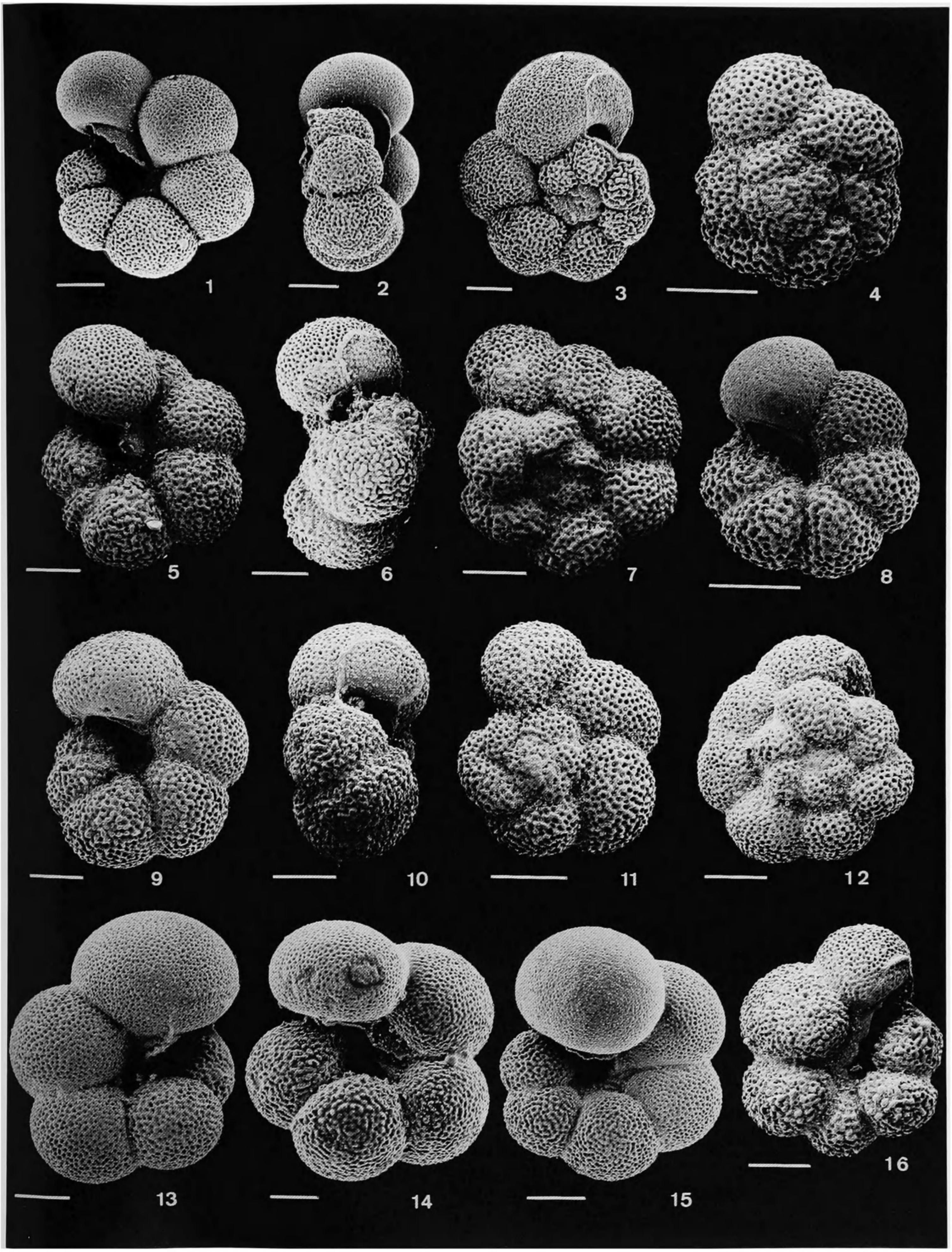
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PLATE 60

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.

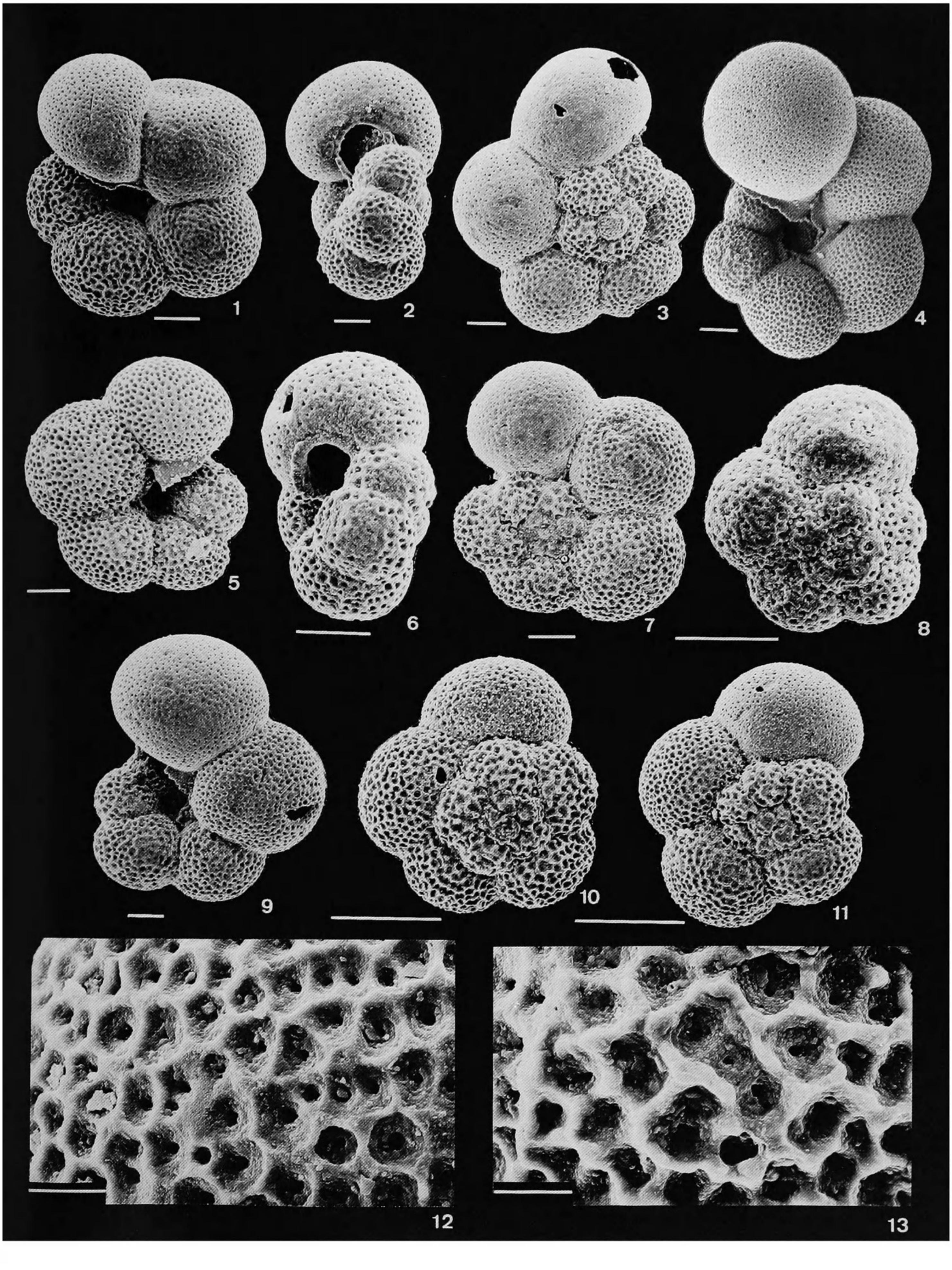
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PLATE 61

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.

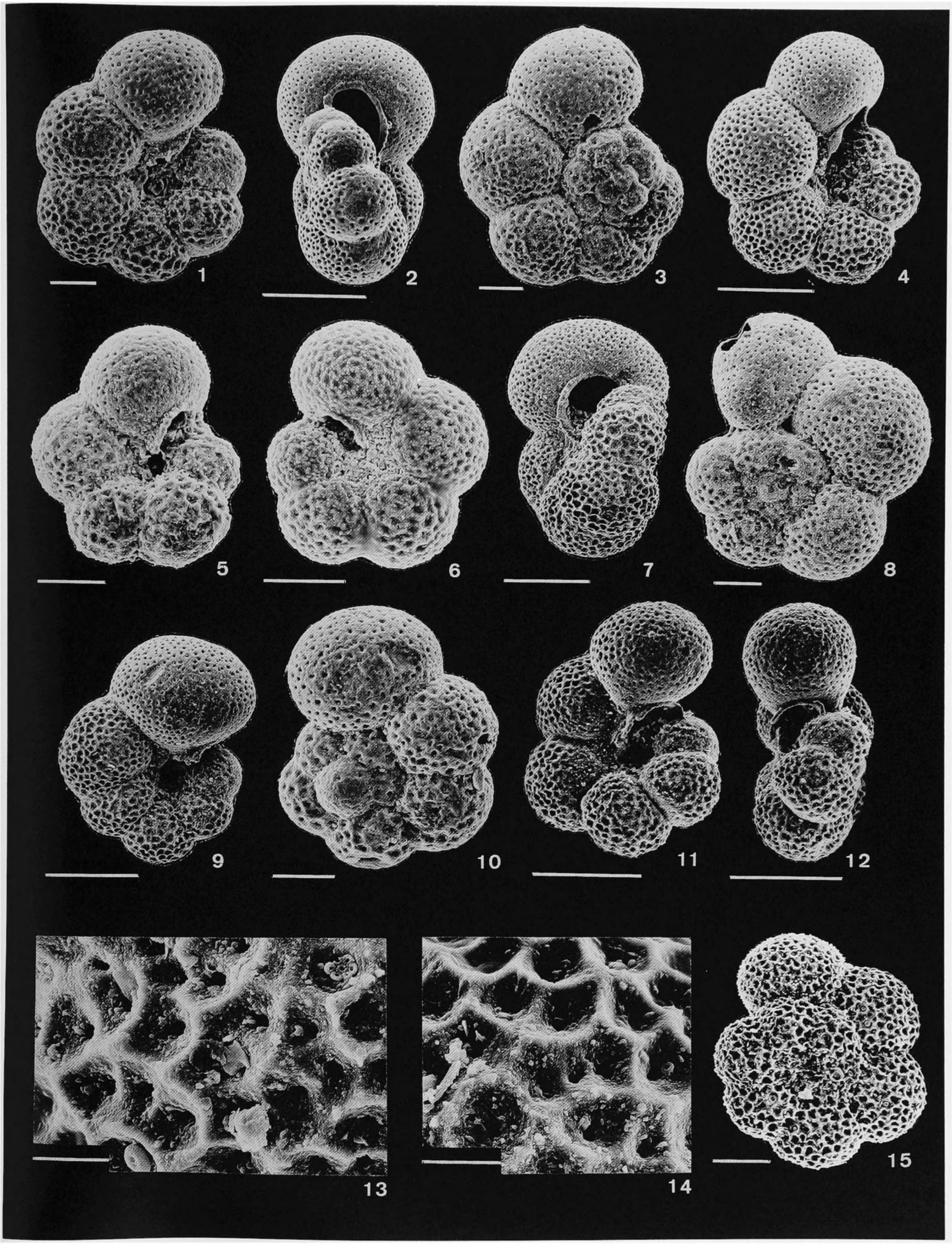


PLATE 62

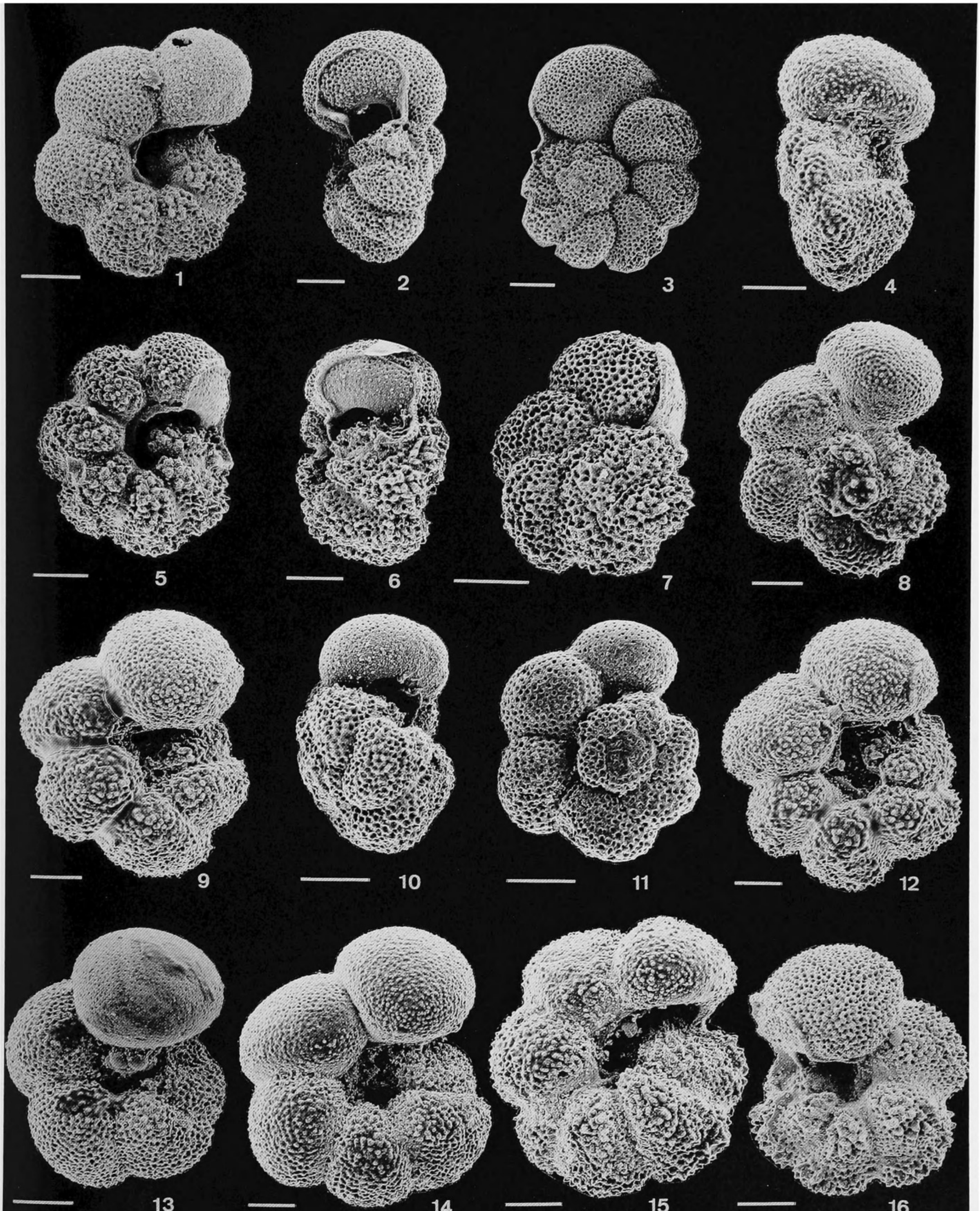
Praemurica uncinata (Bolli, 1957)

(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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