

## LARGER FORAMINIFERA FROM A RELICT STRUCTURE OFF KARWAR WESTERN INDIAN CONTINENTAL MARGIN

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Grab samples collected off Karwar from a depth of 77-201 m yielded several larger foraminifera from calcareous relict sediments. This sediment was characterised by opaline silica which was formed during the close of the Pleistocene or the beginning of the Holocene. The relict sands yielded fossilised larger foraminifera which invariably mixed with the Recent fauna. Larger foraminifera were abundant numerically but they include some large-sized benthonics (e.g. *Elphidium indicum*) and planktonics including *Globoquadrina conglomerata*, *G. hexagona* and dextrally coiled *Neogloboquadrina pachyderma typica* (reported earlier). The occurrence of some of the planktonics was suggestive of upwelling and their record in the sediment was indicative of such water masses having been present in the region. Among the larger forms, *Amphistegina bicirculata*, *A. radiata* var. *papillosa* and *Operculina ammonoides* indicate mixing, while *Nummulites cumingii* and *Borelis schlumbergeri* were relict forms of Pleistocene time.

**Key Words :** Foraminifera; Relict Structure; Western Indian Continental Margin; Benthonics; Recent Fauna; Planktonics; Relicts of Pleistocene Age; Oceanographic Conditions; Faunal Assemblage

### INTRODUCTION

LARGER foraminifera were recovered from the bottom sediments of the western continental margin of India in Cruise No. 25 on board INS KISTNA during the International Indian Ocean Expedition (IIOE). The samples were collected off Karwar at locations between 14°47.5'N and 73°59.8'E at a depth range of 77-201 m. Foraminiferal assemblage and organic carbon relationship of the shelf inclusive of this region was reported by Setty and Nigam (1982). Occurrence of larger foraminifera and the effects of pollutants on them in the marine environment near Trivandrum and Karwar were also reported (Setty and Nigam, 1984).

### OCEANOGRAPHIC CONDITIONS

The grab samples when fresh were greenish grey, medium textured, medium grained and sandy. The sand-silt-clay ratio upon examination was found to be variable (sand 48.0-75.6; silt 13.3-30.0; clay 10.7-21.0). The material was a calcareous sediment (variable from 47.0-56.0 per cent CaCO<sub>3</sub>) because of a high content of foraminifera and shell debris in it (Setty and Gupta, 1972). The facies zonation

of the sediment corresponded to that proposed by Schött (1968), Stackelberg (1972) and Setty and Nigam (1982).

The surface and bottom temperature variation was very marginal but at the shelf edge the bottom temperature was almost half of that of surface temperature. The salinity varied from 33.288 per thousand at 195 m to 36.032 per thousand at 50 m depth but it increased to 36.284 per thousand at the shelf edge. The oxygen content of the water (0-22 ml/l) was very low at the shelf edge (Setty and Gupta, 1972).

In the outer shelf, the Recent sediment became coarser and the thin upper veneer deposit often exposed the coarse, relict sands. A major constituent of these sands is subrounded quartz (opaline silica). These relict sands were formed in shallow agitated waters when the sea reached its lowest level during the close of the Pleistocene or beginning of the Holocene (Stackelberg, 1972). These calcareous relict sands yielded larger foraminifera (fossil) which invariably got mixed with the recent sediment and the modern fauna.

#### FAUNAL ASSEMBLAGE

The carbonate composition of the relict sand was biogenic in origin and composed chiefly of shell debris, foraminiferal tests, algal and bryozoan fragments. The biogenic fraction being broken down invariably to sand size, it was assumed that the larger foraminifera constituted to be a major component which occupied such a substratum.

*Globigerina bulloides*, *G. calida*, *Globigerinoides succulifer*, *Orbulina universa*, *Globoquadrina dutertrei*, *G. conglomerata*, *G. hexagona*, *Globigerinella aequilateralis* and *Globorotalia menardii* were reported from this region (Setty and Gupta, 1972) and dextrally coiled *Neogloboquadrina pachyderma typica*, (Setty, 1977). Among the benthonics, *Ammonia annectanz*, *Florilus* sp., *Quinqueloculina horrida*, and *Cibicides* sp. were abundant. *Elphidium indicum* was exceptionally rich with large-sized (upto 1 mm) specimens. The larger foraminifera which were abundant numerically include, *Amphistegina radiata* var. *papillosa*, *A. cf. bicirculata*, *Borelis schlumbergeri*, *Cellanthus craticulatus*, *Gypsina globula*, *Heterostegina suborbicularis*, *H. aequatoria*, *Operculina ammonoides*, *O. ornata*, *O. bartschi*, *O. complanata*, and *Operculinoides venosus* and *Nummulites cumingii*.

#### DISCUSSION

The study area is within the regime of annually recurring upwelling phenomenon. The intensity and magnitude of upwelling reflected in the composition and preservation of foraminiferal fauna, distribution of organic carbon under midwater oxygen minima conditions, presence of quartz, and the nature of water masses. The relict sands characterised by opaline silica also includes fossilised larger foraminifera which got mixed with the Recent forms.

Setty (1983) stated that appearance of populations of *Globigerina bulloides* and dextrally coiled *Neogloboquadrina pachyderma typica* is suggestive of upwelling and a

record in the sediment of the presence of such water masses in the region. *Globogadrina conglomerata* and *G. hexagona* were also encountered. Besides, some large-sized benthonics like *Elphidium indicum* were observed. However, larger foraminifera were abundant numerically.

Some foraminifera are fresh, clean, white, translucent and empty tests while the rest are abraded, ironstained, encrusted with algae and bryozoans, broken and subjected to possible subaerial exposure. Thus it is a mixed fauna with Recent assemblage. This character is suggestive of slow sedimentation rate during the Recent.

*Amphistegina bicirculata*, *A. radiata* var. *papillosa* and *Operculina ammonoides* are indicative of present deep water conditions. Test thickness decreases with habitat depth in the large symbiont-bearing foraminifera and the trochospiral species are thicker than planispiral and discoid forms. The presence of such forms together indicate mixing. Therefore, it may be stated that *Amphistegina bicirculata*, *A. radiata* var. *papillosa* and *Operculina ammonoides* while indicate mixing, *Nummulites cumingii* and *Borelis schlumbergeri* are Pleistocene forms which occur as relicts.

**Family :** Camerinidae MEEK & HAYDEN 1865

**Genus :** *Operculina* D'ORBIGNY 1826

*Operculina ammonoides* (GRONOVIVS)

Pl. I, Figs : 1-3

1963 *Operculina ammonoides* (Gronovivus) Cole, *U. S. Geol. Surv. Prof. Paper*, 403-E, p. E 14, pl. 5, figs. 13-24, 26-30, 33-35.

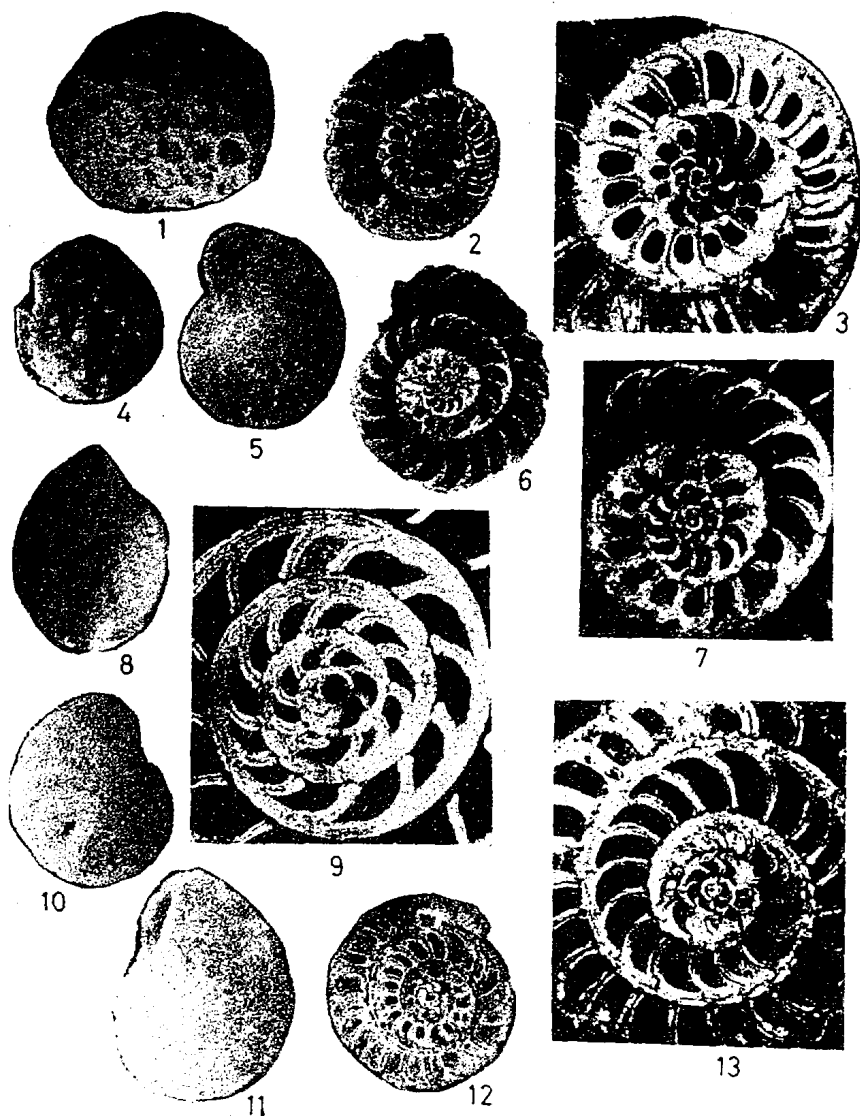
Test bilaterally symmetrical, involute, lenticular to evolute, compressed interseptal sutures flushed, raised and beaded, marginal and septal canals well developed. Some specimens are ornamented by beads along suture lines, and the umbonal region somewhat raised. Some fossil tests encrusted by bryozoans. The embryonic chambers are small, bilocular; microspheric as well as megalospheric; chambers increase in height as added.

#### Measurements

1. *Embryonic chambers (max. diameter); microspheric form* : protoconch—0.035 mm; dutoeroconch—0.0438 mm. Maximum diameter of embryonic apparatus—0.0565 mm. 2. *Wall thickness* : protoconch—0.007 mm; dutoeroconch—0.01 mm.

#### Remarks

Cole (1963) observed that the Operculinids of Indo-Pacific region have a considerable variation in the shape of the test. Specimens vary from small unornamented evenly lenticular tests to relatively large compressed evolute tests. Hofker (1927) combined all the Operculinids into one, while Cushman (1921) had divided them into many. Cole (1959) found that *Operculina ammonoides* and *Operculinella venosa* (now *Operculinoides venosus*) could be recognised as two distinct species.



## PLATE I

- 1-3 *Operculina ammonoides* (Gronovius) 1. External view of test encrusted with bryozoan growth  $\times 30$ ; 2: equatorial section of microspheric form  $\times 36$ ; 3: enlarged equatorial section  $\times 96$ .
- 4-7 *Operculina bartschi* Cushman 4: External view of test showing pustules radiating from centre;  $\times 30$ ; 5: another test showing sutures raised, recurved and beaded  $\times 20$ ; 6: enlarged equatorial section showing wavy and crenulated chamber walls and irregular chamberform  $\times 96$ .
- 8-9 *Operculina ornata* Cushman 8: Test showing strongly curved, depressed sutures and rapidly enlarging spire,  $\times 30$ ; 9: equatorial section of a megalospheric form  $\times 96$ .
- 10-13 *Operculinoides venosus* (Fichtel and Moll) 10-11: Test external views (10)  $\times 36$ ; (11)  $\times 43$ ; 12: equatorial view of a microspheric form  $\times 45$ ; 13: enlarged equatorial section  $\times 96$ .

Common in Enivetok, Bikini and Rongerick atolls, of Marshall, Saipan, Fiji and Guam Islands. *O. ammonoides* is common in Tertiary stage of the Indo-Pacific region occurring along with *Lepidocyclina* (*Nephrolepidina*) *rutteni lauensis* Cole (Cole, 1959). Age late Pliocene to Recent.

*Operculina bartschi* CUSHMAN 1921

Pl. I, Fig. 4-7

1963 *Operculina bartschi* Cushman Cole *U. S. Geol. Surv. Prof. Paper.* 403—E p. E 15, pl. 3, fig. 1-17; pl. 4, fig. 1.

Test large, evolute, flat, and thin or with a small umbo and surrounded by a flat rim; surface ornamented by rows of pustules radiating from centre; sutures raised, recurved and beaded. A small subcentral zone of papillae over the embryonic chambers. The chamber walls are even and regularly curved but sharply recurved towards their distal ends.

*Remarks*

The external appearance is distinctive but internally it has wavy, crenulated chamber walls resulting in irregular chamber form; both microspheric and megalospheric forms found. This species is normally larger than *O. ammonoides*; ornamentation less pronounced, and in transverse shape different. The axial plugs are well developed and large. Age Recent. *O. bartschi* occurring in Tertiary deposits of Guam to Recent also found along western shelf of India.

*Measurements*

1. *Embryonic chambers (max. diameter); microspheric form* : protoconch—0.042 mm; dutoconch—0.0625 mm; Maximum diameter of embryonic apparatus—0.0750 mm.

2. *Wall thickness* : protoconch—0.008 mm; dutoconch—0.0125 mm.

*Operculina ornata* CUSHMAN 1921

Pl. I, Figs. 8 & 9

1940 *Operculina bartschi* var. *ornata* Cushman 1921, (*vide* Ellis and Messina, 1940, *et seq.*)

Test evolute, with strongly curved, depressed sutures with or without coarsely set granules and a marginal cord; spire rapidly enlarging. This species occurs with *O. ammonoides* on the western continental margin; age Pleistocene to Recent.

*Measurements*

1. *Embryonic chambers (max. diameter) megalospheric form* : protoconch—0.05 mm; dutoconch 0.0875 mm. Maximum diameter of embryonic apparatus—0.10 mm.

2. *Wall thickness* : protoconch—0.0188 mm; dutoconch—0.0875 mm.

**Genus :** *Operculinoides* HANZAWA 1935

*Operculinoides venosus* (FICHTEL *et* MOLL)

Pl. I, Figs. 10—13

1933 *Operculinoides venosa* (Fichtel *et* Moll) Cushman, *U. S. Natn. Mus. Bull.*, No. 161, pt. 2, p. 1-79; pl. 1-19.

1957 *Operculinoides venosus* (Fichtel and Moll) Cole, *U. S. Geol. Surv. Prof. Paper*, 280—I, p. 331, pl. 94, figs. 4-11.

Test involute, small (1-2 mm) and having a maximum concentration between 1.2-1.6 mm. Differs from *O. ammonoides* by the presence of an umbonal boss and straight to slightly curved sutures. The chamber walls are nearly straight and recurve gently.

#### Remarks

The involute test grades imperceptibly into evolute types comparable to *O. ammonoides*. These are comparable to *Operculina hanzawai* Smout and Eames (1960). Hanzawa (1934) combined *O. venosa* and *O. ammonoides* but they belong to different genera, since *O. ammonoides* is evolute hence belongs to *Operculinoides*.

This species occurs in Tertiary to Recent sediments. It occurs very commonly in the Indian shelf sediments wherever larger living foraminifera dominate. Age Pleistocene to Recent.

#### Measurements

1. *Embryonic chambers (max. diameter) megalospheric form*; protoconch—0.0375 mm; dutoeroconch—0.05 mm. Maximum diameter of embryonic apparatus—0.07 mm.

2. *Wall thickness* : protoconch—0.0125 mm; dutoeroconch—0—0.175 mm.

**Family :** Amphisteginidae D'ORBIGNY

**Genus :** *Amphistegina* D'ORBIGNY 1826

*Amphistegina radiata* var. *papillosa* SAID

1949 *Amphistegina radiata* (Fichtel *et* Moll) var. *papillosa* Said, Cushman Found. *Foram. Res. Spl. Publ.*, 26, p. 39, pl. 4, fig. 12.

Test lenticular, trochoid, involute, sutures with a prominent angle, calcareous perforate, aperture ventral and small. The species is more compressed, biconvex, dextral, with limbate ridges, radially papillose making the sutures more distinct. It is extremely variable in size, shape and ornamentation.

#### Remarks

Todd (1976) is of the opinion that the genus *Amphistegina* is limited to the equatorial regions but in the Indian Ocean it occurs along the coasts of India, and further extending into regions of 25°N and 25°S (Red Sea). It is an outer shelf-

outer slope, deeper water species, thus it can be used for deducing the depth and location of deposition. Age—Recent.

**Genus :** *Nummulites* LAMARCK 1801

*Nummulites cumingii* CARPENTER

Pl. II, Figs. 1-5

1884 *Nummulites cumingii* (Carpenter) Brady, *Challenger Repts. Zoology* Vol. 9, p. 749, pl. 112, figs. 11-13.

Test white, globular, 0.8 to 1.8 mm thick. The anastomosing sigmoid septal filaments on the umbonal area make a distinctive feature in somewhat weathered specimens. The proloculus in megalospheric forms is large followed by a rapidly opening spire of 28-30 chambers in 3 whorls showing highly curved septa. Megalospheric and microspheric forms are found. The fossilised specimen indicate a Pleistocene to Sub-Recent age.

#### Measurements

1. *Embryonic chambers (max. diameter), megalospheric form* : protoconch—0.1125 mm; deuteroconch—0.1125 mm; microspheric form : protoconch—0.0663 mm; deuteroconch—0.1125 mm. Maximum diameter of embryonic apparatus—in megalospheric form is 0.175 mm while it is 0.126 mm in the microspheric form.

(2) *Wall thickness* : megalospheric form : protoconch—0.0125 mm; deuteroconch 0.1125 mm but it is 0.025 mm and 0.028 mm for microspheric form respectively.

Cole (1953, p. 33) considers that *Operculinella* is not a valid genus and *O. cumingii* (= *O. venosa*) is a gerontic development and concludes that *Operculinella* is a synonym of *Operculina*.

**Family :** Planorbulinidae SCWAGER 1877

**Genus :** *Gypsina* CARTER 1877

*Gypsina globula* (REUSS)

Pl. II, Figs. 6-7

1884 *Gypsina globulus* H. B. BRADY, *Challenger Repts. Zool.*, 9, p. 717, p. 101, fig. 8.

When well preserved, the test is generally spherical in shape but the immature ones have a flat surface on one side. The individual chambers are usually smaller and result in a fine textured surface.

**Genus :** *Heterostegina* D'ORBIGNY 1826

*Heterostegina suborbicularis* D'ORBIGNY 1904

Pl. II, Figs. 8-11

1957 *Heterostegina suborbicularis* D'Orbigny Cole, *U. S. Geol. Surv. Prof. Paper*, 260—V, p. 762, pl. 235, figs. 14-20.

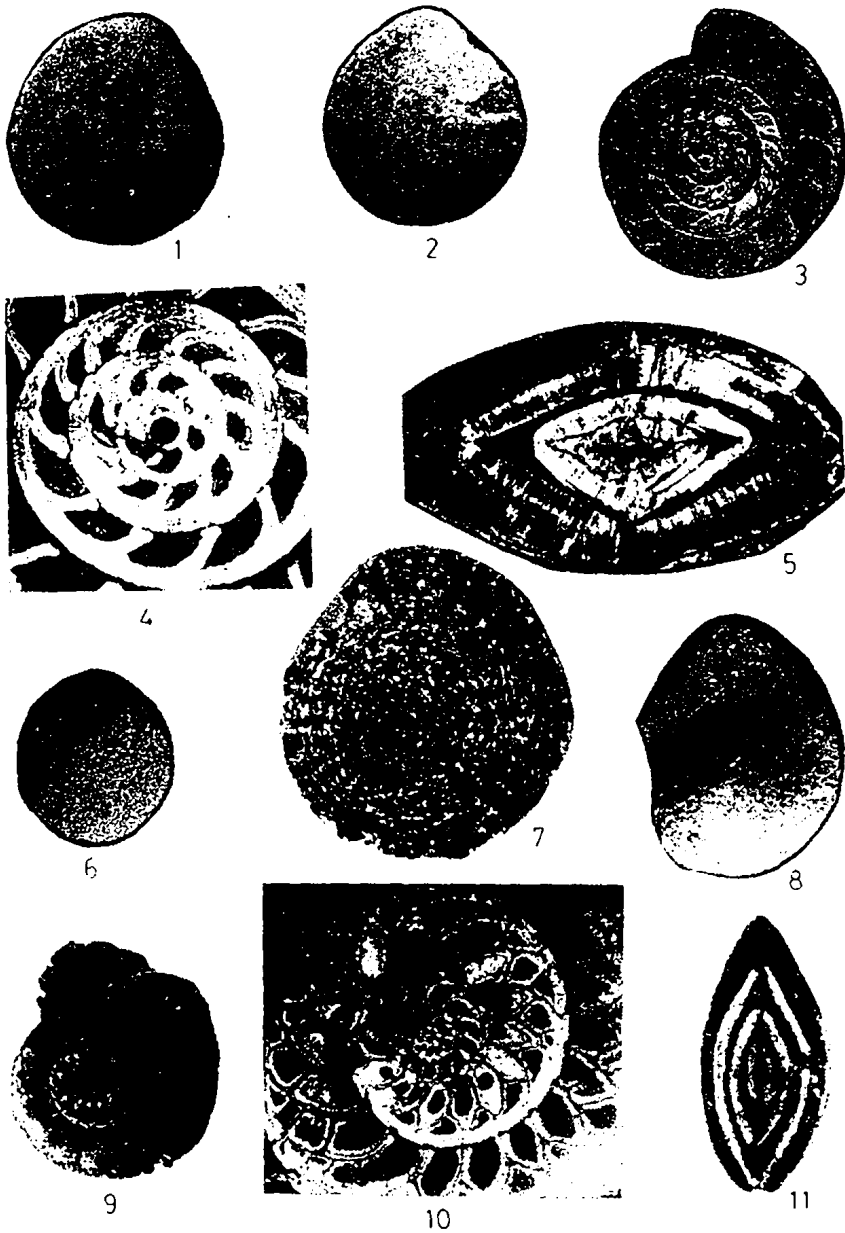


PLATE II

- 1-5 *Nummulites cumingii* Carpenter 1-2; Tests globular external view  $\times 30$ ; 3: equatorial section of a megalospheric form  $\times 45$ ; 4: Enlarged equatorial section  $\times 96$ ; 5: Transverse view  $\times 96$ .  
 6-7 *Gypsina globula* (Reuss) 6: Test Surface view  $\times 43$ ; 7: equatorial section  $\times 96$ .  
 8-11 *Heterostegina suborbicularis* d'Orbigny 8: Test, external view  $\times 22$ ; 9: equatorial view of a microspheric form  $\times 50$ ; 10: enlarged equatorial view  $\times 96$ ; 11: Transverse view  $\times 50$ .



Test lenticular, inflated, planispiral, wall granulate, rapidly flaring in side view; similar to *Operculina*, periphery thin; early chambers simple but later chambers divided to chamberlets, aperture row of rounded openings on narrow apertural face.

#### Remarks

The specimen show more (27) operculine chambers in the first two volutions and the heterostegine chambers are developed in later ones. The chambers are completely subdivided into chamberlets only at the later stages of the final volution. Megalospheric and microspheric forms common.

#### Measurements

1. *Embryonic chamber (max. diameter) in microspheric form*: protoconch—0.025 mm; dutoconch—0.0225 mm. Maximum diameter of embryonic apparatus—0.05 mm.

2. *Wall thickness*: protoconch—0.01 mm; dutoconch—0.0125 mm.

The Tertiary b specimens of Bikini atolls of Marshall islands are identical with the living specimens except for differences in preservation. In the Maemong Limestone member (Tertiary e) as in Enivetok atoll sediments (Recent) and the present Caribbean region, *Heterostegina* presumably developed in warm water shallow (approx. 30 m) depth.

#### *Heterostegina aequatoria* COLE

Pl. III, Figs. 1-5

1963 *Heterostegina aequatoria* Cole, *U. S. Geol. Surv. Prof. Paper*, 403-E, p. E 17, pl. 5, figs. 31, 32.

Test small, with a distinct central umbonate region; no ornamentation. This species has 11-15 operculine chambers before chambers are divided into chamberlets.

#### Remarks

Cole (1957) erected this as a new species; first appeared in Eniwetok atoll in Tertiary b core.

#### Measurements

1. *Embryonic chambers (max. diameter) megalospheric form*: protoconch—0.0313 mm, dutoconch—0.10 mm; maximum diameter of embryonic apparatus—0.875 mm.

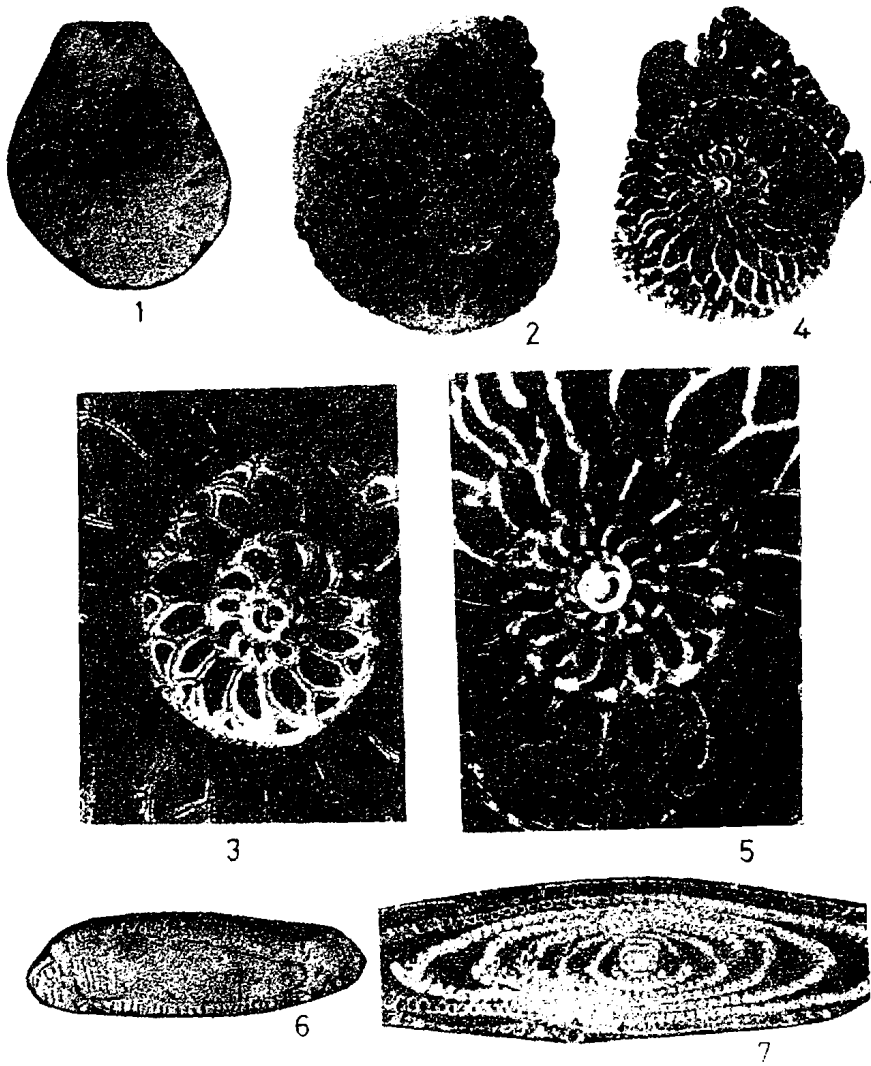
2. *Wall thickness*: protoconch—0.0312 mm; dutoconch—0.0250 mm.

Family: Alveolinellidae EHRENBURG 1839

Genus: *Borelis* DE MONTFORT 1808

*Borelis schlumbergeri* (REICHEL)

Pl. III, Figs. 6-7.



## PLATE III

- 1-5 *Heterostegina aequatoria* Cole 1 : Test external view  $\times 36$ ; 2 : equatorial section of a megalospheric form  $\times 50$ ; 3 : enlarged equatorial section of a megalospheric form  $\times 96$ ; 4 : equatorial section of a microspheric form  $\times 45$ ; 5 : enlarged reversed section of above microspheric form  $\times 96$ .
- 6-7 *Borelis schlumbergeri* (Reichel), 6 : Test showing external features  $\times 43$ ; 7 : equatorial section  $\times 96$ .

1940 *Neovalveolina pygmaea* (Hanzawa) var. *schlumbergeri* (Reichel), (*vide* Catalogue of Foraminifera by Ellis and Messina *et. seq.*).

1954 *Borelis schlumbergeri* (Reichel) U. S. Geol. Surv. Prof. paper, 260-0, pp. 583-584, pl. 209, figs. 10-18.

*Remarks*

The shape of *B. schlumbergeri* is highly variable, ranging from nearly avoid to elongated-fusiform. It is widely distributed in the Indian Ocean and the Red Sea. Cole (1957) recorded their first appearance in Eniwetok Atoll drill holes at 265–275 m depth (Tertiary g).

It occurs in Recent sediments in the Gulf of Elat. It occurs at 1.5–20 m depth. The accompanying fauna is characterised by Miliolidae, *Penetroplis*, *Marginopora*, and *Amphistegina* but at 5–20 m depth with *Operculina*. Alcyonarian spicules, bryozoans and molluscs occur frequently in all *Borelis* bearing assemblages.

*Measurements*

1. *Embryonic chambers (max. diameter)* : protoconch—0.0625 mm
2. *Wall thickness* : protoconch—0.0125 mm.

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