

13. PALEOGENE ABYSSAL FORAMINIFERS FROM THE CAPE AND ANGOLA BASINS, SOUTH ATLANTIC OCEAN¹

Murlene W. Clark,² Florida State University, Tallahassee, Florida
and
Ramil C. Wright, Exxon Production Research Company, Houston, Texas

ABSTRACT

The recovery of calcareous-rich sediments of Paleogene age from three sites in the eastern South Atlantic Ocean provided the opportunity to document the rich abyssal benthic foraminiferal fauna contained within them. The faunal dominance patterns observed at these sites are generally similar to those observed elsewhere in the abyssal Atlantic. There is no unusual faunal turnover at the Oligocene/Eocene boundary, although faunal changes are marked between the middle and upper Eocene.

INTRODUCTION

Benthic foraminifers were examined from three DSDP sites (522, 523, and 524) in the Cape and Angola Basins (Fig. 1) to determine the changes that took place in the Paleogene abyssal population through time. The abyssal environment is one of the most uniform in the ocean; major alterations in diversity and dominance in the deep assemblage can be used as an index of global paleoceanographic changes.

Paleodepths were estimated for Sites 522 and 523 by using the backtracking methods developed by Berger and von Rad (1972). As a result of crustal cooling, the seafloor sank from approximately 2200 to 3600 m below sea level during the Paleogene at Site 522 and from 2200 to 3600 m below sea level at Site 523. Because Site 524 lies on the flanks of the Walvis Ridge, changes in paleodepth due to crustal cooling could not be calculated. The Paleocene and lower Eocene sediments at this site exhibit a "Velasco" type of fauna, and the sediments are therefore considered to be deep (probably abyssal) water deposits.

A Paleogene section was recovered from the Cape and Angola Basins that was complete with the exception of the uppermost portion of the lower Eocene (NP12 to NP14). The sediments were dated biostratigraphically by using calcareous nannofossil and planktonic foraminifers.

Faunal comparisons like those made by Proto Decima and Bolli (1978) could not be made between the Cape and Angola Basins, because coeval sections were not available. Paleocene and lower Eocene sediments were recovered from the Cape Basin, whereas middle Eocene through Oligocene sections were sampled in the Angola Basin. General comparisons can be made between the South Atlantic Paleogene abyssal fauna and the fauna of contemporaneous land sections in the Ca-

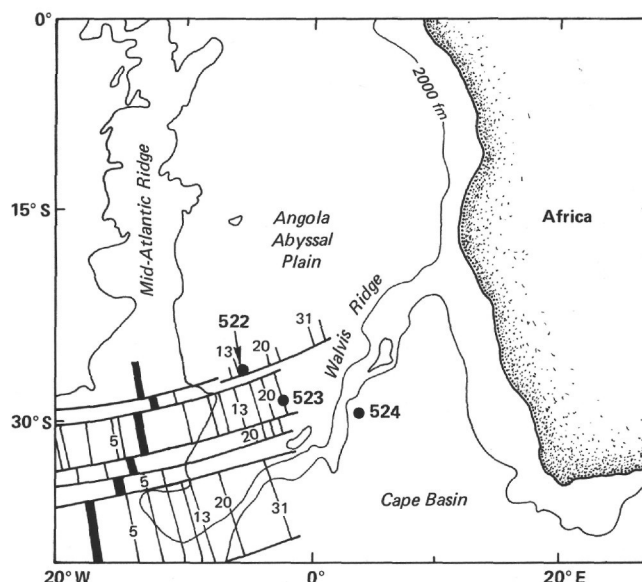


Figure 1. Location map showing positions of sites, marine magnetic anomalies, and the 2000 fm bathymetric contour.

ribbean, particularly Barbados, the Dominican Republic, Trinidad, Cuba, and Mexico.

METHODS

Benthic foraminifers were identified and counted from the > 125 μm size fraction; a taxonomy is presented in the appendix, and range and abundance data are shown in Figures 2 to 4. As a general rule, species that occur in trace quantities are not cited. With a few exceptions, *Lagena*, *Fissurina*, *Oolina*, *Parafissurina*, and *Polymorphinidae* are also omitted because of their great diversity and cosmopolitan distribution. These taxa collectively never comprise more than 5% of any sample.

PRESERVATION

Preservation at Sites 522 and 523 is generally good, although dissolution caused preservation to be poor to moderate during brief intervals of the Paleogene. The samples at Site 524 are less well preserved; calcareous overgrowths occasionally obscure fine detail in the spec-

¹ Hsü, K. J., LaBrecque, J. L., et al., *Init. Repts. DSDP*, 73: Washington (U.S. Govt. Printing Office).

² Present address: Union Oil of California, Houston, Texas.

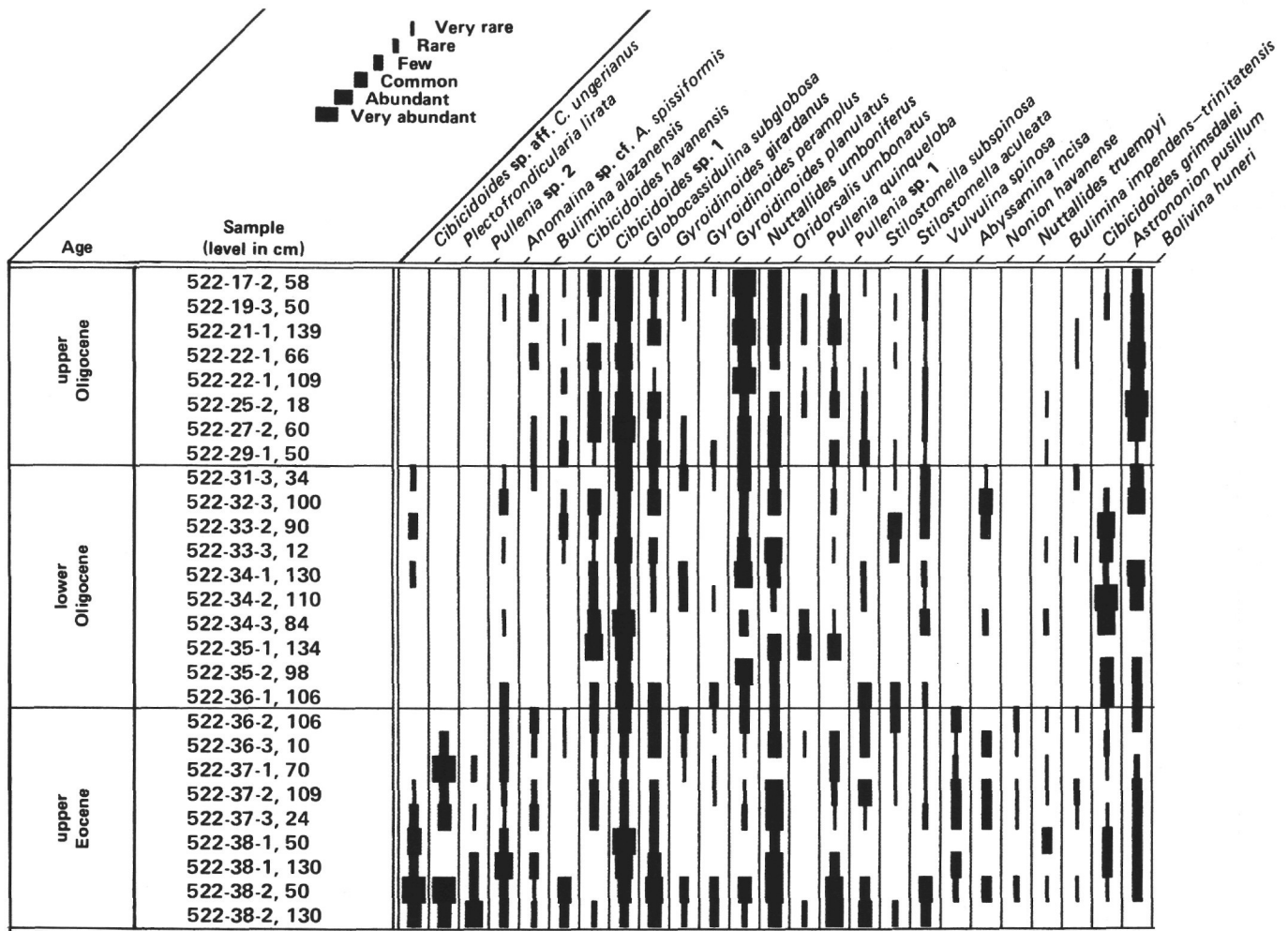


Figure 2. Paleogene benthic foraminifers in Hole 522. The width of each bar is proportional to abundance, which is defined as follows: very rare—<1%; rare—1-2%; few—2-5%; common—5-10%; abundant—10 to 20%; very abundant—>20%.

imens. As the plates illustrate, a light coating of calcareous nannofossils and calcareous debris clings to the etched tests of some of the foraminifers.

CHANGES IN FAUNAL ASSEMBLAGE

The Paleocene fauna is dominated by *Gavelinella beccariiformis*, *Nuttallides crassaformis-truempyi*, and (to a lesser degree) by *Neoepionides hillebrandti* and *Spiroplectammina spectabilis*. A bloom of *Hanzawaia* and *Cibicides* in Zones NP3 through NP5 briefly eclipses all other forms. Tjalsma and Lohmann (1983) described *G. beccariiformis* and *Tritaxia trilatera* as the dominant species of the abyssal Paleocene. The first of these is abundant at Site 524, but the latter is not.

The lower Eocene sediments are characterized by a fauna that is somewhat less diverse than that of the Paleocene. The dominant taxon is clearly *N. crassaformis-truempyi*; the remainder of the assemblage is composed of survivors from the Paleocene, with the exception of *Globocassidulina subglobosa*, *Aragonia semireticulata*, *Clinapertina inflata*, and *Hanzawaia cushmani*, which originate at this time. *Tappanina selmensis*, *Abyssamina quadrata*, and *Anomalina* sp. cf. *A. praeacuta* are well represented in the assemblages. The lower Eo-

cene assemblage at Site 524 is analogous to that described by Tjalsma and Lohmann (1983) by virtue of the dominant position of *N. truempyi*. In the Bay of Biscay, Miller (in press) also found abundant *N. truempyi* in the lower Eocene. In addition, he noted large quantities of *Abyssamina* spp. and *Clinapertina* spp., forms that are not particularly common at Site 524.

During the middle Eocene, *N. crassaformis-truempyi* continued to dominate. This observation is consistent with that of Tjalsma and Lohmann (1983) and Miller (in press) for the same interval. The Leg 73 material also contains significant numbers of *G. subglobosa*, *Gyroidinoides*, and *Oridorsalis umbonatus*, taxa that were destined to assume prominent positions in the late Eocene fauna.

A change is apparent in the character of the abyssal assemblage during the upper Eocene. *N. crassaformis-truempyi*, which dominated the Paleogene assemblages until this time, shows a marked decline in abundance. This event is coincident with the rise of *N. umboniferus*. *Globocassidulina subglobosa*, *Gyroidinoides*, *O. umbonatus*, and *Cibicidoides* sp. cf. *C. ungerianus* are also prominent in the upper Eocene assemblages. *Bolivina huneri* is important but secondary to the aforesaid spe-

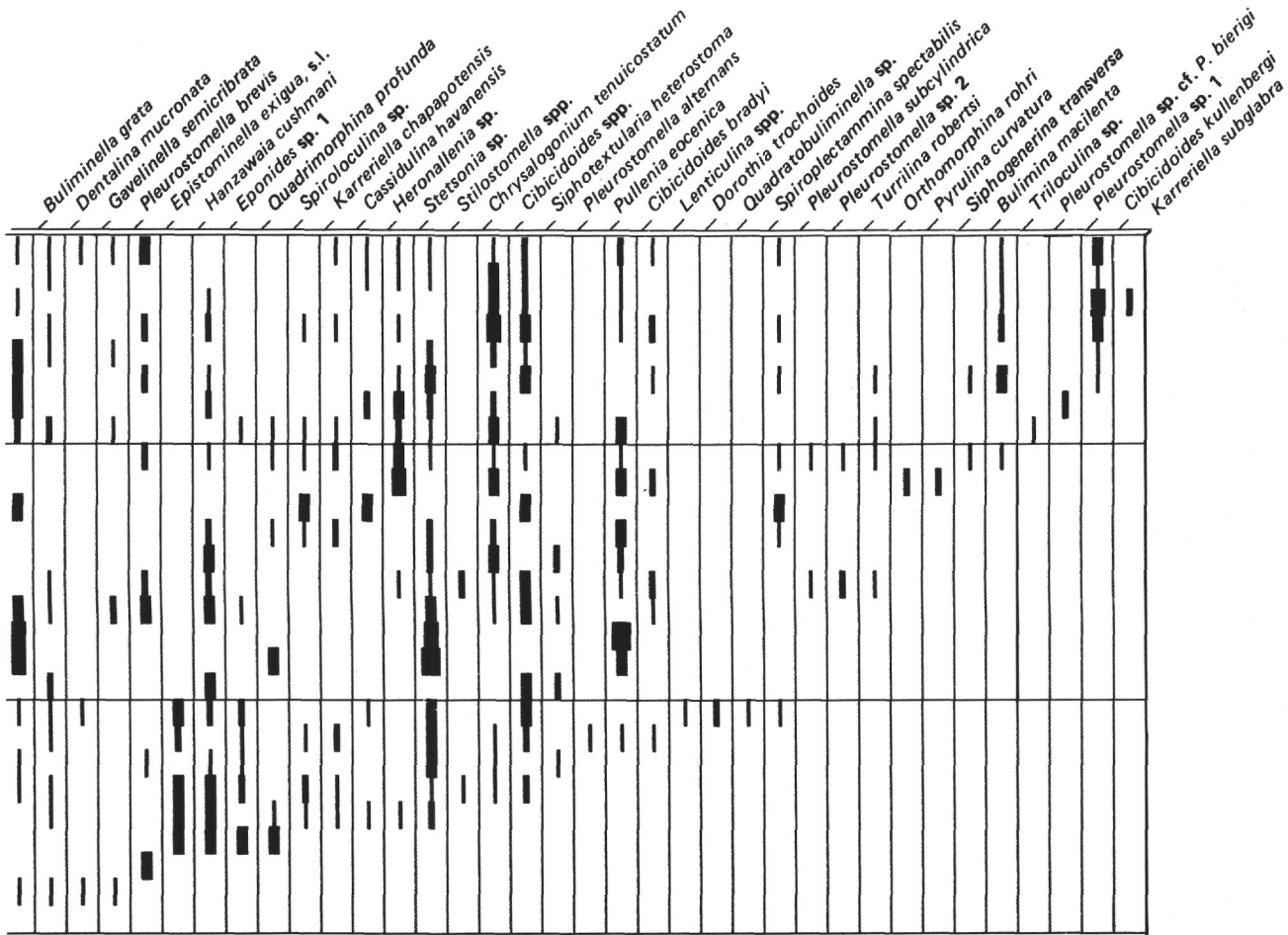


Figure 2. (Continued).

cies. A brief interval coinciding with Zone NP20 witnessed an additional perturbation from the patterns of dominance previously established during the Paleogene. *Plectofrondicularia lirata* increased dramatically, making up to 70% in some samples; this event occurred simultaneously with an increase in the abundance of *Vulvulina spinosa*.

The Oligocene faunal patterns are similar to those of the upper Eocene. *Globocassidulina subglobosa*, *O. umbonatus*, and *Cibicidoides* sp. 1 continue to dominate the assemblage. One prominent new faunal element is *N. umboniferus*, which originates in the late Eocene. *Gyroidinoides* is still well represented, but it assumes secondary significance. These Oligocene and upper Eocene patterns again are similar to those observed elsewhere in the Atlantic by Tjalsma (pers. comm., 1982), Tjalsma and Lohmann (1983), and Miller (in press).

There is no appreciable faunal turnover at the Oligocene/Eocene boundary. Our data here support similar observations made by Beckmann et al. (1981), Corliss (1981), and Tjalsma (pers. comm., 1982). Tjalsma and Lohmann (1983) concluded that a faunal turnover event took place earlier, between the middle and late Eocene. This event involved a change from a fauna dominated by *N. truempyi* to one dominated by *Globocassidulina*

subglobosa, *O. umbonatus*, *Gyroidinoides*, and *C. ungerianus*. The data from Leg 73 show a high rate of faunal turnover at the upper/middle Eocene boundary (Parker et al., this vol.) in addition to the changes in assemblage dominance noted by Tjalsma and Lohmann (1983). There is also an extremely low species origination rate for the Oligocene that may be in response to the development of a psychrospheric ocean at this time (Parker et al., this vol.).

TAXONOMY

Taxonomic references can be found in Ellis and Messina (1940).

Abyssamina incisa Schnitker and Tjalsma (Plate 1, Figs. 1a-c). Intermediate forms between *Abyssamina poagi* and *A. incisa* (Schnitker and Tjalsma, 1980) are here included with *A. incisa*. *A. incisa* and transitional forms with increasingly incised sutures and more elongate final chambers occur most frequently in the upper middle and upper Eocene.

Abyssamina poagi Schnitker and Tjalsma (Plate 1, Figs. 2a-c).

Abyssamina quadrata Schnitker and Tjalsma (Plate 1, Figs. 3a-c).

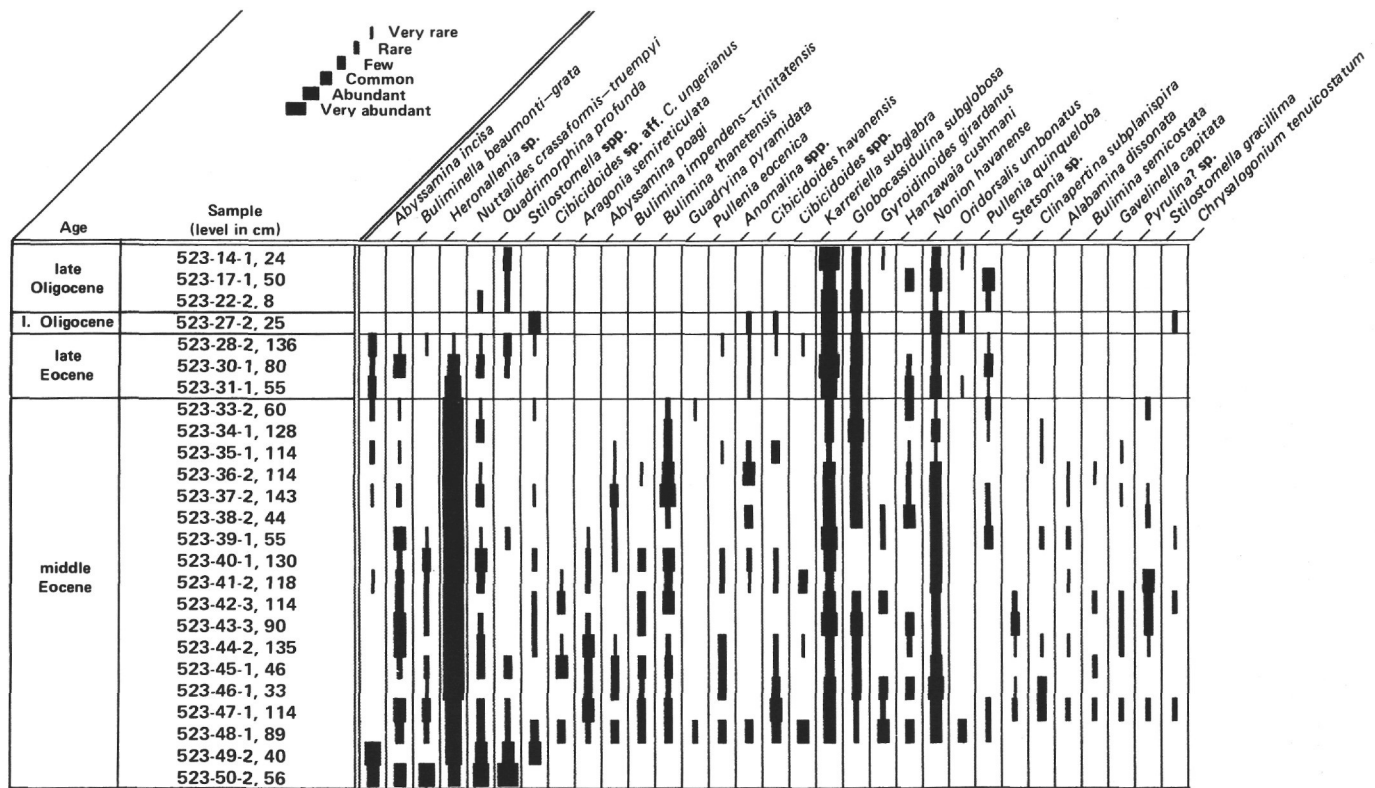


Figure 3. Paleogene benthic foraminifers in Hole 523. Abundance is defined as for Fig. 2.

Alabamina dissonata (Cushman and Renz) (Plate 2, Figs. 5a, b) [= *Pulvinulinella atlantisae* Cushman var. *dissonata* Cushman and Renz].

Anomalina sp. cf. *A. praeacuta* Vasilenko (Plate 2, Figs. 1a-c). The Leg 73 individuals have fewer chambers (10) than the type description indicates.

Anomalina sp. cf. *A. spissiformis* Cushman and Stainforth (Plate 1, Figs. 5a-c) [= *Anomalina alazanensis* Nuttall var. *spissiformis* Cushman and Stainforth]. The Leg 73 specimens are smaller and have fewer chambers (9-10) than specified by the type description.

Anomalina sp. 1 (Plate 2, Figs. 6a, b). This form is very nearly planispiral; the spiral side is very nearly involute. This species occurs only in the upper Paleocene of Site 524.

Anomalina sp. 2 (Plate 1, Figs. 4a-c). This species is similar in form to *Gyroidinoides* except for the anomalinid aperture. The form is subconical on the umbilical side. Chamber expansion is rapid, and the apertural face is large.

Aragonia capdevilensis (Cushman and Bermudez) (Plate 2, Figs. 4a, b) [= *Bolivina capdevilensis* Cushman and Bermudez]. The specimens are somewhat thickened at the apertural end.

Aragonia ouezzanensis (Rey) (Plate 2, Figs. 3a, b) [= *Bolivinooides ouezzanensis* Rey].

Aragonia semireticulata (LeRoy) (Plate 2, Figs. 2a, b) [= *Bolivina semireticulata* LeRoy].

Astrononion pusillum Hornibrook (Plate 3, Figs. 1a, b).

Bolivina huneri Howe (Plate 3, Fig. 2). Ornamentation is usually absent from the last chamber; however, the penultimate chamber may be either smooth or ornamented. Resig (1976) described this form from the upper Eocene to lower Oligocene sediments of the Nazca Plate and called it *Bolivina* sp.

Bolivina sp. cf. *B. spiralis* Cushman (Plate 3, Fig. 3). The Leg 73 specimens lack the spines that Cushman described on the early portion of the test. Mallory (1959) illustrated a spineless form similar to the ones illustrated here and also cited it as *Bolivina spiralis*.

Bolivinooides delicatulus Cushman [= *Bolivinooides decorata* (Jones) var. *delicatula* Cushman].

Bulimina alazanensis Cushman (Plate 3, Figs. 4a, b).

Bulimina bradburyi Martin (Plate 3, Fig. 5). The early chambers of this form sometimes show a rough texture, although this may be a function of preservation.

Bulimina impendens Parker and Bermudez (Plate 3, Fig. 6). *Bulimina impendens* appears to be gradational with *B. trinitatensis*. The two forms are very similar and are tabulated here under the designation *B. impendens-trinitatensis*. *B. impendens*, s.s., which is very rare in the Leg 73 material, is less elongate and has fewer chambers than *B. trinitatensis*.

Bulimina macilenta Cushman and Parker [= *Bulimina denticulata* Cushman and Parker (non Protescu), *Bulimina macilenta* Cushman and Parker].

Bulimina midwayensis Cushman and Parker (Plate 3, Fig. 7) [= *Bulimina arkadelphiana* Cushman and Parker var. *midwayensis* Cushman and Parker].

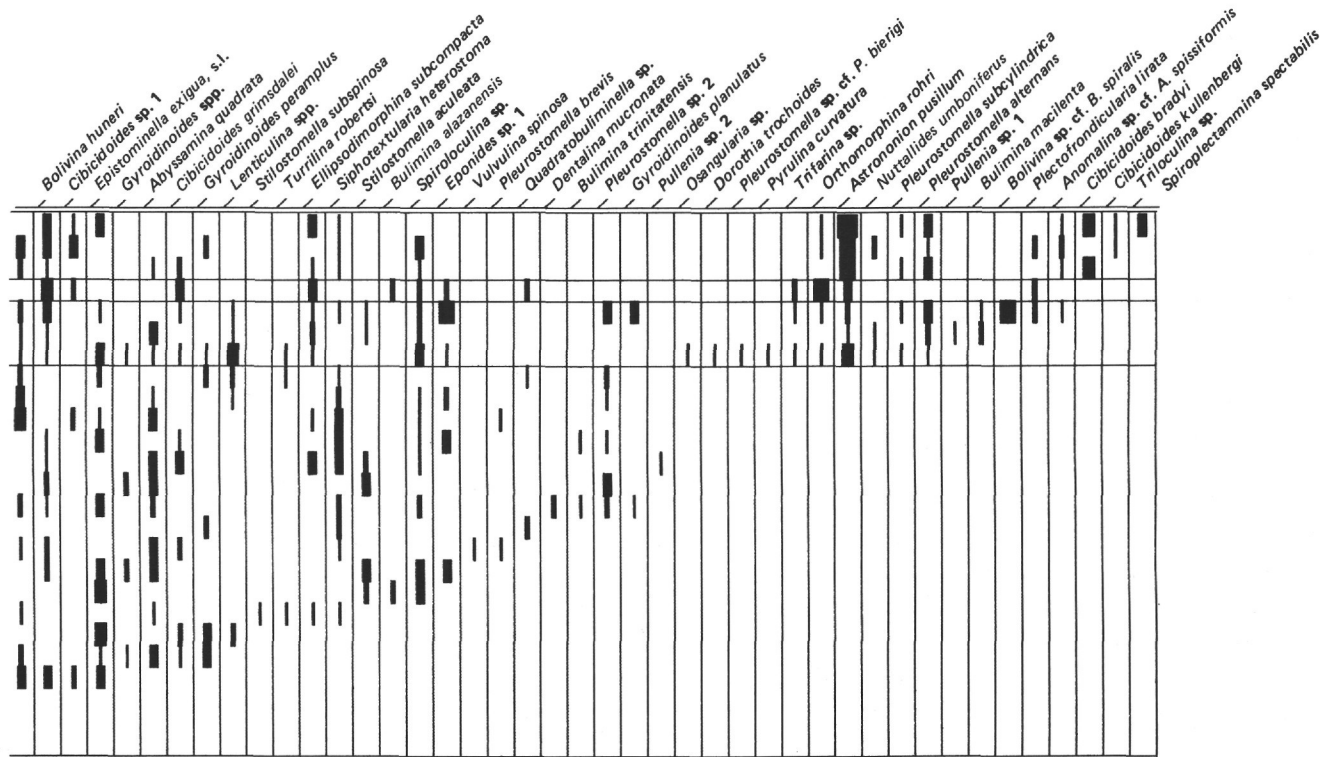


Figure 3. (Continued).

Bulimina semicostata Nuttall (Plate 3, Fig. 8).

Bulimina thanetensis Cushman and Parker (Plate 3, Fig. 10).

Bulimina trihedra Cushman.

Bulimina trinitatensis Cushman and Jarvis (Plate 3, Fig. 9). This species is combined with *Bulimina impendens* for tabulation in the range charts for Sites 522 and 523. The species is more elongate and has more chambers than *B. impendens*.

Buliminella beaumonti Cushman and Renz (Plate 3, Fig. 12). Because of the number of forms that are transitional between *Buliminella beaumonti* and *B. grata* (illustrated in Tjalsma and Lohmann, 1983), we find it impossible to determine the taxon to which the Leg 73 forms belong. Consequently they are listed in the range charts as *B. beaumonti-grata*.

Buliminella grata Parker and Bermudez (Plate 3, Figs. 11a, b). This species is combined with *Buliminella beaumonti* in the range charts for Sites 523 and 524.

Cassidulina havanensis Cushman and Bermudez. This form is found only in the upper Eocene and Oligocene sediments of Site 522.

Chrysalogonium longicostatum Cushman and Jarvis.

Chrysalogonium tenuicostatum Cushman and Bermudez (Plate 3, Fig. 13).

Cibicides sp. 1 (Plate 5, Figs. 5a, b). This form is found exclusively in the Paleocene sediments of Site 524; abundance is maximum in Zones NP3 to NP5. The species is similar in chamber pattern and design to *Cibicidoides subspiratus* (Nuttall), but it has a distinctly plano-convex form, in contrast to the unequal biconvexity of *C. subspiratus*.

Cibicidoides bradyi (Trauth) (Plate 4, Figs. 1a-c) [= *Truncatulina dutemplei* Brady (non d'Orbigny), *Truncatulina bradyi* Trauth].

Cibicidoides grimsdalei (Nuttall) (Plate 4, Figs. 2a-c) [= *Cibicides grimsdalei* Nuttall].

Cibicidoides havanensis (Cushman and Bermudez) (Plate 4, Figs. 3a-c) [= *Cibicides havanensis* Cushman and Bermudez].

Cibicidoides kullenbergi (Parker). This form is present in the Oligocene down to the calcareous nannofossil zone NP23; it occurs at Sites 522 and 523.

Cibicidoides sp. aff. *C. madruagaensis* (Cushman and Bermudez) (Plate 4, Figs. 5a-c) [= *Cibicides madruagaensis* Cushman and Bermudez]. The Leg 73 forms exhibit depressed but not limbate sutures on the umbilical side and have a less angulate periphery than indicated by the type description.

Cibicidoides sp. aff. *C. ungerianus* (d'Orbigny) (Plate 4, Figs. 4a-c) [= *Rotalina ungeriana* d'Orbigny]. *Cibicidoides ungerianus* resembles *C. kullenbergi* closely and may be its ancestral form. We agree with the observations of Tjalsma and Lohmann (1983) in that our specimens also lack the granular center on the spiral side as noted in the type description. This form is particularly abundant in the upper Eocene.

Cibicidoides sp. 1 (Plate 5, Figs. 1a-c). This unnamed species also occurs in the Bay of Biscay Paleogene (K. Miller, pers. comm., 1982). It may be a morphologic variant of *Cibicidoides* sp. cf. *C. ungerianus* (L. Tjalsma, pers. comm., 1982).

Clinapertina inflata Tjalsma and Lohmann (Plate 5, Figs. 2a-c).

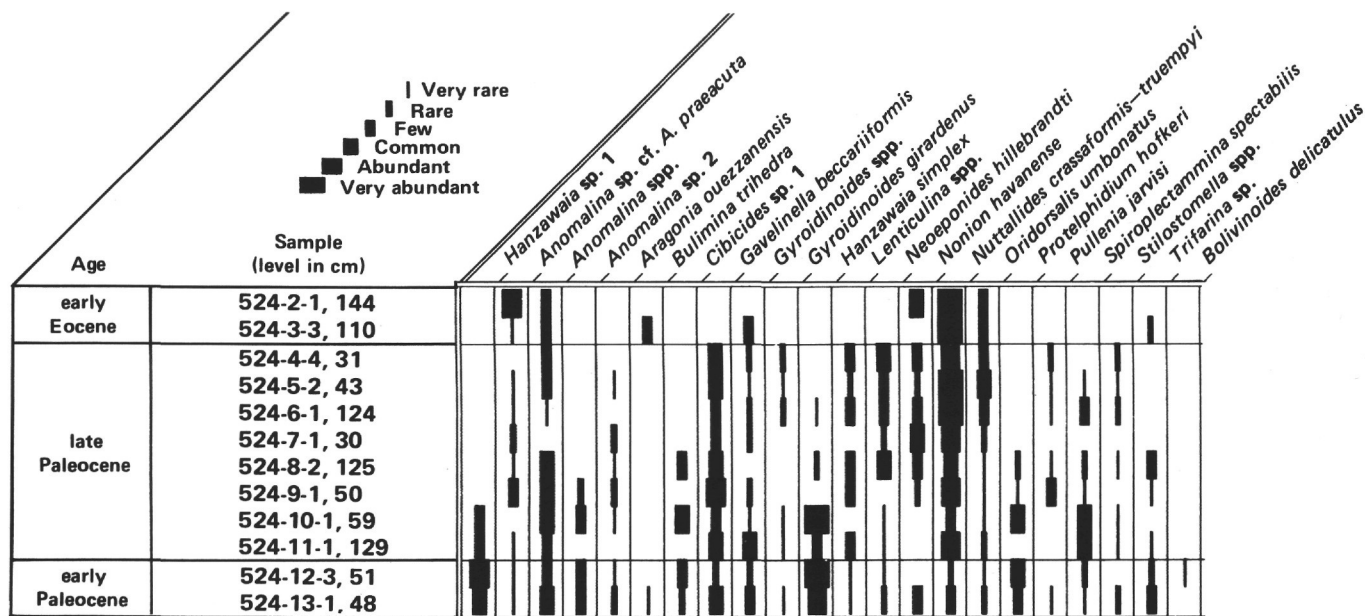


Figure 4. Paleogene benthic foraminifers in Hole 524. Abundance is defined as for Fig. 2.

Clinapertina subplanispira Tjalsma and Lohmann.

Dentalina mucronata Neugeboren (Plate 5, Fig. 6).

Dorothyia oxycona (Reuss) [= *Gaudryina oxycona* Reuss, 1860].

Dorothyia trochoides (Marsson) (Plate 6, Fig. 7) [= *Gaudryina crassa* Marsson var. *trochoides*, 1878].

Ellipsodimorphina subcompacta Liebus (Plate 6, Fig. 5).

Eponides sp. 1 (Plate 6, Figs. 1a-c). This species ranges from the middle Eocene through the Oligocene and is present at Sites 522 and 523. The degree of convexity of the spiral side is variable.

Eorupertia bermudezi Anisgard (Plate 6, Figs. 2a-c). The type illustration of this species is very poor, and a positive identification cannot be made from it. The type description is, however, consistent with the Leg 73 forms. Bermudez and Gamez (1966) illustrated a form as *Eorupertia bermudezi*; the Leg 73 specimens resemble it very closely.

Epistominella exigua, s.l. (Brady) (Plate 5, Figs. 3a-c, 4a-c) [= *Pulvinella exigua* Brady]. Ancestral forms of this species begin to appear in the middle Eocene. Resig (1976) identified this early form as *Epistominella* sp. and suggested its ancestry. By the late Oligocene, clearcut examples of *Epistominella exigua*, s.s. occur. Both the ancestral form and *E. exigua*, s.s. are combined in the range charts as *E. exigua*, s.l.

Gaudryina pyramidata Cushman (Plate 6, Figs. 4a, b) [= *Gaudryina laevigata* Franke var. *pyramidata* Cushman]. This form is restricted to the middle Eocene.

Gavelinella beccariiiformis (White) (Plate 6, Figs. 3a-c) [= *Rotalia beccariiiformis* White]. This form is restricted to the Paleocene, where it is one of the dominant faunal elements.

Gavelinella capitata (Guembel) [= *Rotalia capitata* Guembel]. Tjalsma and Lohmann (1983) distinguished *Gavelinella capitata* from *G. danica* by its

evolute coiling and greater number of chambers (9). We separate them on the basis of the number of chambers because evolute coiling is observed in both forms.

Gavelinella danica (Brotzen) [= *Cibicides danica* Brotzen]. This form is distinguished from *Gavelinella capitata* by having fewer chambers (7).

Gavelinella hyphalus (Fisher) (Plate 7, Figs. 1a-c) [= *Planulina dayi* var. White, *Anomalinoidea hyphalus* Fisher, 1969]. This species is very similar to *Gavelinella velascoensis* but can be distinguished by its less convex, involute dorsal side, its greater number of chambers, its more completely developed umbilical plug, and its smaller test (Tjalsma and Lohmann, 1983). The Leg 73 specimens do not have a pronounced umbilical plug or a significantly greater number of chambers.

Gavelinella semicibrata (Beckmann) (Plate 7, Figs. 5a-c) [= *Anomalina pompilioides* Galloway and Heminway var. *semicibrata* Beckmann].

Gavelinella velascoensis (Cushman) (Plate 7, Figs. 2a, b) [= *Anomalina velascoensis* Cushman]. This form is very similar to *Gavelinella hyphalus* but is distinguished by its evolute, convex dorsal side and larger test.

Globocassidulina subglobosa (Brady) (Plate 6, Figs. 6a, b) [= *Cassidulina subglobosa* Brady]. This form first appears in the lower Eocene and increases in abundance to a maximum in the upper Eocene and Oligocene.

Gyroidinoides girardanus (Reuss) (Plate 7, Figs. 4a-c) [= *Rotalia girardana* Reuss]. All *Gyroidinoides* with a vaulted to subconical umbilical side and curved to oblique sutures on the spiral side are included in this taxon. *Rotalia soldanii* (d'Orbigny) var. *subangulata* Plummer, *Gyroidina orbicularis* d'Orbigny var. *obliquata* Cushman and McMasters, and *G. zealandica* Finlay are names that have been used for var-

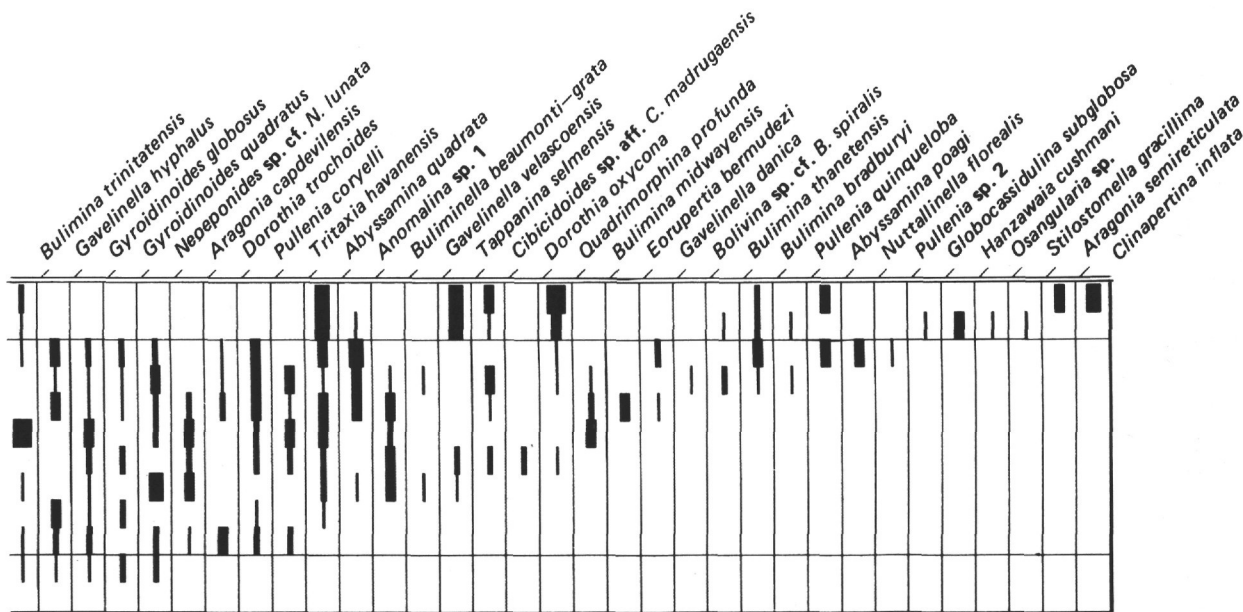


Figure 4. (Continued).

iation on this basic morphology; they are included here in the concept of *Gyroidinoides girardanus*.

Gyroidinoides globosus (Hagenow) [= *Nonionina globosa* Hagenow, *Gyroidinoides globosa* (Hagenow) in Proto Decima and Bolli (1978)].

Gyroidinoides peramplus (Cushman and Stainforth) (Plate 7, Figs. 3a-c) [= *Gyroidina girardana* (Reuss) var. *perampla* Cushman and Stainforth].

Gyroidinoides planulatus (Cushman and Renz) (Plate 8, Figs. 1a-c) [= *Gyroidina planulata* Cushman and Renz]. The convexity of the spiral side is quite variable. Specimens with flattened spiral sides assume the appearance of *Anomalina* but lack the distinctive anomalinid aperture.

Gyroidinoides quadratus (Cushman and Church) (Plate 8, Figs. 2a-c) [= *Gyroidina quadrata* Cushman and Church].

Hanzawaia cushmani (Nuttall) (Plate 8, Figs. 3a-c) [= *Cibicides cushmani* Nuttall].

Hanzawaia simplex (Brotzen) (Plate 8, Figs. 5a-c) [= *Cibicides simplex* Brotzen]. Brotzen's description of *Cibicides simplex* suggests some variability. The Leg 73 forms are encompassed within that variability. The form is flat to concave on the umbilical side with a narrow periphery. This species is found only in the Paleocene sediments of Hole 524. It is the dominant species in Zones NP3 to NP5.

Hanzawaia sp. 1 (Plate 8, Figs. 4a-c). This species is similar to *Hanzawaia simplex*, but it has more inflated chambers and a more lobate outline. It is restricted to the Paleocene sediments of Hole 524 (NP3 to NP5).

Heronallenia sp. (Plate 9, Figs. 5a, b). This species occurs sporadically from the middle Eocene through the Oligocene.

Karreriella chapapotensis (Cole) (Plate 9, Fig. 1) [= *Textularia chapapotensis* Cole].

Karreriella subglabra (Guembel) (Plate 9, Fig. 2) [= *Gaudryina subglabra* Guembel].

Neoponoides hillebrandti Fisher (Plate 9, Figs. 3a-c) [= *Eponoides whitei* Hillebrandt (non Brotzen), *Neoponoides hillebrandti* Fisher]. This form occurs in the Leg 73 material with a bimodal size distribution; the average size of one group is 375 μm , that of the other 180 μm .

Neoponoides sp. cf. *N. lunata* (Brotzen) (Plate 9, Figs. 6a-c) [= *Eponoides lunata* Brotzen]. The Leg 73 specimens differ from *Neoponoides lunata* in having a small umbilical boss and less curved sutures on the umbilical side. These differences were also observed by Tjalsma and Lohmann (1983).

Nonion havanense Cushman and Bermudez (Plate 10, Figs. 1a, b). Specimens with both rounded and subacute peripheral margins are included in our concept of *Nonion havanense*.

Nuttallides crassaformis (Cushman and Siegfus) (Plate 9, Figs. 7a, b) [= *Asterigerina crassaformis* Cushman and Siegfus]. *Nuttallides crassaformis* is not easily separated from *N. truempyi*, although *N. crassaformis* has chamberlets encircling the umbilical boss that are absent in *N. truempyi*. These chamberlets are often indistinct. Both forms are combined in the range charts for Sites 523 and 524.

Nuttallides truempyi (Nuttall) (Plate 9, Figs. 4a, b) [= *Eponoides truempyi* Nuttall]. This species is tabulated with *Nuttallides crassaformis* in the range charts for Sites 523 and 524, because the two forms are not easily distinguished. This taxon is a major constituent of the middle Paleocene through middle Eocene fauna. In the upper Eocene it declines in abundance with the coincident increase of *N. umboniferus*.

Nuttallides umboniferus (Cushman) (Plate 9, Figs. 8a-c) [= *Pulvinulinella umbonifera* Cushman]. This species makes its first appearance in the upper Eocene

- and becomes a dominant faunal element in the Oligocene.
- Nuttallinella florealis* (White) [= *Gyroidina florealis* White].
- Oridorsalis umbonatus* (Reuss) (Plate 10, Figs. 3a-c) [= *Rotalina umbonata* Reuss]. This species is present throughout the Paleogene at all sites.
- Orthomorphina rohri* (Cushman and Stainforth) (Plate 10, Fig. 4) [= *Nodogenerina rohri* Cushman and Stainforth].
- Osangularia* sp. This very rare species occurs in the lower and middle Eocene.
- Plectofrondicularia lirata* Bermudez (Plate 10, Figs. 5a-c). The overall appearance of the test is influenced by the number of chambers; the early portion is biserial, the later portion uniserial. The species is confined to the upper Eocene (NP20 to NP21). It reaches its maximum abundance in NP20, where it may comprise up to 70% of the fauna.
- Pleurostomella alternans* Schwager (Plate 11, Fig. 1).
- Pleurostomella* sp. cf. *P. bierigi* Palmer and Bermudez (Plate 11, Fig. 2). The Leg 73 forms are not as apically acute, nor do they have as many small initial chambers, as in the type description.
- Pleurostomella brevis* Schwager (Plate 11, Fig. 3).
- Pleurostomella subcylindrica* (Cushman) (Plate 11, Fig. 4) [= *Nodosarella subcylindrica* Cushman].
- Pleurostomella* sp. 1 (Plate 11, Fig. 5). This very rare form is characterized by hollow pendant extensions of the chambers that drape longitudinally down over earlier chambers. This form also occurs in the upper middle Eocene of the Southern Ocean (S. Jones, pers. comm., 1980).
- Pleurostomella* sp. 2 (Plate 11, Figs. 6a, b). The final chamber of this species extends three-quarters the length of the test. The form is similar to *Pleurostomella alazanensis* Cushman but is broader and has more inflated chambers.
- Protelphidium hofkeri* Haynes (Plate 10, Figs. 2a, b).
- Pullenia coryelli* White (Plate 12, Figs. 4a, b).
- Pullenia eocenica* Cushman and Siegfus.
- Pullenia jarvisi* Cushman (Plate 11, Figs. 11a, b).
- Pullenia quinqueloba* (Reuss) (Plate 12, Figs. 2a, b) [= *Nonionina quinqueloba* Reuss]. Although the species is described as having five chambers in the final whorl, most of the Leg 73 material exhibits 5.5 chambers.
- Pullenia* sp. 1 (Plate 12, Figs. 1a, b). This form is slightly compressed, oval in peripheral outline, and has an aperture that extends nearly the entire width of the test. Although its aperture is reminiscent of *Pullenia eocenica*, it is more compressed and has a greater number of chambers.
- Pullenia* sp. 2 (Plate 11, Figs. 10a, b). The chamber height expands very rapidly in this *Pullenia*.
- Pyrulina curvatura* Cushman and Stainforth (Plate 11, Fig. 8). [= *Pyrulina cylindroides* (Roemer) var. *curvatura* Cushman and Stainforth].
- Pyrulina?* sp. (Plate 11, Fig. 7). This species was illustrated by Beckmann (1953) as *Pyrulina extensa* (Cushman). However, it does not correspond to the type description of *Polymorphina extensa* Cushman.
- Quadratobuliminella* sp. (Plate 12, Figs. 5a-c). This rare form occurs only in the upper and middle Eocene. Because of the quadrate outline of the final whorl of chambers and the grooves radiating from the aperture, it appears to be related to *Quadratobuliminella pyramidalis* (de Klasz) as illustrated by Tjalsma and Lohmann (1983); however, it does not have the more elongate pyramid-shaped test of *Q. pyramidalis*.
- Quadriformina profunda* Schnitker and Tjalsma (Plate 12, Figs. 3a-c).
- Siphogenerina? transversa* Cushman (Plate 11, Fig. 9) [= *Siphogenerina raphanus* (Parker and Jones) var. *transversus* Cushman]. The indistinct nature of the early chambers precludes a positive generic assignment for this form.
- Siphotextularia heterostoma* (Fornasini) (Plate 13, Fig. 6) [= *Textularia heterostoma* Fornasini]. Tjalsma and Lohmann (1983) refer to this form as *Karrieriella* sp. cf. *K. cubensis* Cushman and Bermudez. Forms from the Paleogene of the Nazca Plate are identified as *Siphotextularia heterostoma* by Resig (1976).
- Spiroloculina* sp. This form is rare in the middle Eocene through Oligocene.
- Spiroplectammina spectabilis* (Grzybowski) (Plate 13, Fig. 5) [= *Spiroplecta spectabilis* Grzybowski].
- Stetsonia* sp. (Plate 12, Figs. 6a-c). The central area of each side of this species is covered by a low clear boss, through which earlier chambers are sometimes visible.
- Stilostomella aculeata* (Cushman and Renz) (Plate 13, Fig. 2) [= *Ellipsonodosaria nuttalli* Cushman and Jarvis var. *aculeata* Cushman and Renz].
- Stilostomella gracillima* (Cushman and Jarvis) [= *Ellipsonodosaria nuttalli* Cushman and Jarvis var. *gracillima* Cushman and Jarvis].
- Stilostomella subspinosa* (Cushman) (Plate 13, Fig. 3) [= *Ellipsonodosaria subspinosa* Cushman].
- Tappanina selmensis* (Cushman) (Plate 13, Fig. 7) [= *Bolivinita selmensis* Cushman]. This form is found in the Paleocene and lower Eocene.
- Trifarina* sp. (Plate 13, Fig. 9). This form is present in the Paleocene and Eocene.
- Triloculina* sp. This rare form occurs only in the Oligocene at Sites 522 and 523.
- Tritaxia havanensis* (Cushman and Bermudez) (Plate 13, Figs. 4a-b) [= *Clavulinoides havanensis* Cushman and Bermudez].
- Turrilina robertsi* (Howe and Ellis) (Plate 13, Figs. 8a, b) [= *Bulimina robertsi* Howe and Ellis].
- Vulvulina spinosa* Cushman (Plate 13, Fig. 1). We agree with Tjalsma and Lohmann (1983) that *Vulvulina jarvisi* is a synonym of *V. spinosa*.

Paleontological Sources

- The authors consulted the following sources in constructing the taxonomy.
- Beckmann, J. P., 1953. Die Foraminiferen der Oceanic Formation (Eocaen-Oligocaen) von Barbados, Kl. Antillen. *Ecol. Geol. Helv.*, 46:301-412.
- Bermudez, P. J., 1949. Tertiary smaller foraminifera of the Dominican Republic. *Spec. Publ. Cushman Lab. Foraminiferal. Res.*, 25: 1-322.

- Bermudez, P. J., and Gamez, H. A., 1966. Estudio paleontológico de una sección del Eoceno. *Mem. Soc. Cienc. Nat. La Salle*, 26: 205-259.
- Cushman, J. A., 1925. Some new foraminifera from the Velasco Shale of Mexico. *Contrib. Cushman Lab. Foraminiferal Res.*, 1: 18-23.
- Cushman, J. A., and Jarvis, P. W., 1932. Upper Cretaceous foraminifera from Trinidad. *Proc. U.S. Natl. Mus.*, 80(14):1-60.
- Cushman, J. A., and Renz, H. H., 1947. The foraminiferal fauna of the Oligocene Ste. Croix Formation of Trinidad, B. W. I. *Spec. Publ. Cushman Lab. Foraminiferal Res.*, 22:1-46.
- Douglas, R. G., 1973. Benthonic foraminiferal biostratigraphy in the central North Pacific, Leg 17, Deep Sea Drilling Project. In Winterer, E. L., Ewing, J. I., et al., *Init. Repts. DSDP*, 17: Washington (U.S. Govt. Printing Office), 607-671.
- Mallory, V. S., 1959. Lower Tertiary biostratigraphy of the California Coast Ranges. *Stud. Geol. Tulsa Okla.*, pp. 1-416.
- Nuttall, W. L. F., 1932. Lower Oligocene foraminifera from Mexico. *J. Paleontol.*, 6:3-45.
- Schnitker, D., 1979. Cenozoic deep water benthic foraminifera, Bay of Biscay. In Montadert, L., Roberts, D. G., et al., *Init. Repts. DSDP*, 48: Washington (U.S. Govt. Printing Office), 377-413.
- White, M. P., 1928. Some index foraminifera of the Tampico Embayment area of Mexico. *J. Paleontol.*, 2:177-215.
- nannofossil and foraminiferal events between the middle Eocene and early Miocene. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 36:155-190.
- Berger, W. H., and von Rad, U., 1972. Cretaceous and Cenozoic sediments from the Atlantic Ocean. In Hayes, D. E., Pimm, A. C., et al., *Init. Repts. DSDP*, 14: Washington (U.S. Govt. Printing Office), 787-954.
- Corliss, B. H., 1981. Deep-sea benthonic foraminiferal faunal turnover near the Eocene-Oligocene boundary. *Mar. Micropaleontol.*, 6:367-384.
- Ellis, B. F., and Messina, Angelina, 1940 (supplements, post-1940). *Catalogue of Foraminifera*: New York (Am. Mus. Nat. Hist.).
- Miller, K. G., in press. Late Paleogene (Eocene to Oligocene) paleoceanography of the deep Bay of Biscay: benthic foraminiferal evidence. *Mar. Micropaleontol.*
- Proto Decima, F., and Bolli, H. M., 1978. Southeast Atlantic DSDP Leg 40 Paleogene benthic foraminifera. In Bolli, H. M., Ryan, W. B. F., et al., *Init. Repts. DSDP*, 40: Washington (U.S. Govt. Printing Office), 783-809.
- Resig, J. M., 1976. Benthic foraminiferal stratigraphy, eastern margin, Nazca Plate. In Yeats, R. S., Hart, S. R., et al., *Init. Repts. DSDP*, 34: Washington (U.S. Govt. Printing Office), 743-759.
- Schnitker, D., and Tjalsma, R. C., 1980. New genera and species of benthic foraminifera from Paleocene and Eocene deep-water deposits. *J. Foraminiferal Res.*, 10:235-241.
- Tjalsma, R. C. and Lohmann, G. P., 1983. Paleocene-Eocene bathyal and abyssal benthic foraminifera from the Atlantic Ocean. *Micropaleontology*, Spec. Publ. 4.

ACKNOWLEDGMENTS

We thank Charles Pflum and Sherwood Wise, Jr. for critically reviewing the manuscript, and we especially thank Leonard Tjalsma for valuable taxonomic discussions. Ralph Hockett is gratefully acknowledged for his preparation of the SEM illustrations.

REFERENCES

- Beckmann, J. P., Bolli, H. M., Perch-Nielsen, K., Proto Decima, F., Saunders, J. B., and Toumarkine, M., 1981. Major calcareous

Date of Initial Receipt: August 13, 1982

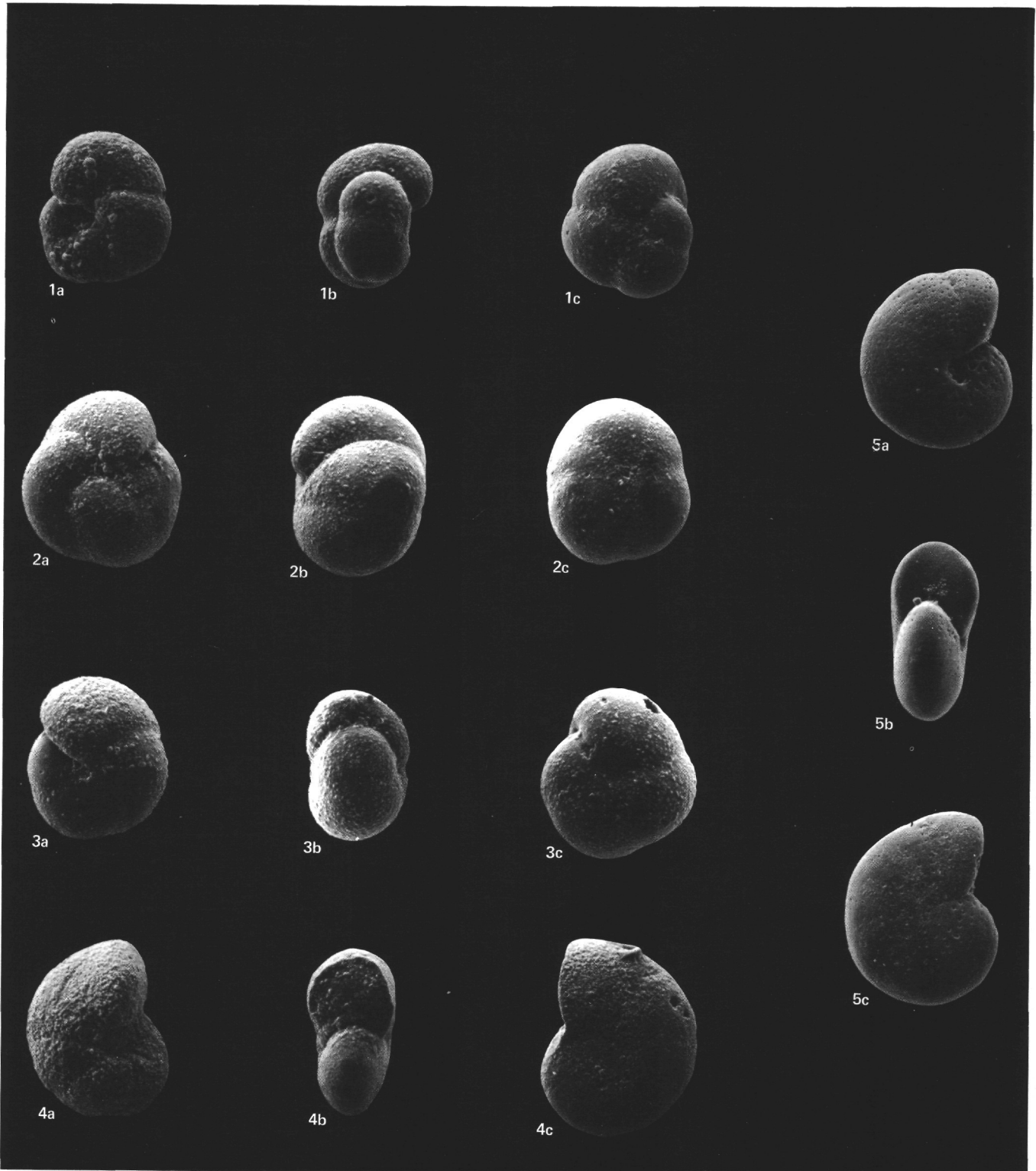


Plate 1. Benthic foraminiferal species. 1. *Abyssamina incisa*. a. Umbilical view, Core 522-37, 184 μm . b. Edge view, Core 523-31, 186 μm . c. Spiral view, Core 523-28, 181 μm . 2. *Abyssamina poagi*. a. Umbilical view, Core 523-42, 246 μm . b. Edge view, Core 523-47, 253 μm . c. Spiral view, Core 523-45, 234 μm . 3. *Abyssamina quadrata*. a. Umbilical view, Core 524-3, 190 μm . b. Edge view, Core 524-3, 219 μm . c. Spiral view, Core 524-5, 186 μm . 4. *Anomalina* sp. 2. a. Umbilical view, Core 524-12, 224 μm . b. Edge view, Core 524-12, 208 μm . c. Spiral view, Core 524-12, 251 μm . 5. *Anomalina* sp. cf. *A. spissiformis*. a. Umbilical view, Core 522-37, 373 μm . b. Edge view, Core 522-37, 373 μm . c. Spiral view, Core 522-38, 387 μm .

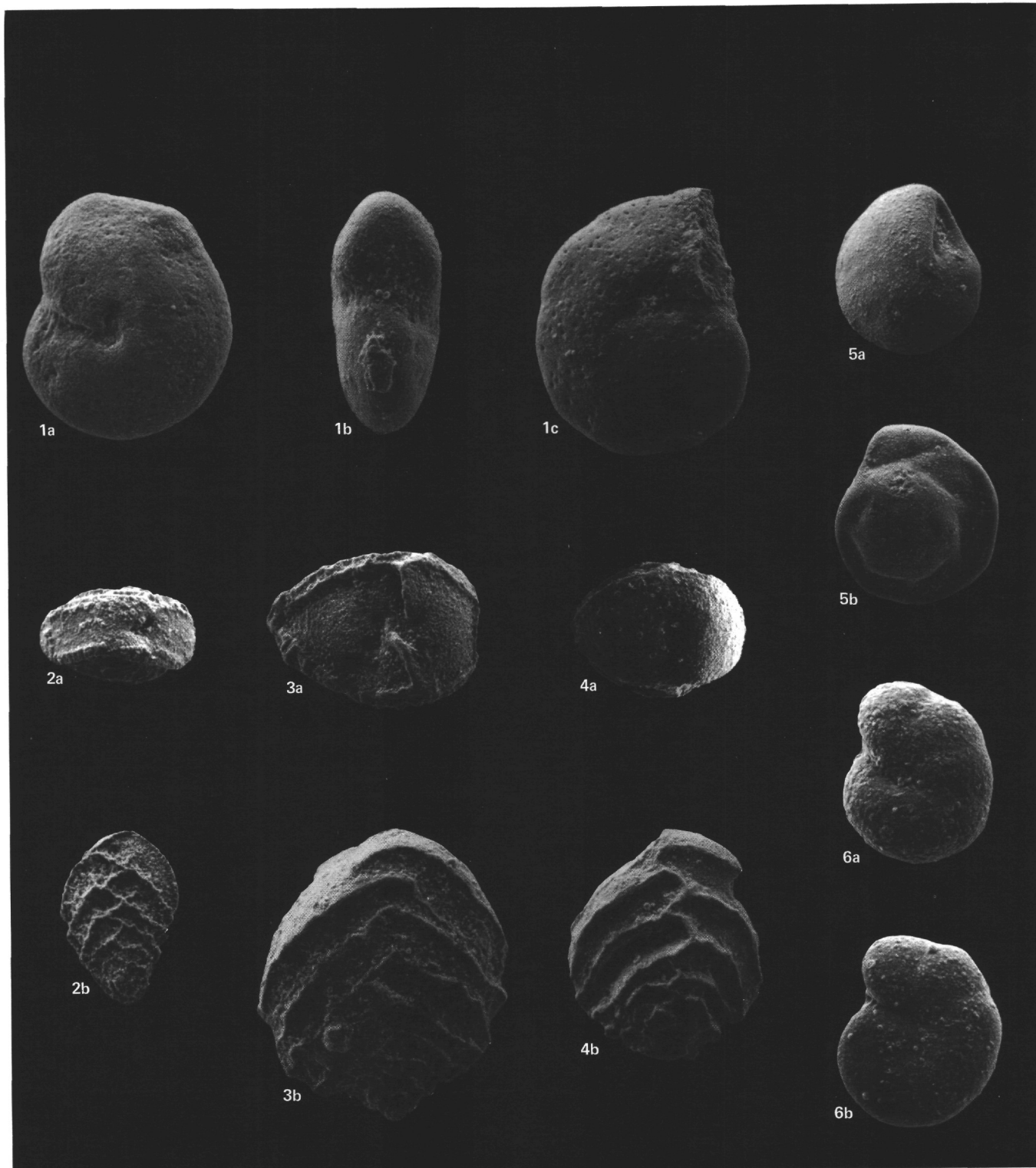


Plate 2. Benthic foraminiferal species. 1. *Anomalina* sp. cf. *A. praeacuta*. a. Umbilical view, Core 524-4, 301 μm . b. Edge view, Core 524-8, 312 μm . c. Spiral view, Core 524-9, 251 μm . 2. *Aragonia semireticulata*. a. Apertural view, Core 523-41, 211 μm . b. Core 523-44, 290 μm . 3. *Aragonia ouezzanensis*. a. Apertural view, Core 524-12, 315 μm . b. Core 524-13, 368 μm . 4. *Aragonia capdevilensis*. a. Apertural view, Core 524-9, 251 μm . b. Core 524-6, 240 μm . 5. *Alabamina dissonata*. a. Umbilical view, Core 523-46, 326 μm . b. Spiral view, Core 523-44, 326 μm . 6. *Anomalina* sp. 1. a. Umbilical view, Core 524-5, 227 μm . b. Spiral view, Core 524-8, 237 μm .



Plate 3. Benthic foraminiferal species. 1. *Astrononion pusillum*. a. Core 522-34, 227 μm . b. Edge view, Core 522-34, 238 μm . 2. *Bolivina huneri*. Core 522-34, 422 μm . 3. *Bolivina* sp. cf. *B. spiralis*. Core 523-28, 374 μm . 4. *Bulimina alazanensis*. a. Core 522-36, 200 μm . b. Core 522-38, 245 μm . 5. *Bulimina bradburyi*. Core 524-3, 290 μm . 6. *Bulimina impendens*. Core 523-35, 176 μm . 7. *Bulimina midwayensis*. Core 524-2, 195 μm . 8. *Bulimina semicostata*. Core 523-36, 368 μm . 9. *Bulimina trinitatensis*. Core 523-46, 387 μm . 10. *Bulimina thanetensis*. Core 524-5, 288 μm . 11. *Buliminella grata*. a. Apertural view, Core 523-30, 178 μm . b. Core 522-22, 208 μm . 12. *Buliminella beaumonti*. Core 523-14, 192 μm . 13. *Chrysalogonium tenuicostatum*. Core 522-34, 1056 μm .

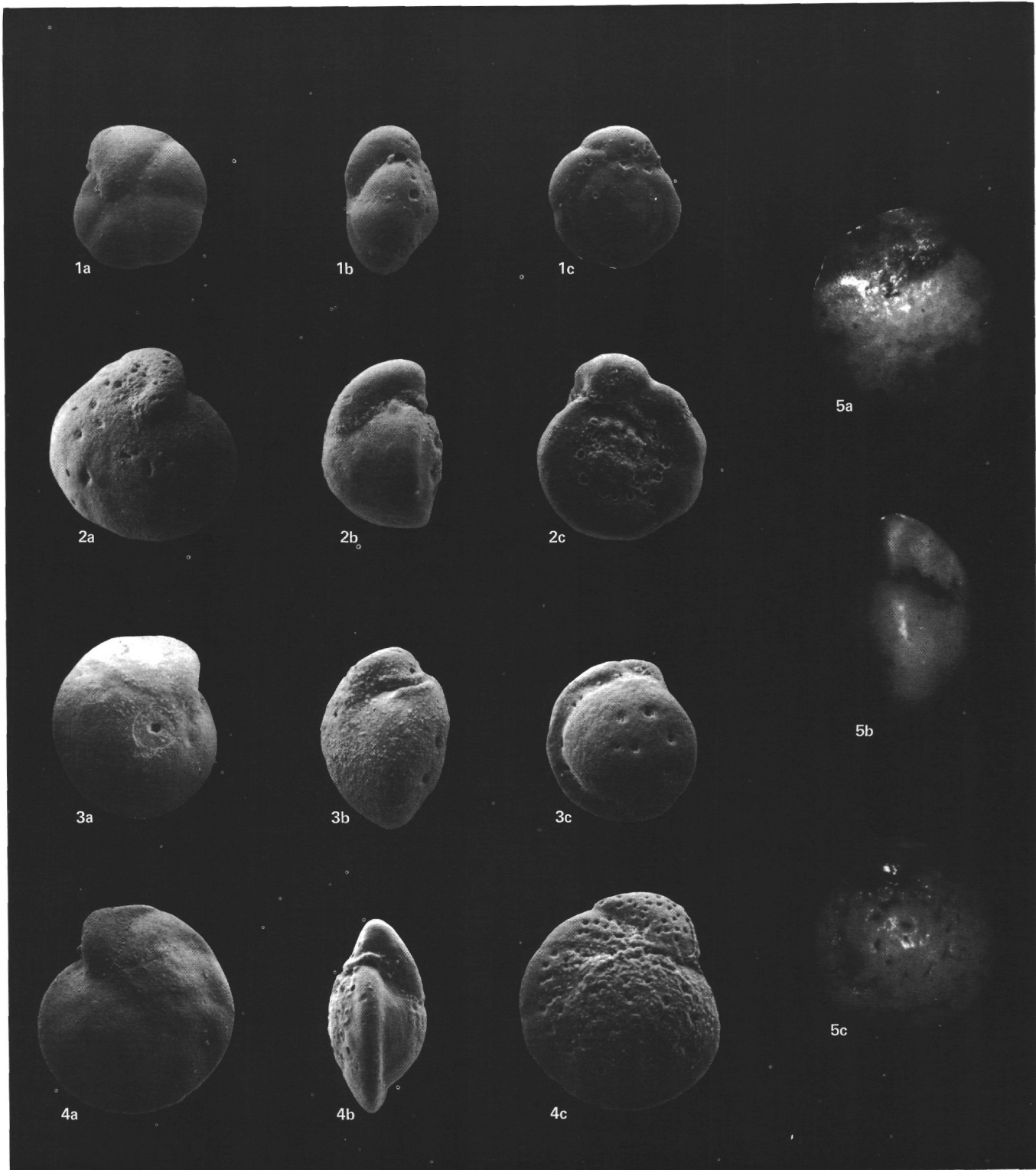


Plate 4. Benthic foraminiferal species. 1. *Cibicoides bradyi*. a. Umbilical view, Core 522-34, 277 μm . b. Edge view, Core 522-33, 245 μm . c. Spiral view, Core 522-33, 210 μm . 2. *Cibicoides grimsdalei*. a. Umbilical view, Core 522-21, 765 μm . b. Edge view, Core 523-43, 240 μm . c. Spiral view, Core 523-42, 261 μm . 3. *Cibicoides havanensis*. a. Umbilical view, Core 522-38, 509 μm . b. Edge view, Core 522-38, 349 μm . c. Spiral view, Core 523-35, 446 μm . 4. *Cibicoides* sp. aff. *C. ungerianus*. a. Umbilical view, Core 522-37, 298 μm . b. Edge view, Core 522-37, 278 μm . c. Spiral view, Core 522-37, 320 μm . 5. *Cibicoides* sp. aff. *C. madrugeensis*. a. Umbilical view, Core 524-8, 584 μm . b. Edge view, Core 524-5, 624 μm . c. Spiral view, Core 524-8, 584 μm .

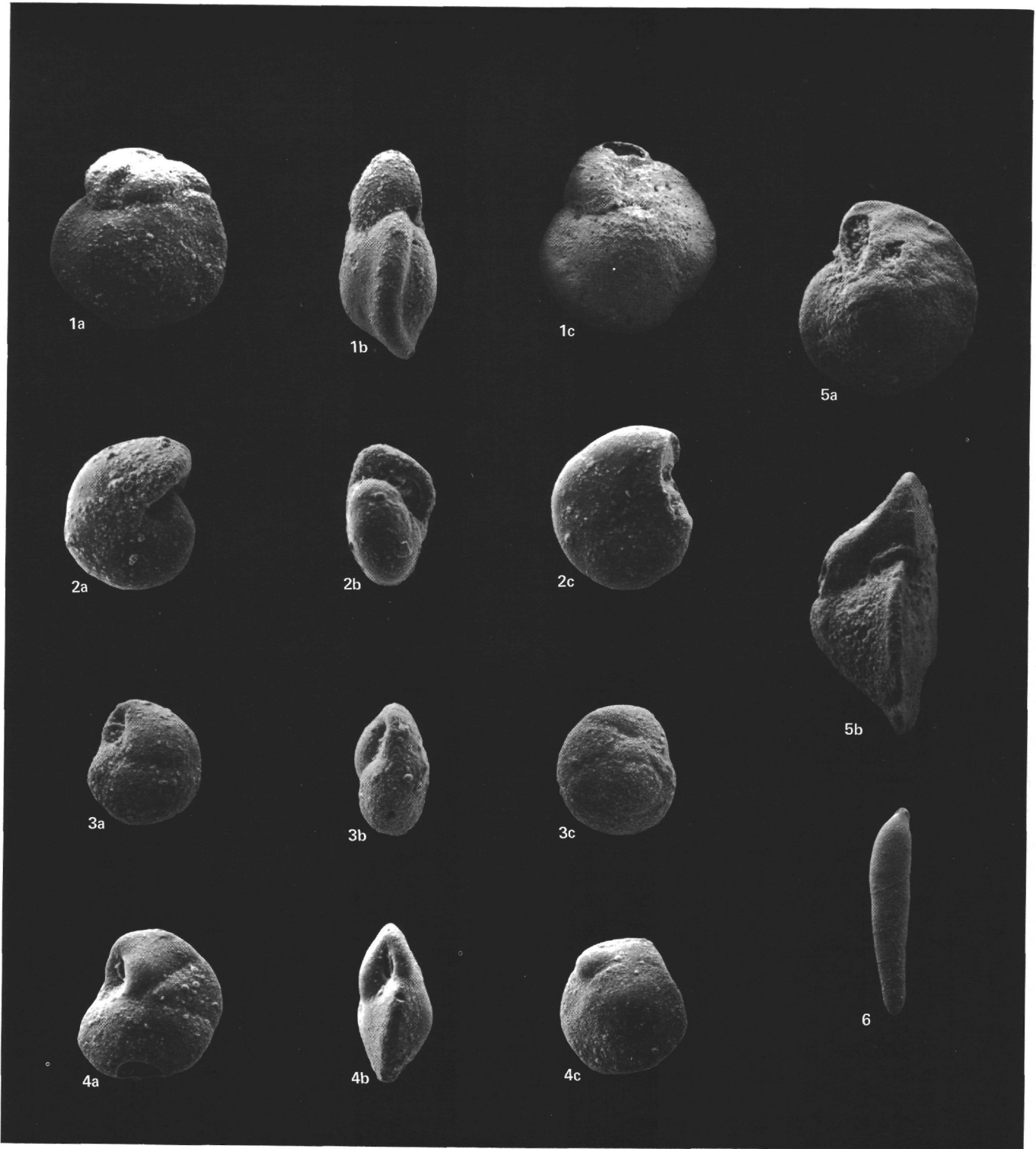


Plate 5. Benthic foraminiferal species. 1. *Cibicidoides* sp. 1. a. Umbilical view, Core 522-36, 285 μm . b. Edge view, Core 522-36, 291 μm . c. Spiral view, Core 522-37, 280 μm . 2. *Clinapertina inflata*. a. Umbilical view, Core 524-2, 235 μm . b. Edge view, Core 524-2, 205 μm . c. Spiral view, Core 524-2, 240 μm . 3. *Epistominella exigua*, s.l. a. Umbilical view, Core 522-31, 179 μm . b. Edge view, Core 522-31, 171 μm . c. Spiral view, Core 522-31, 184 μm . 4. *Epistominella exigua*, s.s. a. Umbilical view, Core 522-31, 224 μm . b. Edge view, Core 522-31, 218 μm . c. Spiral view, Core 522-31, 214 μm . 5. *Cibicides* sp. 1. a. Umbilical view, Core 524-12, 253 μm . b. Edge view, Core 524-12, 253 μm . 6. *Dentalina mucronata*. Core 522-34, 578 μm .

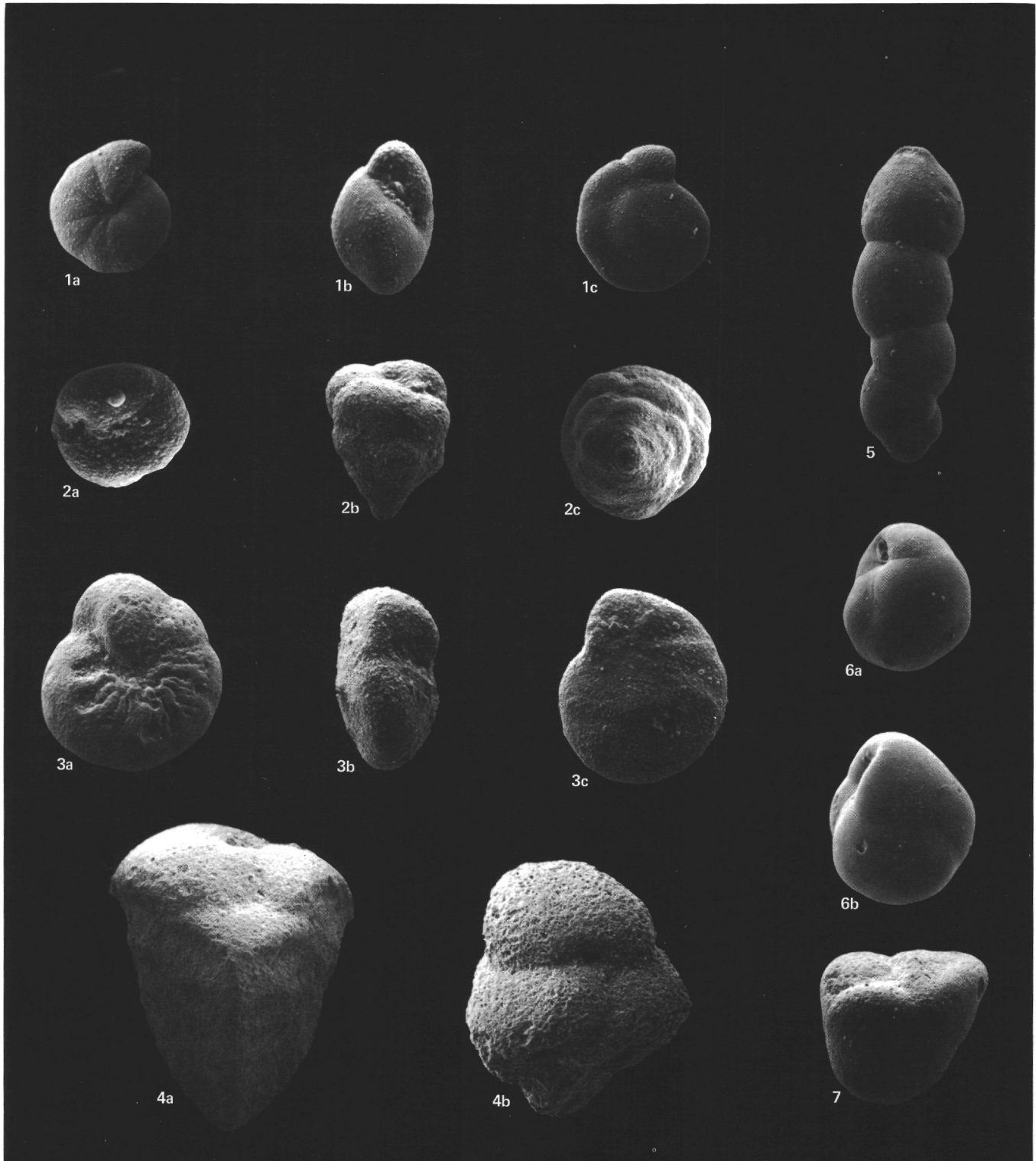


Plate 6. Benthic foraminiferal species. 1. *Eponides* sp. 1. a. Umbilical view, Core 522-34, 181 μm . b. Edge view, Core 522-34, 163 μm . c. Spiral view, Core 522-34, 192 μm . 2. *Eorupertia bermudezi*. a. Umbilical view, Core 524-6, 168 μm . b. Core 524-6, 144 μm . c. Spiral view, Core 524-6, 184 μm . 3. *Gavelinella beccariiiformis*. a. Umbilical view, Core 524-9, 499 μm . b. Edge view, Core 524-10, 410 μm . c. Spiral view, Core 524-10, 432 μm . 4. *Gaudryina pyramidata*. a. Core 523-36, 832 μm . b. Apertural view, Core 523-36, 440 μm . 5. *Ellipsodimorphina subcompacta*. Core 523-44, 710 μm . 6. *Globocassidulina subglobosa*. a. Core 522-31, 322 μm . b. Core 522-31, 261 μm . 7. *Dorothisia trochoides*. Core 524-5, 424 μm .



Plate 7. Benthic foraminiferal species. 1. *Gavelinella hyphalus*. a. Spiral view, Core 524-11, 258 μm . b. Edge view, Core 524-11, 259 μm . c. Umbilical view, Core 524-6, 266 μm . 2. *Gavelinella velascoensis*. a. Edge view, Core 524-5, 374 μm . b. Umbilical view, Core 524-9, 304 μm . 3. *Gyroidinoides peramplus*. a. Umbilical view, Core 522-31, 376 μm . b. Edge view, Core 522-29, 336 μm . c. Spiral view, Core 522-29, 326 μm . 4. *Gyroidinoides girardanus*. a. Umbilical view, Core 523-38, 288 μm . b. Edge view, Core 523-38, 246 μm . c. Spiral view, Core 523-37, 242 μm . 5. *Gavelinella semicribrata*. a. Spiral view, Core 522-17, 238 μm . b. Edge view, Core 522-17, 333 μm . c. Umbilical view, Core 522-36, 318 μm .

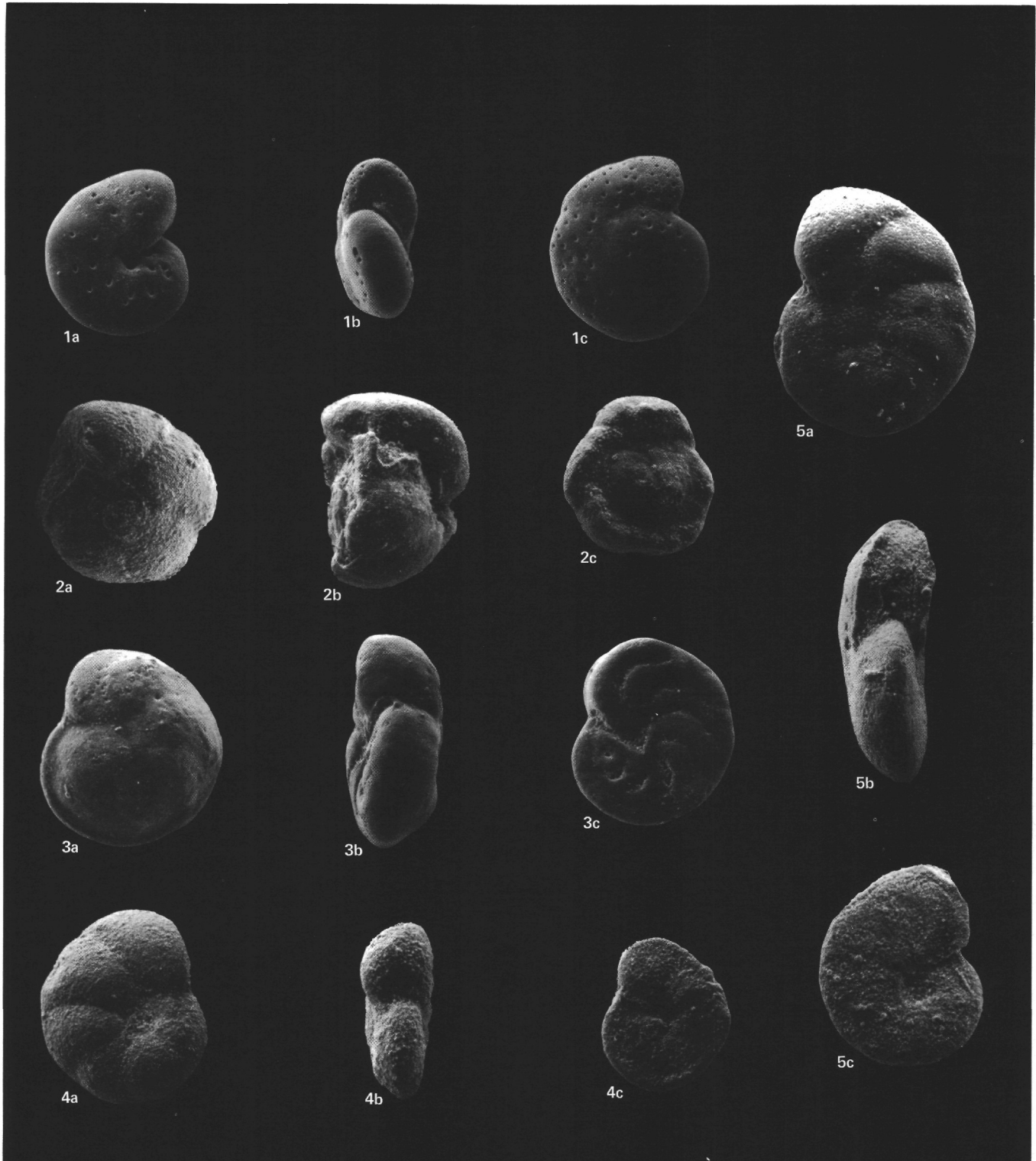


Plate 8. 1. *Gyroidinoides planulatus*. a. Umbilical view, Core 523-28, 274 μm . b. Edge view, Core 523-28, 286 μm . c. Spiral view, Core 522-38, 342 μm . 2. *Gyroidinoides quadratus*. a. Umbilical view, Core 524-4, 237 μm . b. Edge view, Core 524-4, 240 μm . c. Spiral view, Core 524-10, 192 μm . 3. *Hanzawaia cushmani*. a. Umbilical view, Core 523-48, 280 μm . b. Edge view, Core 522-37, 797 μm . c. Spiral view, Core 523-42, 414 μm . 4. *Hanzawaia* sp. 1, a. Umbilical view, Core 524-13, 488 μm . b. Edge view, Core 524-13, 440 μm . c. Spiral view, Core 524-13, 392 μm . 5. *Hanzawaia simplex*. a. Umbilical view, Core 524-12, 408 μm . b. Edge view, Core 524-12, 325 μm . c. Spiral view, Core 524-12, 240 μm .

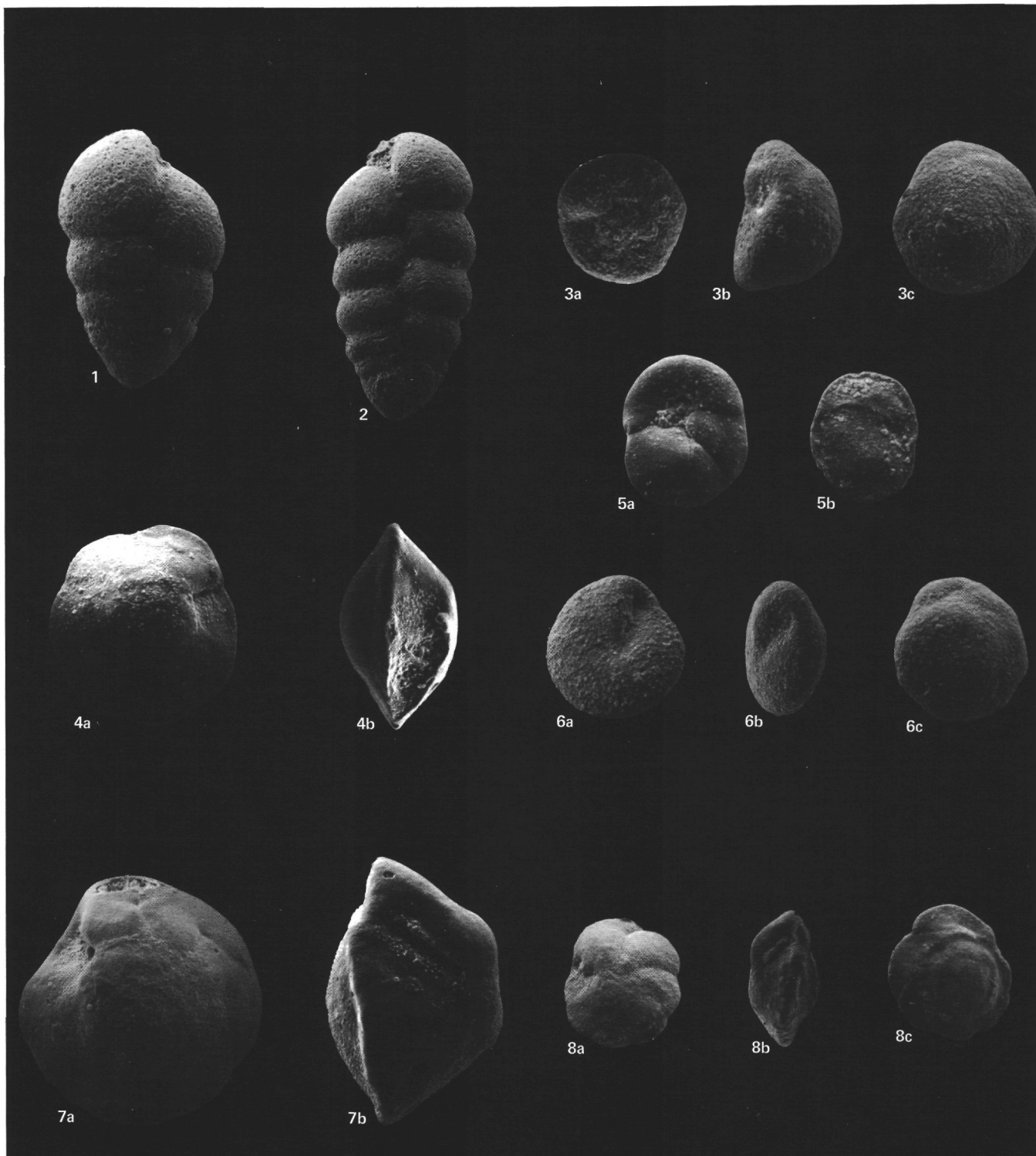


Plate 9. Benthic foraminiferal species. 1. *Karreriella chapapotensis*. Core 522-36, 563 μm . 2. *Karreriella subglabra*. Core 523-14, 624 μm . 3. *Neoeponides hillebrandti*. a. Umbilical view, Core 524-4, 160 μm . b. Edge view, Core 524-4, 181 μm . c. Spiral view, Core 524-4, 200 μm . 4. *Nuttallides truempyi*. a. Umbilical view, Core 6-1, 320 μm . b. Edge view, Core 6-1, 330 μm . 5. *Heronallenia* sp. a. Umbilical view, Core 522-19, 253 μm . b. Spiral view, Core 522-27, 219 μm . 6. *Neoeponides* sp. cf. *N. lunata*. a. Umbilical view, Core 524-4, 181 μm . b. Edge view, Core 524-4, 176 μm . c. Spiral view, Core 524-5, 178 μm . 7. *Nuttallides crassaformis*. a. Umbilical view, Core 523-36, 347 μm . b. Edge view, Core 523-34, 352 μm . 8. *Nuttallides umboniferus*. a. Umbilical view, Core 522-31, 224 μm . b. Edge view, Core 522-31, 246 μm . c. Spiral view, Core 522-29, 254 μm .

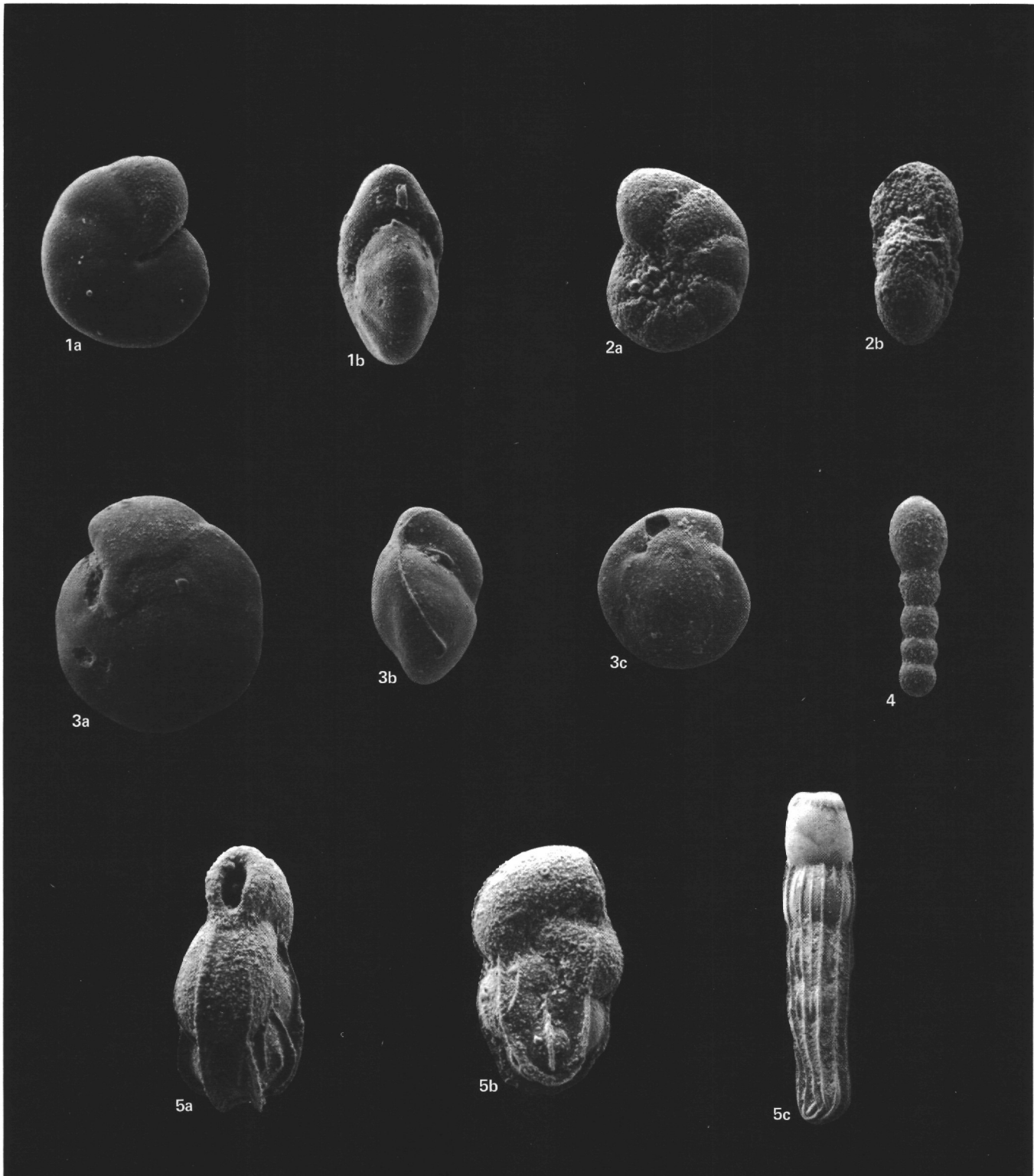


Plate 10. Benthic foraminiferal species. 1. *Nonion havanense*. a. Core 522-37, 293 μm . b. Edge view, Core 522-37, 306 μm . 2. *Protelphidium hofkeri*. a. Core 524-12, 224 μm . b. Edge view, Core 524-12, 227 μm . 3. *Oridorsalis umbonatus*. a. Umbilical view, Core 522-29, 358 μm . b. Edge view, Core 522-29, 282 μm . c. Spiral view, Core 522-29, 240 μm . 4. *Orthomorphina rohri*. Core 522-31, 432 μm . 5. *Plectrofrondicularia lirata*. a. Apertural view, Core 522-37, 344 μm . b. Core 522-37, 360 μm . c. Core 522-37, 2224 μm .

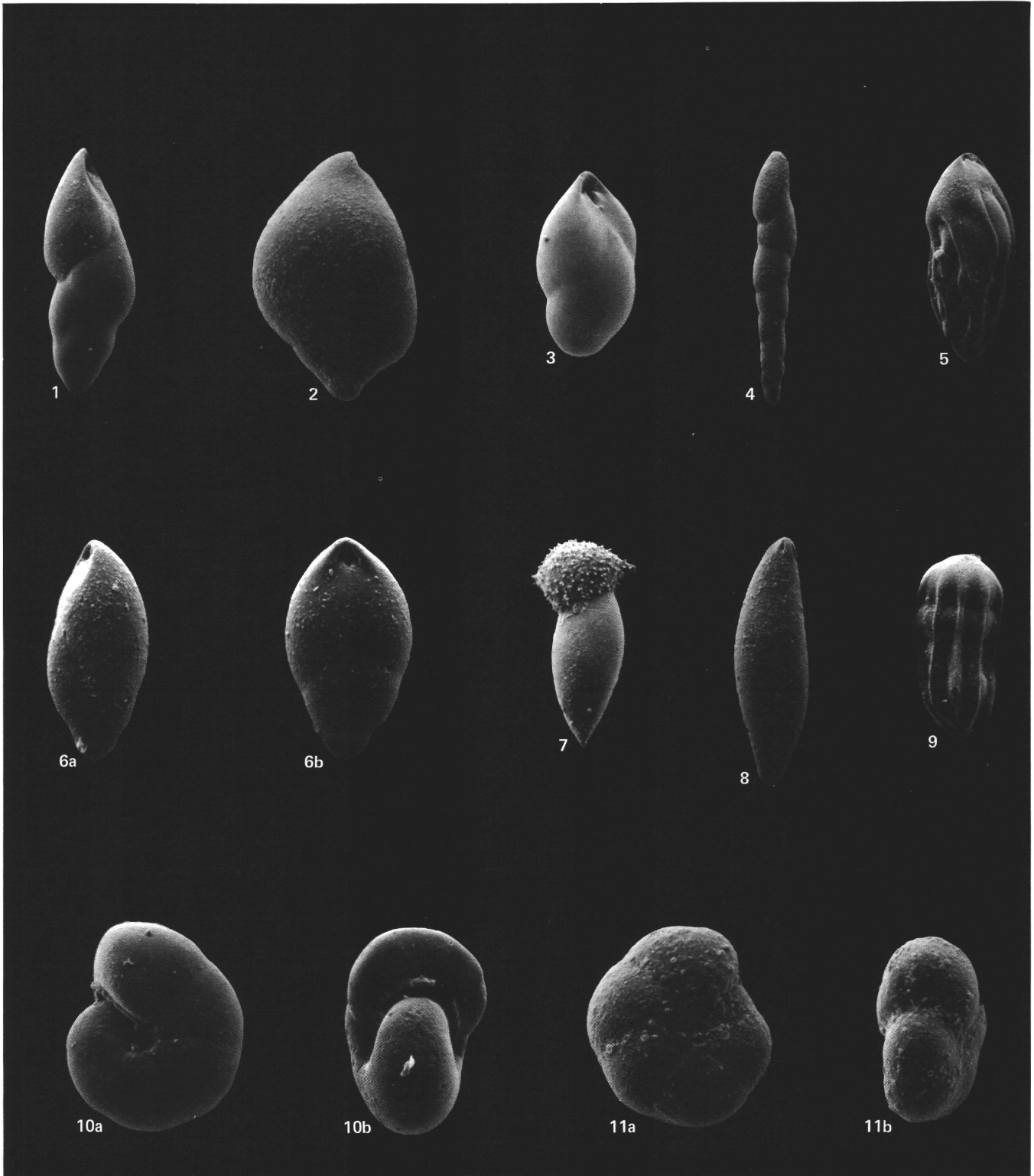


Plate 11. Benthic foraminiferal species. 1. *Pleurostomella alternans*. Core 522-34, 749 μm . 2. *Pleurostomella* sp. cf. *P. bierigi*. Core 523-31, 336 μm . 3. *Pleurostomella brevis*. Core 522-34, 387 μm . 4. *Pleurostomella subcylindrica*. Core 522-33, 770 μm . 5. *Pleurostomella* sp. 1. Core 522-27, 378 μm . 6. *Pleurostomella* sp. 2. a. Core 522-31, 278 μm . b. Core 522-31, 301 μm . 7. *Pyrulina?* sp. Core 523-47, 533 μm . 8. *Pyrulina curvatura*. Core 522-32, 674 μm . 9. *Siphogenerina transversa*. Core 522-32, 301 μm . 10. *Pullenia* sp. 2. a. Core 522-38, 272 μm . b. Edge view, Core 522-38, 274 μm . 11. *Pullenia jarvisi*. a. Core 524-9, 248 μm . b. Edge view, Core 524-9, 256 μm .

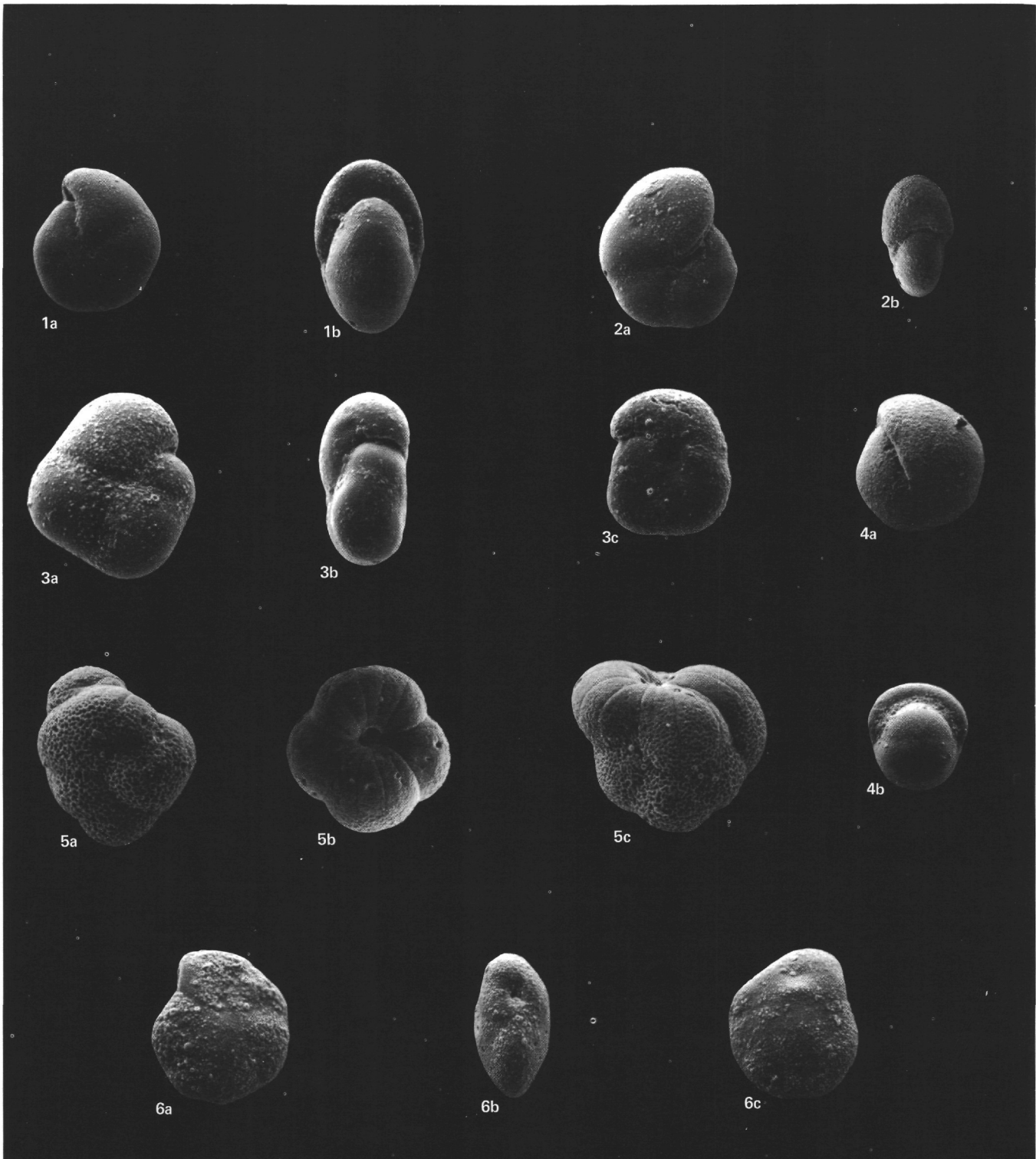


Plate 12. Benthic foraminiferal species. 1. *Pullenia* sp. 1. a. Core 522-38, 272 μm . b. Edge view, Core 522-22, 230 μm . 2. *Pullenia quinqueloba*. a. Core 524-34, 293 μm . b. Edge view, Core 522-34, 234 μm . 3. *Quadriformorphina profunda*. a. Umbilical view, Core 523-28, 270 μm . b. Edge view, Core 524-2, 195 μm . c. Spiral view, Core 523-30, 206 μm . 4. *Pullenia coryelli*. a. Core 524-6, 344 μm . b. Edge view, Core 524-6, 198 μm . 5. *Quadratobuliminella* sp. a. Core 522-36, 162 μm . b. Apertural view, Core 522-36, 149 μm . c. Core 522-36, 165 μm . 6. *Stetsonia* sp. a. Spiral view, Core 522-31, 194 μm . b. Edge view, Core 522-32, 211 μm . c. Spiral view, Core 522-31, 190 μm .

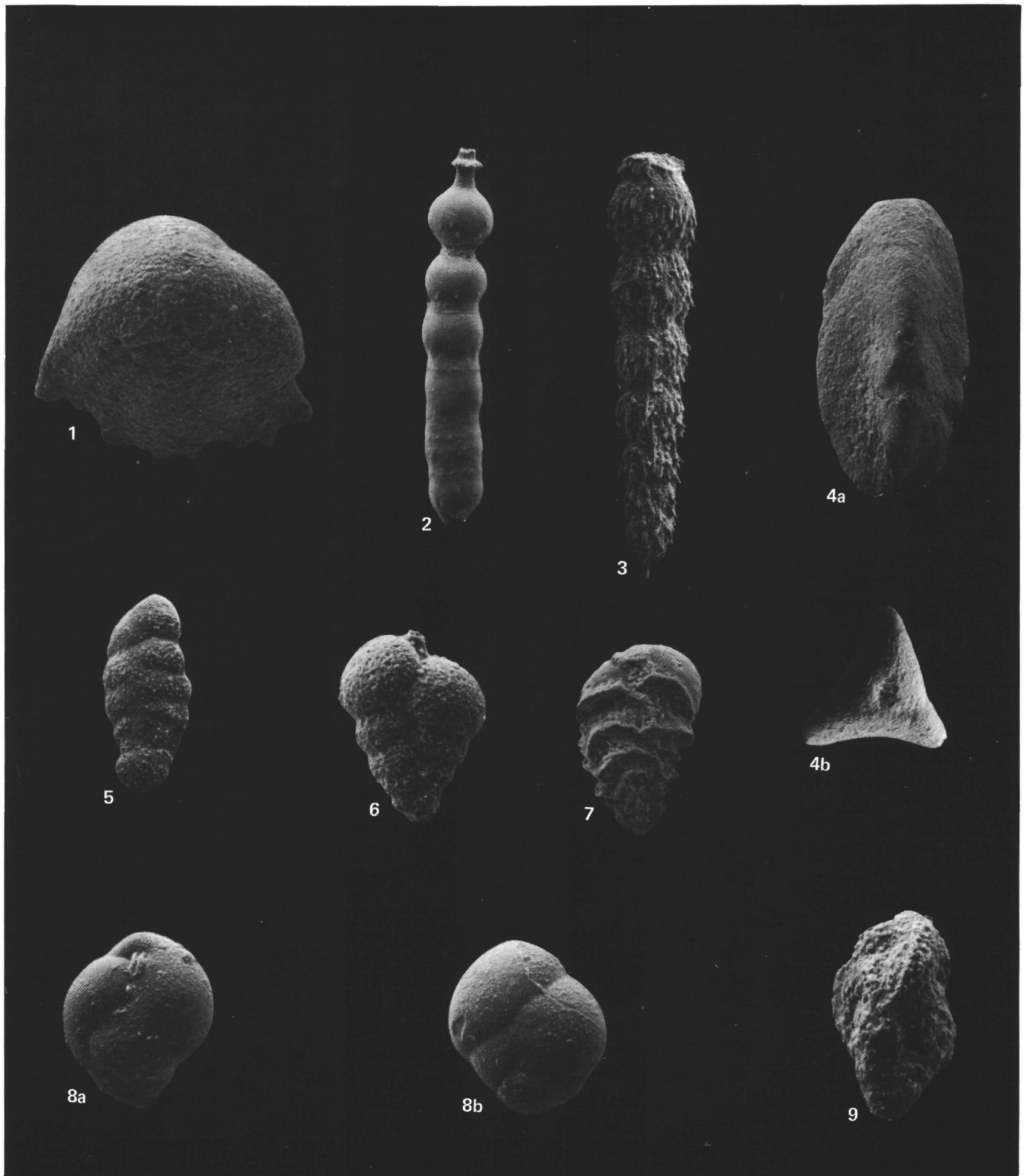


Plate 13. Benthic foraminiferal species. 1. *Vulvulina spinosa*. Core 522-31, 384 μm . 2. *Stilostomella aculeata*. Core 523-37, 928 μm . 3. *Stilostomella subspinoso*. Core 523-31, 1011 μm . 4. *Tritaxia havanensis*. a. Core 524-5, 656 μm . b. Apertural view, Core 524-5, 432 μm . 5. *Spiroplectammina spectabilis*. Core 522-11, 440 μm . 6. *Siphotextularia heterostoma*. Core 522-34, 227 μm . 7. *Tappanina selmensis*. Core 524-3, 272 μm . 8. *Turrilina robertsi*. a. Core 522-34, 192 μm . b. Core 522-34, 162 μm . 9. *Trifarina* sp. Core 524-13, 240 μm .