Journal of The Palaeontological Society of India
Vol. 47, 2002, pp. 1-15

EARLY PALAEOCENE PLANKTIC FORAMINIFERAL ASSEMBLAGES AND BIOSTRATIGRAPHY AT SITE 237, CENTRAL WESTERN INDIAN OCEAN

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ABSTRACT

Seven early Palaeocene planktic foraminiferal genera and their fourteen species have been identified using wall texture criterion in combination with test architecture at DSDP Site 237, Western Tropical Indian Ocean. This is a significant improvement over the record of six species in the previous work. The wall texture criterion is included for taxonomy of planktic foraminifers obtained from the siliceous nannochalk, affected by different levels of diagenetic alteration. It has been observed under SEM that diagenesis does not affect the wall texture in smooth wall normal perforate tests; in microperforate pustulose tests the diagenetic overprinting is directed by the original pattern of ornamentation, whereas remains of cancellate texture are recognizable in the specimens affected by dissolution and overgrowth. To differentiate the cancellate spinose from cancellate nonspinose (premuricate wall texture) forms the disposition of ridges is a clue, but for observing the presence or absence of spine holes good preservation is a prerequisite. Based on the assemblages of species, their ranges and FAD/LAD biochrons, biozones P1b-P2 have been demarcated with redefined boundaries. It is inferred that lower Palaeocene rocks underlain by Upper Cretaceous rocks are likely to be present in the unpenetrated interval of strata above the basement at the DSDP Site 237. *Globoconusa daubjergensis*, earlier recorded mainly from high latitudes, occurs commonly at Site 237.

Key words : Early Palaeocene, planktic foraminifera, biostratrigraphy, Central Western Indian Ocean.

INTRODUCTION

In the Central Western Indian Ocean, sediments of early Palaeocene age were recovered only at Site 237, DSDP Leg 24 (fig.1), where 300 meters of recrystallized nannofossil chalk accumulated at upper bathyal depths along with slumped neritic material (Fisher, Bunce, Cernock, Clegg, Cronan, Drimitriev, David, Roth, and Vincent, 1974; Vincent, Gibson and Brun, 1974). Planktic foraminifers occur as the main skeletal grain in the Palaeocene biomicrites and recrystallization is pronounced below Core 45. Hole 237 was terminated at 696.5 meters depth within the sediments of early Palaeocene age (*Cruciplacolithus tenuis* Zone and Zone P1). Undifferentiated early Palaeocene Zones P1-P2 were recognized by Heimen, Frerichs and Vincent (1974) in the core interval 67-5 to 64-2 by the presence of *Parasubbotina pseudobulloides* and *Praemurica trinidadensis* in Core 64 and Core 67 contained these two species and some specimens of *Globanomalina compressa.*

Lower cores of litho-unit V of Fisher *et al.* (1974) were selected for the present study of Palaeocene planktic foraminifers in the context of taxonomic definition and geological ranges revised over the last two decades. Small size and mostly unspecialized morphology of Palaeocene foraminifers hindered distinction between taxa. The study of Steineck and Fleisher (1978), Banner (1989) and Hemleben, Muhlen, Olsson and Berggren (1991) focussed on the significance of wall texture and structure in the phylogenetically based taxonomic classification of planktic foraminifers. Wall texture classification is realistic as the functional morphological aspect of the four types of wall texture present in living planktic foraminifers is well understood and similar type of wall texture is present in the Danian assemblages. Olsson, Hemleben, Berggren and Liu (1992) using this classification erected two new genera *Parasubbotina* and *Praemurica* to represent cancellate spinose and cancellate nonspinose (Neogloboquadrinid) linneages in the Danian. In the early Palaeocene, muricate wall structure is represented by only one species of *Morozovella* (namely *M. praeangulata*). Wall texture classification and taxonomy of Palaeocene planktic foraminifers by Olsson, Hemleben, Berggren and Huber (1999) is followed here and eighteen species have been identified based

on the test architecture and the wall texture from the Danian and early late Palaeocene strata.

In the Danian, only the final stage of calcification is observed in the test of planktic foraminifers (Olsson *et al.,* 1992). Recrystallization of the original wall, development of diagenetic calcite over the originally secreted calcitic wall and dissolution of part of the wall generally alters the wall texture of the test. Even in the best-preserved specimens of Palaeocene age, diagenetic calcite is generally present in pelagic chalk.

Five types of wall textures identified in the early Palaeocene planktic foraminifers by Olsson *et al.* (1992; 1999) namely-microperforate, normal perforate smooth, normal perforate cancellate, normal perforate cancellate spinose and muricate wall textures are also recognized in the lower cores at Site 237. It has been observed that even in diagenetically altered tests of planktic foraminifers, the vestiges of original wall texture can be recognized using SEM. Synonymy lists are omitted as they are available in the atlas of Palaeocene Foraminifers (Olsson *et al.,* 1999). All the figured specimens are housed in the Museum, Department of Geology, University of Delhi, Delhi.

MATERIAL AND METHODS

Fifteen core samples from partly silicified foram-bearing chalk with chert were processed for the present study (fig.2). Following six samples yielded identifiable, moderately to well preserved planktic foraminifers:

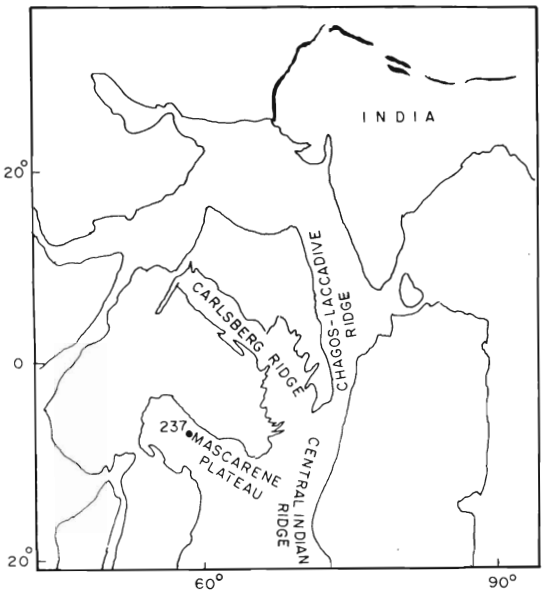


Fig. 1. Map showing location of the DSDP Site 237, Indian Ocean (after McGowran, 1978).

(1) 52-01 (120-121 cm) (2) 58-01 (121-122cm) (3) 61-01 (102-103cm) (4) 63-01 (105-106cm) (5) 64-02 (083-084cm) (6) 66-01 (112-113cm).

The specimens up to 0.088mm diameter (ASTM size 170) have been incorporated in the study to get the entire population range of the planktic foraminifers.

SYSTEMATIC PALAEONTOLOGY

Family **Globigerinidae** Carpenter, Parker and Jones, 1862

Genus ***Eoglobigerina*** Morozova, 1959

EXPLANATION OF PLATE I

[Scale bars showing 10 μm for figures 1-6; 30 μm for figures 7, 9, 11, 13-19 & 3 μm for figures 8, 10, 12]

1-6. ***Globoconusa daubjergensis,*** 1. High trochospiral test of a four chambered form (Core 66); 2. Oblique umbilical view (of 1) showing umbilical aperture (Core 66); 3. Test showing well developed umbilical bulla (Core 66); 4. Oblique spiral view of high spired test (Core 66); 5. High trochospiral test of a three chambered form (Core 66); 6. Umbilical view, test surface is covered by overgrown pustules (core 61).

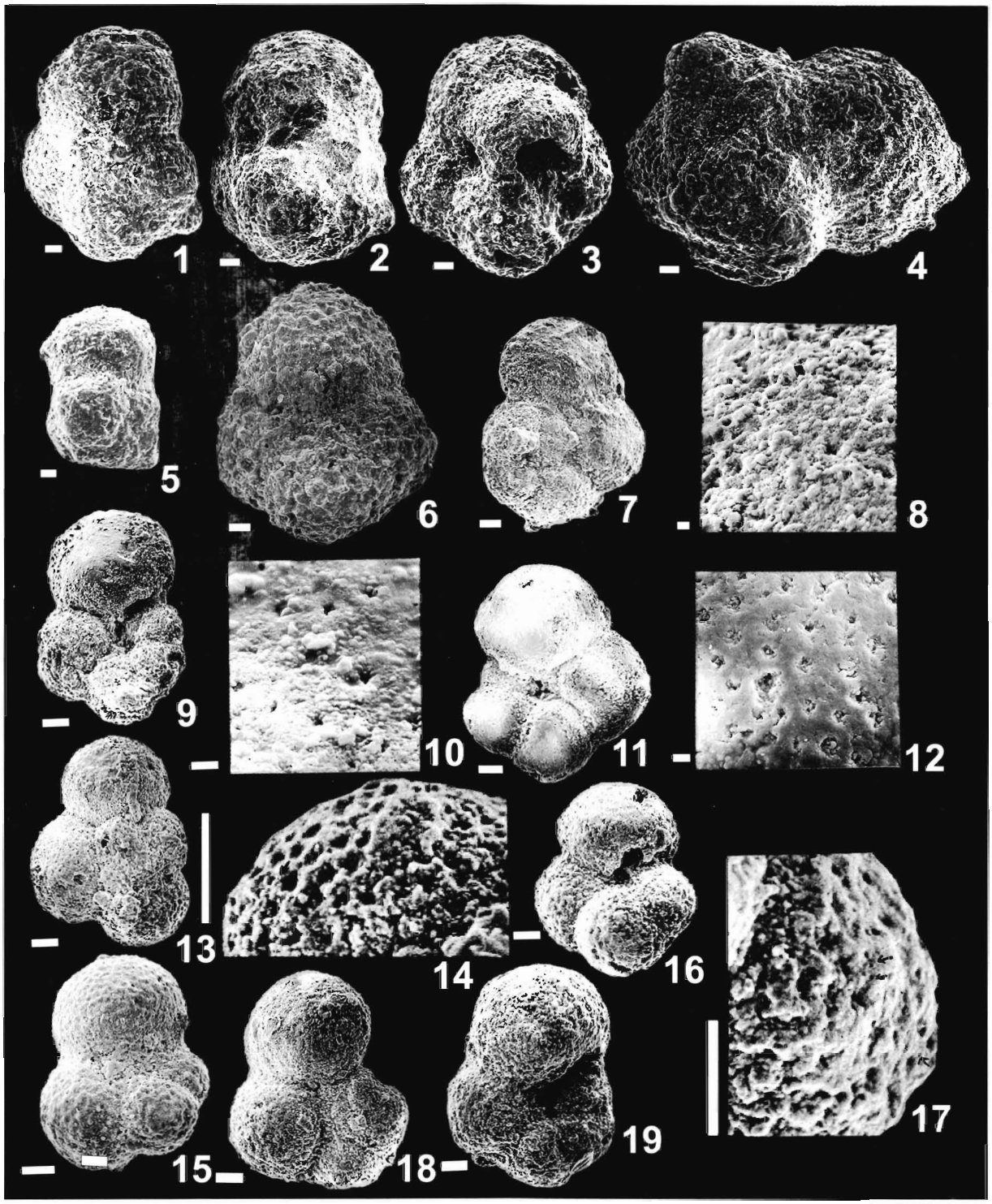
7-10. ***Globanomalina planocompressa,*** 7. Spiral view (Core 64); 8. Detail of corroded wall showing normal pores (Core 64); 9. Umbilical view; 10. Detail of normal perforate smooth wall (Core 64).

11-12. ***Praemurica taurica,*** 11. Umbilical view; 12. Wall showing gametogenetic calcification (Core 64).

13-15. ***Subbotina trivialis,*** 13. Spiral view (Core 64); 14. Details of weakly cancellate wall with spine holes at the juncture of the ridges (→) (Core 64); 15. Umbilical view, aperture concealed under extraneous matter (Core 64).

16-17. ***Eoglobigerina edita,*** 16. Umbilical view (Core 64); 17. Wall with diagenetically altered cancellate texture; Spine holes (→) are visible along cancellate ridges (Core 64).

18-19. ***Parasubbotina pseudobulloides,*** wall is recrystallized and corroded (Core 64); 18. Spiral view of the very low trochospiral test, 19. Umbilical view (Core 64).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(Type species: *Globigerina (Eoglobigerina) eobullodies* (Morozova, 1959))

Eoglobigerina eobulloides (Morozova, 1959)

(P1.II, fig.3; P1.III, figs. 6-7)

Type reference: *Globigerina (Eoglobigerina) eobulloides* Morozova, 1959, p. 1115, text-fig. 1a-c.

Remarks: Tests with moderately elevated trochospire, globular chambers 4-4½ in the final whorl gradually increasing in size, umbilical to slightly extraumbilical rounded aperture bordered by a narrow lip. Cancellate wall texture weakly developed (P1.3, figs. 6-7).

Occurrence: Core 66 and 64.

Stratigraphic range : Zone P0 (upper) to Zone Plb (lower).

Eoglobigerina edita Subbotina, 1953

(P1. I, figs.16-17; P1. III, fig.1)

Type reference: *Globigerina edita* Subbotina, 1953, p. 62, pl. II, figs. 1a-c.

Remarks: The presence of a rounded umbilical aperture and 5-5½ chambers in the final whorl distinguish this species from *E. eobulloides*; the cancellate spinose wall texture is better developed (P1.I, fig.16; P1.III, fig.1). Variation in the high to low coiled test is recorded. Spiral side is more convex than umbilical side. Aperture is umbilical to extraumbilical in position.

Occurrence : Cores 64, 63 and 58.

Stratigraphic range : Zone Pα (lower) to Zone P1.

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

(Type species: *Globigerina pseudobulloides* Plummer, 1926)

Parasubbotina pseudobulloides (Plummer, 1926)

(P1. I, figs.18-19; P1. II, figs. 8-9)

Type reference: *Globigerina pseudo-bulloides* Plummer, 1926, p. 133, pl.8, fig.9a-c.

Remarks: Test is very low trochospiral, globular-ovate chambers rapidly increase in size in the last whorl, with umbilical to extraumbilical high arched lipped aperture, umbilicus is deep and narrow. Wall shows dissolution effect and the species is identified on the basis of test architecture and remnant of cancellate texture.

Occurrence: Rare, Core 66, 64, 63 and 61.

Stratigraphic range : Zone Pα (upper) to Zone P3a.

Genus ***Subbotina*** Brotzen and Pozaryska, 1961

(Type species: *Globigerina triloculinoides* Plummer, 1926)

Subbotina triloculinoides (Plummer, 1926)

(P1.III, figs.2-3)

Type reference: *Globigerina triloculinoides* Plummer, 1926, p.134, pl.8, fig.10a-b.

Remarks: Low trochospiral, tightly coiled trilobate test with 3 to 3½ globular chambers in last whorl rapidly increasing in size. The last chamber occupies half of the test diameter. The wall texture is distinctly cancellate spinose (P1. III, fig.3). Typical forms of species with these characters are present in Core 66, 61 and 58.

EXPLANATION OF PLATE II

[Scale bars showing 10 μm for all figures excepting figure 6 for which the bar represents 100 μm]

1-2. ***Subbotina trivialis,*** 1. Spiral view showing tripartite test with weakly developed cancellate spinose texture (Core (66); 2. enlarged view (of 1) of the diagenetically altered test surface. Cancellate outline and spine holes (→) can still be observed (Core 66).

3. ***Eoglobigerina eobulloides,*** Highly corroded specimen (Core 66).

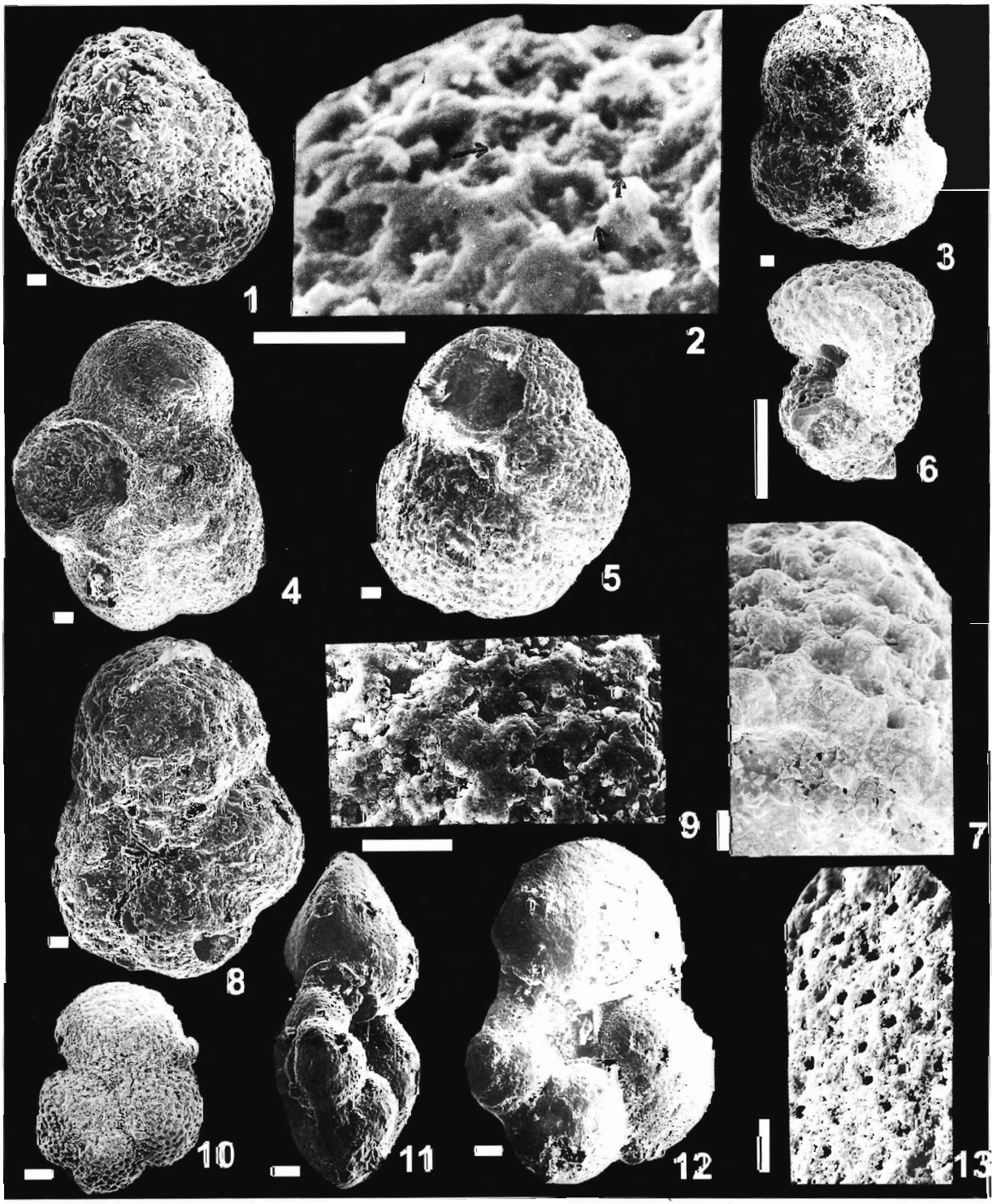
4. ***Globanomalina planocompressa,*** spiral view, very low trochospire and smooth surface with normal perforations. Natural section of the chamber wall depicts the pores (Core 66).

5-7. ***Praemurica inconstans,*** 5. umbilical view showing cancellate texture (Core 61); 6. Side view showing aperture (Core 61); 7. Enlarged view (of 6), diagenetically altered test surface showing well developed subparallel ridges connected by faint cross ridges (Core 61).

8-9. ***Parasubbotina pseudobulloides,*** 8. umbilical view (Core 61); 9. Enlarged view (of 8) showing recognisable cancellate texture and spine holes (Core 61).

Praemurica pseudoinconstans, spiral view (**Core 64**).

11-13. ***Globanomalina compressa,*** 11. Lateral view showing noncarinate periphery (Core 58); 12. Umbilical view (Core 58); 13. Enlarged view (of 12) showing details of normal perforate smooth slightly corroded wall (Core 58).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Occurrence: Cores 66, 61 and 58.

Stratigarphic range: Zone P1b to Zone P4a (lower).

Subbotina trivialis (Subbotina, 1953)

(P1. I, figs.13-15; P1. II, figs.1-2; P1. III, figs.10-12)

Type reference: *Globigerina trivialis* Subbotina, 1953, p. 78-79, p1.IV, fig.4-12.

Remarks: Tightly coiled tripartite test with 3-3½ chambers in the last whorl, aperture umbilical, cancellate spinose wall texture. The spine holes positioned more regularly at juncture of ridges (P1.II, fig.2). The wall texture shows well developed cancellate spinose texture (P1.III, fig.11).

Occurrence: Rare in Core 66, 64 and 58.

Stratigraphic range: Zone Pα to Zone P2 (lower).

Subbotina cancellata Blow, 1979

(P1. III, figs. 4-5)

Type reference: *Subbotina triangularis cancellata* Blow, 1979, p. 1284, holotype-pl. 80, fig.7.

Remarks: This coarsely cancellate species of genus *Subbotina* is being recorded for the first time from the Indian Ocean. Earlier, this species was reported only from North Atlantic and South Atlantic DSDP Sites.

Occurrence: Core 58.

Stratigraphic range: P1c (upper) to P4b.

Family **Hedbergellidae** Loeblich and Tappan, 1961

Genus ***Globanomalina*** Haque, 1956, emended

(Type species: *Globanomalina ovalis* Haque, 1956)

Globanomalina compressa (Plummer, 1926)

(P1. II, figs. 11-13)

Type reference: *Globigerina compressa* Plummer, 1926, p.135, p1.8, fig.11a-c.

Remarks: Low trochospiral, slightly angular test, characterized by axial periphery with imperforate peripheral margin, with five chambers that show rapid size increase in the last whorl. The specimens exhibit the typical morphological features of the species. Wall normal perforate smooth (P1. II, figs. 11-13).

Occurrence: Rare in cores 63, 61, 58 and 52.

Stratigraphic range: Zone P1c to Zone P3a (lower).

Globanomalina ehrenbergi (Bolli, 1957)

(P1. IV, figs. 4-5)

Type reference: *Globortalia ehrenbergi* Bolli, 1957, p.77, pl.20, figs.18-20.

Remarks: Compressed test with lobulate equatorial profile, 5½ chambers in the last whorl and thickened imperforate margin characterise this species. Penultimate chamber is not larger that the ultimate one. Normal perforate smooth nature of the wall is seen in Pl. IV, fig. 5.

Occurrence: Rare in Core 52.

Stratigraphic range: Zone P2 (upper) to Zone P3.

Globanomalina imitata (Subbotina, 1953)

(P1. IV, figs. 6-7)

EXPLANATION OF PLATE III

[Scale bars showing 100 μm for figures 1-4; 10 μm for figures 5, 9-14; 30 μm for figures 6, 8; and 3 μm for figure 7]

1. ***Eoglobigerina edita,*** oblique lateral view showing umbilical aperture and partly corroded test surface (Core 58).

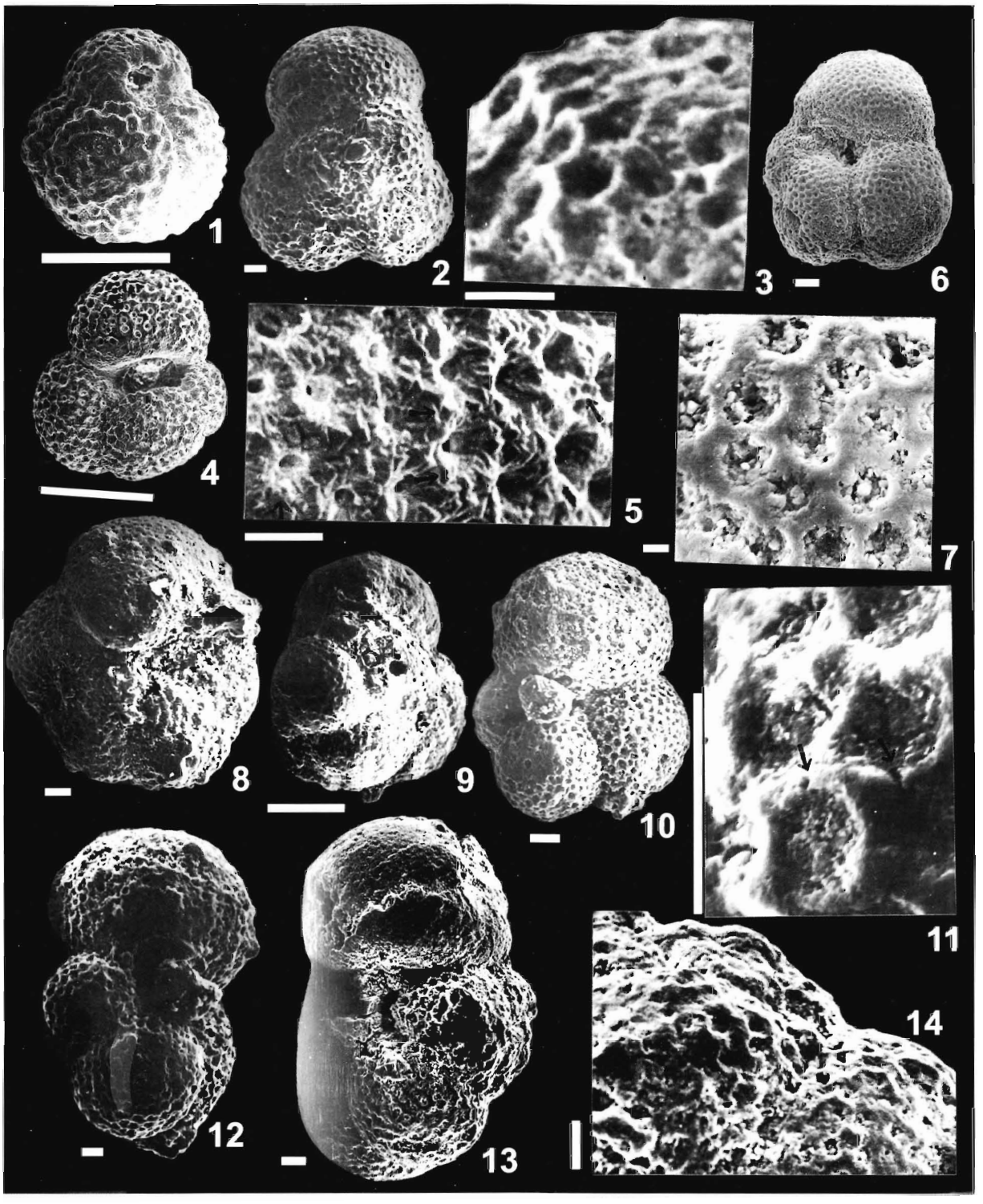
2-3 ***Subbotina triloculinoides,*** 2. Spiral view (Core 58); 3. Enlarged view (of 2) showing cancellate wall with spine holes (Core 58).

4-5. ***Subbotina cancellata,*** 4. Umbilical view (Core 58); 5. Enlarged view (of 4) showing the diagenetic overprinted cancellate wall with spine holes (→).

6-7. ***Eoglobigerina eobulloides,*** 6. Umbiliacal view (Core 64); 7. Enlarged view (of 6) showing gametogenic calcification (Core 64).

8-9, 13-14. ***Praemurica uncinata,*** 8. Oblique view (Core 58); 9. Oblique spiral view showing the noncarinate peripheral margin, trapezoidal chambers and strongly recurved sutures (Core 58); 13. Umbilical view (Core 58); 14. Enlarged view (of 13) showing Neogloboquadrinid wall texture (Core 58).

10-12. ***Subbotina trivialis,*** 10. Umbilical view (Core 58); 11. Enlarged view (of 10) showing cancellate spinose wall with observable spine holes (→); 12. Oblique lateral view (Core 58).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Type reference: *Globorotalia imitata* Subbotina, 1953, 206, holotype pl.16, fig.14a-c.

Remarks: Test small with 4½-5 inflated ovoid chambers in the last whorl. Test wall smooth perforate throughout as seen in the figure (Pl. IV, fig. 6), aperture is a high arch, umbilical-extraumbilical.

Occurrence: Core 52.

Stratigraphic range: Zone Plc (upper) to Zone P4.

Globanomalina planocompressa (Shutskaya, 1965)

(Pl. I, figs. 7-10; Pl. II, fig. 4)

Type reference: *Globorotalia planocompressa planocompressa* Shutskaya, 1965, p. 179, pl.1, fig.6a-c.

Remarks: This species is greater than 220 μm in maximum diameter, with flat to depressed spiral side, five inflated ovoid chambers in the final whorl increase gradually in size. Shallow umbilicus is broad, aperture located between the umbilicus and outer margin is a narrow arch uniformly bordered by a lip. Smooth normal perforate wall texture with evenly distributed pores on the test wall excluding the peripheral part (Pl. I, fig. 9). Wall thickness is 5 μm (Pl. II, fig. 4) which is well within the 4-7 μm range considered diagnostic for this species (Olsson *et al.*, 1999).

Occurrence: Core 66, 64, 63.

Stratigraphic range: Zone Pα (upper) to Zone Plc (lower).

Family **Truncorotaloididae** Loeblich and Tappan, 1961

Genus ***Morozovella*** McGowran, in Luterbacher, 1964

(Type species: *Pulvinulina velascoensis* Cushman, 1925)

Morozovella angulata (White, 1928)

(Pl. IV, figs. 8-10)

Type reference: *Globigerina angulata* White, 1928, p.191, pl.27, fig.13.

Remarks: Umbilico-convex test with rapidly enlarging 4-6 angular-conical chambers in the last whorl, periphery murico-carinate. Wall pronouncedly muricate (= pustulose, Olsson *et al.*, 1992) along the margin and umbilicus (Pl. IV, figs. 8, 10).

Occurrence: Core 52, common.

Stratigraphic range: Zone P3 to Zone P4a (lower).

Morozovella praeangulata (Blow, 1979)

(Pl. IV, figs. 11-12)

Type reference: *Globorotalia (Acarinina) praeangulata* Blow, 1979, p. 942-944, pl. 82, figs. 5, 6.

Remarks: Umbilico-convex tests with 4-5 tangentialy elongated chambers in the last whorl, with strongly muricate but non-carinate margin (Pl. IV, figs. 11, 12) occur commonly in smaller fraction of the samples from the Core 58-01 (121-122 cm). Appearance of angulo-conical tests in this core was marked by Heimen *et al.* (1974). Small-sized tests of *M. praeangulata* in Core 58-01 represent early forms of this species.

Occurrence: Core 58.

Stratigraphic range: Zone P2 to Zone P3a.

Genus ***Igorina*** Davidzon, 1976.

(Type species: *Igorina tadjikistanensis* (Bykova, 1953)

Igorina pusilla (Boli, 1957).

(Pl. IV, fig. 1)

Type reference: *Globorotalia pusilla pusilla* Bolli, 1957, 78, pl. 20, fig. 8-10.

Remarks: Small biconvex tightly coiled test with non-carinate periphery, 5-6 chambers in the last whorl. Sutures on spiral side are curved backwards. Wall is coarsely cancellate (praemuricate). Olsson *et al.* (1999) showed the stratigraphic range of *Igorina pusilla* as Zone P3 which has been extended to Zone P5 (Berggren, *personal communication*).

Occurrence: Core 52.

Stratigraphic range: Zone P3.

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

(Type species: *Globigerina* (*Eoglobigerina*) *taurica* Morozova, 1961)

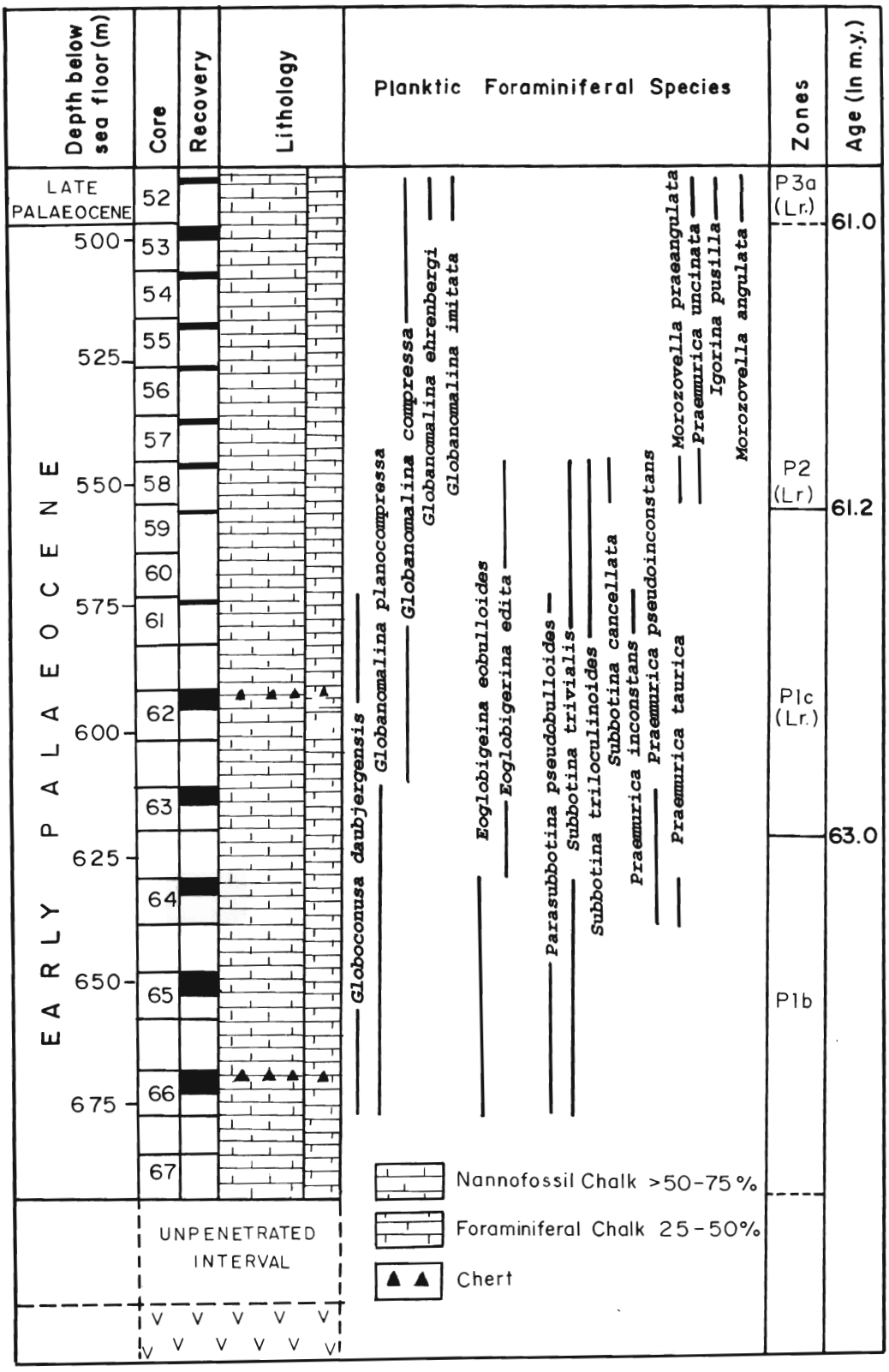


Fig. 2. Early Palaeocene planktic foraminiferal assemblage and biostratigraphy at the DSDP Site 237, Indian Ocean. An age calibration of the datum events is after Berggren *et al.* (1995).

Praemurica inconstans (Subbotina, 1953)

(Pl. II, figs. 5-7)

Type reference: *Globigerina inconstans* Subbotina, 1953, p. 58, pl. 3, figs.1-2.

Remarks: Low trochospiral test with depressed early portion on the flat spiral side and 5-6 globular chambers in the last whorl increasing gradually in size. Umbilicus wide and shallow. Wall texture is weakly cancellate with pronounced subparallel ridges connected by short ridges (Pl. II, fig. 7).

Occurrence: Core 61.

Stratigraphic range: Zone Plc to Zone P3a (lower).

Praemurica pseudoinconstans (Blow, 1979)

(Pl. II, fig. 10)

Type reference: *Globorotalia* (*Turborotalia*) *pseudoinconstans* Blow, 1979, p. 1105, pl.67, fig.4.

Remarks: Very low trochospiral test with flat spiral side and 5 to 5½ chambers in the last whorl increase gradually in size at first, but rapidly in the last few chambers. Preservation state is not suitable for the confirmation of the absence of spine holes (Pl. II, fig.10). Identification is based on the test architecture.

Occurrence: Common, Cores 64 and 63.

Stratigraphic range: Zone Pα (upper) to Zone P2 (lower).

Praemurica uncinata (Bolli, 1957)

(Pl. III, figs.8, 9, 13, 14; Pl. IV, figs. 2-3)

Type reference: *Globorotalia uncinata* Bolli, 1957, p.74, pl.17, figs.13-15.

Remarks: Low trochospiral test with angular conical early chambers of the last whorl and the strongly backwardly curved sutures on the spiral side characterise this species. Cancellate nonspinose wall texture is well developed (Pl. III, figs. 13,14).

Occurrence: Cores 58 and 52, common.

Stratigarphic range: Zone P2 to Zone P3a (lower).

Praemurica taurica (Morozova, 1961)

(Pl. I, figs. 11-12)

Type reference: *Globigerina* (*Eoglobigerina*) *taurica* Morozova, 1961, 10, pl.1, fig. 5a-c.

Remarks: Very low trochospiral test, with 4½-5 subspherical chambers increasing gradually in size, with low rounded arch-like umbilical-extraumbilical aperture bordered by a narrow lip. Wall shows diagenetic overprinting but the cancellate pattern can be observed (Pl. I, figs. 11,12). The species is identified on the basis of general morphology of the test. Average size of the specimens is 0.3 mm.

Occurrence: Core 64.

Stratigraphic range: P0 (upper) to P1b (lower).

Family **Guembelitriidae** Montanaro Gallitelli, 1957

Genus ***Globoconusa*** Khalilov, 1956

(Type species: *Globoconusa conusa* Khalilov, 1956 = *Globigerina daubjergensis* Bronnimann, 1953)

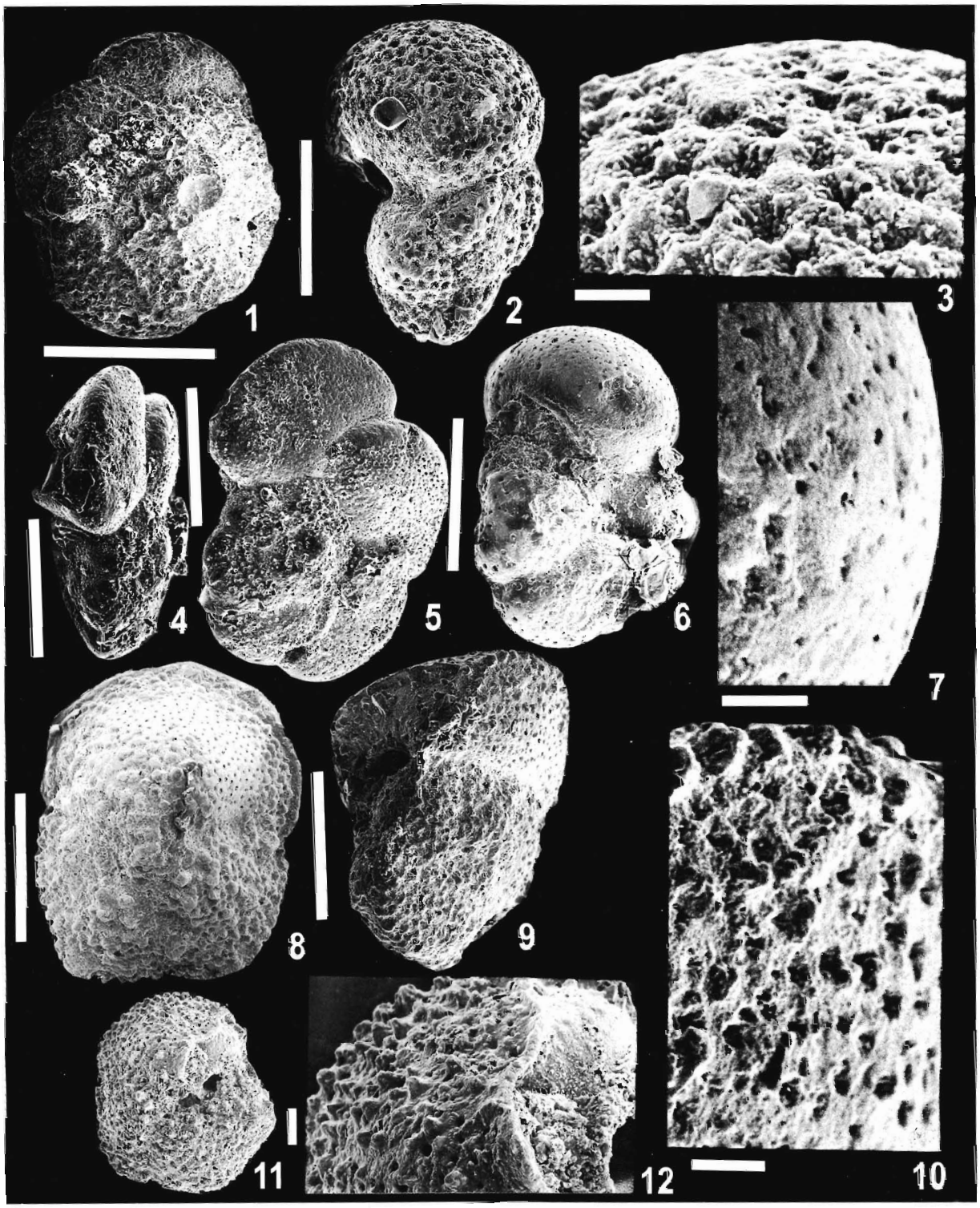
Globoconusa doubjergensis (Bronnimann, 1953)

(Pl. I, figs. 1-6)

EXPLANATION OF PLATE IV

[Scale bars showing 100 μm for figures 1,2,4-6,8,9 and 10 μm for figures 3,7,10-12]

1. ***Igorina pusila,*** spiral view showing slightly corroded pustulose test surface (Core 52).
2-3. ***Preamurica uncinata,*** 2. Side view showing umbilico-conical chambers (Core 52); **3.** Enlarged view (of 2) showing weakly cancellate nonspinose wall with diagenetic overprinting (Core 52).
4-5. ***Globanomalina ehrenbergi,*** 4. Oblique side view showing broad imperforate margin (Core 52); 5. Spiral view (Core 52).
6-7. ***Globanomalina imitata,*** 6. Oblique lateral view (Core 52); 7. Enlarged view (of 6) showing normal perforate smooth wall texture (Core 52).
8-10 ***Morozovella angulata,*** 8. Umbilical view showing development of muricae near the peripheral margin and umbilical shoulders (Core 52); 9. Oblique lateral view showing aperture and murico-carinate periphery (Core 52); 10. Enlarged view (of 9) showing muricate carina and muricae near peripheral margin (Core 52).
11-12. ***Morozovella praeangulata,*** 11. Side view showing aperture (Core 58); 12. Enlarged view (of 11) showing non-muricocarinate periphery (Core 58).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Type reference: *Globigerina daubjergensis* Bronnimann, 1953, p. 340, text-fig. 1.

Remarks: *G. daubjergensis* is represented by an entire plexus of high to low trochospiral forms with 3-4 subglobular chambers in each whorl. The microperforate wall is characterised by the presence of overgrown sharp pustules and calcite crystals implying diagenetic overprinting of original wall (P1.I, fig.6). Specimens of *G. daubjergensis* occurring very commonly in core 66 include high as well as low trochospiral forms many of which exhibit the presence of spiral sutural openings and the umbilical bulla (P1. I, fig. 3).

A neritoplanktic habit and abundant occurrence in high latitude is suggested for *G. daubjergensis* (Boersma and Premoli-Silva, 1983; Liu and Olsson, 1992, Olsson *et al.,* 1999). The occurrence of this species at DSDP Site 237, is therefore significant as it represents one of the few records of the species from the low latitudes. Site 237 has been an area of pelagic sedimentation since early Palaeocene (Fisher *et al.,* 1974; Vincent, 1974) although nearby shoals serve as the source for the slumped material redeposited in the pelagic sediments. Small amounts of coralline algal fragments recorded in foraminiferal nannochalk in 61-1 corroborate shallow water habitat of *G. daubjergensis.*

Occurrence : Very common 66, 64 (P1b), common in 63, 61 (P1c).

Stratigraphic range : Zone Pα to P1c (lower).

BIOZONATION

Identification of species from the lower 6 Cores (66-52) at DSDP Site 237 and their documented geological ranges have helped develop a more refined biozonation. Zone P1b to Zone P3a are delineated in cores 66 through Core 52 (fig. 2) which is a significant improvement over the biozonation proposed in the preliminary report of the DSDP Leg 24 (Fisher *et al.,* 1974).

In the previous work at Site 237 (Fisher *et al.* 1974; Heimen *et al.,* 1974), Core 67 through 61 were relegated to undifferentiated interval of Zones P1-P2. This assignment was based on the identification of *Turborotalia pseudobulloides* and *T. trinidadensis* in core 64 and *T. compressa* in Core 67 in addition to the two species present in core 64 (Heimen *et al.,* 1974). The base of Zone P3 was considered to lie in Core 58 near the lowest occurrence of anguloconical tests referable to *Morozovella angulata* (Fisher *et al.,* 1974).

In the present work, Zone P1 is characterised by the presence of *Globoconusa daubjergensis, Globanomalina planocompressa, G. compressa, Eoglobigerina eobulloides, Parasubbotina pseudobulloides, Subbotina trivialis, S. triloculinoides, Praemurica taurica* and *P. pseudoinconstans.* Within this zone, subzone P1b is identified on the co-occurrence of *Subbotina triloculinoides, S. trivialis, Eoglobigerina eobulloides,* and *Praemurica taurica* in the core interval 66-01 to 63-01. FAD of *G. compressa* in Core 63-01 (105-106cm) marks the P1b/P1c boundary. Lower boundary of P1b cannot be defined as identifiable assemblage is not present below Core 66. Subzone P1c is identified on the basis of the occurrence of *Globanomalina compressa, G. planocompressa, Globoconusa daubjergensis, Eoglobigerina edita* and *Praemurica inconstans* in Core 63 to 61. Core Interval 59 to 60 has not yielded any identifiable assemblage, therefore P1c/P2 boundary placement is not possible, however, it is tentatively placed in Core 58 based on the occurrence of *Praemurica uncinata and Morozovella praeangulata* that first appear in Zone P2. Also, *G. daubjergensis* that ranges from Pα – P1c does not continue into Core 58. Core 58 is characterised by the assemblage of *Praemurica uncinata, Morozovella praeangulata, Globanomalina compressa, Subbotina triloculinoides S. trivialis* and *S. cancellata.* The occurrence of *Morozovella angulata, Globanomalina ehrenbergi, G. compressa, G. imitata and Igorina pusilla* characterises the Core 52 as Zone P3a (fig.2). The P2/P3 boundary is possibly situated in Core 57 based on biochronological estimates (Olsson *et al.,* 1999) and the rate of sedimentation of 68 m/my (Vincent *et al.,* 1974) for the Palaeocene carbonates.

DISCUSSION AND CONCLUSION

In the preliminary report of the DSDP Leg 24, samples below Core 49 at Site 237 were reported

(Fisher *et al.,* 1974) to be affected by high degree of recrystallization inhibiting sufficient species determination for age assignment. In a few suitable samples of Cores 66 to 52 (fig.2) moderately well preserved forms belonging to eighteen species of planktic foraminifers have been identified. Classification by Olsson *et al.* (1992 & 1999) that combines wall texture and test architecture was particularly useful for the taxonomic placement of the small sized early Palaeocene species.

Planktic Foraminiferal Assemblages

Planktic foraminiferal assemblages recorded in the core samples comprise forms that display a varying degree of diagenetic overprinting of the wall texture. The diagenetic overprint provides an armour-like cover making the forms belonging to the species *Globoconusa daubjergensis* resistant to dissolution, apparently increasing its percentage of occurrence due to preservational bias. Species of the genus *Eoglobigerina* are preserved well where they get silicified (P1.I, figs.16-17; P1.III, figs.1, 6, 7). Other species like *Parasubbotina pseudobulloides* with cancellate spinose wall texture show dissolution (P1.I, figs.18, 19; P1.II, figs.8, 9) resulting in their low percentage of occurrence in the samples.

In the previous work (Fisher *et al.,* 1974) only four species formed the basis for a tentative assignment of Core interval 67-05 (65-67) to 64-02 (42-44) to Zone P1-P2. The base of P3 was considered to lie in Core 58-01 (145-147) due to the presence of angular-conical tests (*Acarinina angulata, A. uncinata, Morozovella aequa*). The present study of Cores 66, 64, 63, 61 and 58 have resulted in the identification of early Palaeocene assemblages composed of a total number of fourteen species (fig.2). In Core 52, four species representing late Palaeocene assemblage have been recorded.

Subbotina cancellata has been recorded in north Indian ocean, thus expanding geographical distribution of the species. Earlier, this species was found to occur in Atlantic ocean and Kerguelen Plateau, south Indian Ocean.

The present study demonstrates that microperforate species *Globoconusa daubjergensis,* not recorded in the previous work, occurs commonly in the lower cores. This species is easily recognized by its test architecture and wall texture even in the specimens affected by diagenetic overprinting. The record of this species at low latitude DSDP Site 237, Indian Ocean is significant as it was mainly recorded from high latitude.

Wall Texture

The identification of the wall texture under SEM demonstrated that even in some recrystallized, diagenetically altered and corroded tests, it was possible to observe the remnants of wall texture. Early Palaeocene species characterised by the forms belonging to the microperforate, cancellate spinose and smooth-walled normal perforate groups were conveniently discriminated. Microperforate taxon *Globoconusa daubjergensis* that dominates the early Palaeocene assemblages is identified on the basis of test morphology and wall texture even though the microperforations were not observed due to diagenetic alteration of the pustulose test surface. The distinction between spinose and nonspinose cancellate wall texture is difficult in diagenetically affected forms as the nonspinose cancellate texture was defined on negative evidence of the absence of spine holes (Pearson, 1993). Praemuricate wall texture is similar to the cancellate texture of *Neogloboquadrina dutertrei* which is characterised by subparallel long ridges of plate-like crystals, connected by feebly developed short ridges (Hemleben *et al.,* 1991). This type of cancellate texture present in the early Palaeocene species of the genera *Igorina* and *Praemurica* is seen in diagenetically affected tests (P1.II, fig.7; P1.IV, fig.1).

Comparison with nannofossil biostratigraphy

Core 45 through 51 were assigned (Fisher *et al.* 1974) to the *Fasciculithus tympaniformis* Zone (upper part of Zone NP5) characterized by the occurrence of *Fasciculithus tympaniformis, F. pileatus, F.* sp. cf. *F. ullii, Chiasmolithus consuetus, C. danicus, Neochiastozygus concinnus, Prinsius bisulcus* and *Zygodicus plectopons.* Zone NP5 broadly corresponds to planktic foraminiferal Zone P3 to upper part of Zone P2. Core 52 through 54 and Core 64 through 67 (Bukry, 1974) belong to the

Cruciplacolithus tenuis Zone with poor assemblage recovery including *Chiasmolithus danicus, Cruciplacolithus tenuis, Zygodicus plactopons and Biantholithus sparsus.*

The *Cruciplacolithus tenuis* Zone broadly corresponds to the upper part of Zone P1b to lower part of Zone P1c. In the present study the lowest Cores (66 and 64) that have yielded recognizable planktic foraminifers are marked as P1b and Cores 63 and 61 as Zone P1c. These assignments are broadly in agreement with the nannoplankton biozonation as opposed to previous planktic foraminiferal biostratigraphy by Fisher *et al.* (1974).

Biochronology

The delineation of Zones P1b to P3a in the lower cores (Core 66 through 58) in DSDP section 237 provides the biochronological evidence for their assignment to early Palaeocene (Danian) age. The early/late Palaeocene boundary lies somewhere above Core 58-01 (121-122cm.) and below Core 52-01 (02-03 cm.) assigned to Zone P2 and zone P3a respectively. The Danian/Thanetian boundary is likely situated within Core 57 using the biochronological scale of Berggren, Kent, Swisher and Aubry (1995) and the sedimentation rate of 68.2 m/my (Fisher *et al.*, 1974) for the pelagic carbonate, accumulated in upper bathyal depth with an added influx of neritic sediments. Also about 100 m. of sediments is estimated to lie below the hole bottom and above the igneous basement at the Site 237 (Fisher *et al.*, 1974). Within this unpenetrated sedimentary interval Zones Plα, Pa and P0 (spanning 0.5 my) may be present over the Upper Cretaceous rocks, provided the accumulation rate of 68.2 m/my remained constant in the early Palaeocene.

ACKNOWLEDGEMENTS

Authors are thankful to ODP, Texas A & M University Research Park, Texas for providing the samples. We thank Department of Science & Technology, India for financial assistance. We also thank SIFEM (All India Institute of Medical Sciences), New Delhi and Dr. N.C. Mehra, USIC (University Science Instrumentation Centre), University of Delhi, Delhi for SEM.

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Manuscript Accepted July 2002