SECTION 8
Table 3
Table 3 Check-list of Recent Foraminifera from the east coast of India

<table>
<thead>
<tr>
<th>BEACHES</th>
<th>Puri</th>
<th>Vishakhapatnam</th>
<th>Marina</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spiroloculina antellarium d'Orbigny</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. communis Cushman and Todd</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Q. vulgaris</em> d'Orbigny</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quinqueloculina seminulum (Linne)</td>
<td>F</td>
<td>F</td>
<td>R</td>
</tr>
<tr>
<td>Q. tropicalis Cushman</td>
<td>R</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td><em>Q. vulgaris</em> d'Orbigny</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quinqueloculina sp. indet</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dentostomina agglutinans (d'Orbigny)</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triloculina terouemiana (Brady)</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T. tricarinata d'Orbigny</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>T. trigonula</em> (Lamarck)</td>
<td>R</td>
<td>F</td>
<td>R</td>
</tr>
<tr>
<td>Biloculina sp. indet.</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glabrataella sp. indet</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Ammonia annectens</em> (Parker and Jones)</td>
<td>R</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td><em>A. dentata</em> (Parker and Jones)</td>
<td>R</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td><em>A. cf. A. hozanensis</em> (Nakamura)</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asterorotalia trispinosa (Thalmann)</td>
<td>R</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>Pararotalia nipponica (Asano)</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pseudorotalia schroeteriana (Parker and Jones)</td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elphidium advenum (Cushman)</td>
<td>R</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td><em>E. crispum</em> (Linne)</td>
<td>A</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td><em>E. indicum</em> Cushman</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. minutum (Reuss)</td>
<td>R</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>E. simplex Cushman</td>
<td>F</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Elphidium sp. A</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elphidium sp. B</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elphidium sp. indet.</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Poroeponides lateralis</em> (Terquem)</td>
<td>R</td>
<td>F</td>
<td>R</td>
</tr>
<tr>
<td>Amphistegina madagascariensis d'Orbigny</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cibicides sp. indet</td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Florilus scaphum</em> (Fichtel and Moll)</td>
<td>F</td>
<td>R</td>
<td></td>
</tr>
</tbody>
</table>

INDEX

A - abundant, F - frequent, R - rare;
* - species common to east and west coasts.
SECTION 8

RECENT FORAMINIFERA FROM EAST COAST

Following James Hutton's time-honoured principle that "the present is the key to the past", a study of Recent foraminifera from the east coast of India was undertaken in order to advance our knowledge of these organisms from the Indian shores which would contribute towards a better understanding of the coastal formations of the country, particularly those of Andhra Pradesh.

The foraminifera from Indian waters have been studied only in a cursory way. The study had to be restricted to shore sands only as off-shore samples were not available. For the purpose of this investigation, three beaches along the eastern coast-line, bordering Andhra Pradesh, were selected: Puri in the north, Vishakhapatnam, approximately in the middle, and Marina (Madras) in the south (Figure 1).

A detailed study of foraminifera from the above three beaches was made by the author (Bhatia and Bhalla, 1964; Bhalla, 1968, 1970). It was qualitative in nature, i.e., 1, to record the different foraminiferal species along with their frequencies, 2, to deduce the latitudinal variation in the foraminiferal fauna, 3, to compare and contrast the Recent foraminiferal assemblage of the east coast with that from the west coast and, 4, to place the east coast foraminiferal fauna in the proper faunal province of the Indian Ocean. It is the first investigation of Recent foraminifera from India on these lines.

A total of thirty species of foraminifera were described from the above three beaches on the east coast (Table 3). No new species was
found but some were recorded for the first time from the Indian region (Bhalla, 1968, 1970). During the course of the study, a few taxonomic problems concerning certain species of Pararotalia were also solved (Bhalla, 1972).

A comparison of the east coast foraminiferal fauna with that from the west coast described by other authors reveals that out of thirty species, only nine are common to both the regions and they are mostly cosmopolitan in occurrence. The number of species on the east coast is markedly lesser than the west coast and both the assemblages are somewhat different. Another feature worth noting is that the number and frequency of foraminiferal species in the east coast assemblage increases with the decrease in latitude, i.e., southwards, while it is just the reverse on the west coast. These and other data suggest that the Bay of Bengal and the Arabian Sea probably represent two different faunal provinces (vide etiam Boltovskoy and Wright, 1976).

The major part of the east coast and almost entire Bay of Bengal is covered by a zone containing an admixture of East African and Indo-Pacific fauna. This "mixed zone" extends from the Bay of Bengal up to the Great Australian Bight. True to its geographical setting, the foraminiferal assemblage of the east coast beaches of India is a characteristic warm-water "mixed" assemblage. Out of thirty species of foraminifera in it, twelve species belong to the Indo-Pacific province, eight to East African province, and ten are cosmopolitan in occurrence.

The different water-masses develop their characteristic fauna but, at their margins, where the blending of two water-masses takes place, a mixed fauna may be present. In the present study, the "mixed zone" appears to be a similar case. The waters of the
East African and Indo-Pacific provinces, aided by ocean currents, intermingle at their margins and a "mixed zone" comprising elements of both the realms develop. A major part of the Bay of Bengal and the east coast of India belongs to this "mixed zone" (Bhalla, 1968, 1970).

REFERENCES

BHALLA, S. N.


BHATIA, S. B. and BHALLA, S. N.

BOLTOSKOV, ESTEBAN and WRIGHT, RAMIL
RECENT FORAMINIFERA FROM VISHAKAPATNAM BEACH SANDS
AND ITS RELATION TO THE KNOWN FORAM GEOGRAPHICAL
PROVINCES IN THE INDIAN OCEAN
(PAGES 376—392)

By
S. N. BHALLA

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March 1967, under the joint auspices of the National Institute of Sciences of India
and Indian National Committee on Oceanic Research (Bulletin N.I.S.I. No. 38)
RECENT FORAMINIFERA FROM VISHAKAPATNAM BEACH SANDS AND ITS RELATION TO THE KNOWN FORAMGEOGRAPHICAL PROVINCES IN THE INDIAN OCEAN

by S. N. BHALLA

Department of Geology, Aligarh Muslim University, Aligarh, India

Ten samples of beach sands from Vishakapatnam were examined for a study of their foraminiferal fauna. A total of sixteen species of Foraminifera are described and illustrated. The foraminiferal assemblage includes elements of both Indo-Pacific and East African provinces. An explanation has been suggested to account for this mixed fauna.

INTRODUCTION

The study of Recent Foraminifera is important for interpreting the palaeoecology of ancient foraminiferal assemblages. Prolific foraminiferal fauna is often found in beach sands, especially those which face open-sea and have luxuriant growth of algae and other water plants.

From a review of literature, it is rather surprising that very little work has been done on the Foraminifera of the Indian Ocean although it provides a very wide scope for foraminiferal research. The main aim of the present study is to contribute towards an understanding of the occurrence and distribution of Recent Foraminifera in the Indian Ocean. The author collected ten samples of beach sands along the coast of Vishakapatnam town (Fig. 1) and studied the foraminiferal fauna contained therein. The results are presented in this paper.

The Vishakapatnam beach is an open-sea beach facing the Bay of Bengal. There is a great surf action at the beach which leaves only the thick-walled species of Foraminifera, e.g. *Quinqueloculina seminulum*, *Poroeponides lateralis*, various species of *Elphidium*, etc., to withstand the rigours of abrasion otherwise, mostly, the forms are either broken or abraded. The hydrological conditions prevailing in the area, have not been studied in detail. However, Rao (1961) has given a brief account of this aspect.

The samples were floated with carbon tetrachloride for concentrating the foraminiferal tests. However, a check for heavy-shelled species was made from the original samples. A check-list of the Foraminifera recovered from the beach sands at Vishakapatnam, is given below:

**Abundant:**

- *Ammonia dentata*
- *Elphidium crispum*
RECENT FORAMINIFERA FROM VISHAKHPATNAM

Common:

Quinqueloculina seminulum
Triloculina trigonula
Pseudorotalia Schroeteriana
Elphidium advenum
E. simplex
Poroeponides lateralis

Rare:

Quinqueloculina (tropicalis)
Spiroloculina antillarium
S. communis
Trioculina terquemiana
T. tricarinata
Asterorotalia trispinosa
Elphidium indicum
E. cf. E. minutum

Fig. 1. Locality sketch map.
The earliest record of Foraminifera from the Bay of Bengal is, perhaps, by John Murray in 1889. He gave a list of thirty-seven species of Foraminifera obtained from a depth of 1,300 fathoms (Sethulekshmi Amma 1958).

Gnanamuthu (1943) described several species of Recent Foraminifera from near Krusadi Island.

Bhatia and Bhalla (1959) described and illustrated fourteen species of Foraminifera, including a few Indo-Pacific species, from the shore sands at Puri, on the East Coast of India.

Rao (1961) reported the presence of abundant Ammonia becarii, Quinqueloculina, Elphidium cf. E. crispum, Rotalia amphistegina, etc., obtained from between 40-97 fathoms off Vishakapatnam coast. On foraminiferal basis, he inferred that the sea-level at the outer-shelf of the area studied, was lower in Pleistocene than what it is today. However, neither systematic accounts nor illustrations of the Foraminifera were given by him.

Recently, Ghose (1968) collected Asterorotalia trispinosa from the Digha beach in southern Bengal and made a detailed statistical study of this species.

In the following pages, the classification of Foraminifera adopted in the Treatise (Loeblich and Tappan 1964), has been followed as it is considered to be the most up-to-date classification. Synonymies have been greatly reduced; only important shifts in the generic names have been included. The species are arranged alphabetically and only brief notes, taxonomic as well ecological, have been added for the sake of completeness. An attempt has been made to include all the available references of different species from recent sediments of the Indian region.

Systematic Descriptions

Order FORAMINIFERIDA Eichwald, 1830
Suborder MILIOLINA Delage and Herouard, 1896
Superfamily MILIOLACEA Ehrenberg, 1839
Family NUBECULARIIDAE Jones, 1875
Subfamily SPIROLOCULININAE Wiesner, 1920
Genus SPIROLOCULINA d'Orbigny, 1826
Spiroloculina antillarium d'Orbigny
Plate 1, figures 7a, b

PLATE 1

Fig. 1. Quinqueloculina seminulum (Linnaeus), X 36.
Fig. 2. Triloculina trigonula (Lamarck), X 36.
Fig. 3. Triloculina tricarinata d'Orbigny, X 36.
Fig. 4. Quinqueloculina tropicalis Cushman, X 36.
Fig. 5. Triloculina terquemiana (Brady), X 36.
Fig. 6. Spiroloculina communis Cushman and Todd, X 36.
Fig. 7. Spiroloculina antillarium d'Orbigny, X 36.
Fig. 8. Ammonia dentata (Parker and Jones), X 36.
Remarks.—Well-developed specimens of this species rarely occur in the present material. Sethulekshmi Amma (1958) reported it from Travancore coast and Albani (1965) from Durban Bay, South Africa.

**Spiroloculina communis** Cushman and Todd
Plate 1, figures 6a, b


Remarks.—This Indo-Pacific species is represented by rare specimens in the present material. The Indian specimens show variation in the length of the neck, sutures, periphery, width of the test, etc., but come well within the range of variation of the species. From the Indian coasts, it has been recorded by Gnanamuthu (1943) and Sethulekshmi Amma (1958). Recently, Albani (1965) reported it from the Durban Bay.

Family MILIOLIDAE Ehrenberg, 1839
Subfamily QUINQUELOCULININAE Cushman, 1917
Genus QUINQUELOCULINA d’Orbigny, 1826

**Quinqueloculina seminulum** (Linnaeus)
Plate 1, figures 1a, b


Remarks.—This is, perhaps, the most widely recorded species of *Quinqueloculina*, both in space and time: Todd and Low (1961) reported it from open-sea beaches of Martha’s Vineyard Island, U.S.A., in 19°C to 23°C temperature and 31.1%o to 32.1%o salinity range. However, according to Adams and Frampton (1965), the frequency of *Q. seminulum* generally increases as the temperature decreases. Recently, Boltovskoy (1964) made a study of seasonal occurrence of some living Foraminifera from Puerto Deseado and found that the reproduction of *Q. seminulum* takes place during September-March, the living population being highest in January. According to him, its life is of one year duration.
From a study of published records, it appears that more than one species of *Quinqueloculina* have been lumped together under the name *Q. seminulum*. It is suggested that this species should be thoroughly studied in cultures to get a clear picture of its range of variation.

It is common in the present material. The known geological range of this species is from Eocene to Recent.

*Quinqueloculina tropicalis* Cushman
Plate 1, figures 4a, b

*Millolina gracilis* (d'Orbigny) *BRADY*, 1884, *Challenger* Rept., Zool., vol. 9, pl. 5, fig. 3.


*Remarks.*—It is a characteristic Indo-Pacific species and is represented in the present material by only three specimens. The specimens are typical of this species. Brady (1884) recorded it off Papua in Pacific at 37 fathoms. Bhatia and Bhalia (1959) described it from the beach sands at Puri, on the East Coast of India.

*Genus Triloculina* d'Orbigny, 1826

*Triloculina terquemiana* (Brady)
Plate 1, figures 5a, b


*Remarks.*—A few specimens of this distinctive species of *Triloculina* were found in the present material. Brady (1884) recorded it from the shore sand of Madagascar in the Indian Ocean. From the Indian region, Bhatia (1956) reported *T. terquemiana* from the shore sands of western India and Sethulekshmi Amma (1958) from the Travancore coast.

*Triloculina tricarinata* d'Orbigny
Plate 1, figures 3a, b


Remarks.—In our material, a few specimens of this cosmopolitan species having sharp, triangular outline, were found. Bhatia (1956) and Sethulekshmi Amma (1958) recorded it from the Recent sediments of Indian coast and, Albani (1965) from the Durban Bay. However, this is the first record of this species from the East Coast of India. It ranges from Eocene to Recent.

*Triloculina trigonula* (Lamarck)

Plate 1, figures 2a, b


Remarks.—It is well-known species of *Triloculina* and has been reported from different parts of the world. From the Recent sediments of Indian region, it has been recorded by Bhatia and Bhalla (1959) from the beach sands at Puri. Recently, Albani (1965) reported it from Durban Bay, South Africa. It is common in the present material. The geological range of this species is from Eocene to Recent.

Suborder ROTALIINA Delage and Hérouard, 1896

Superfamily ROTALIOIDEA Ehrenberg, 1839, nomen correctum Souaya, 1966

Family ROTALIIDAE Ehrenberg, 1839

Subfamily ROTALIINAE Ehrenberg, 1839

Genus *AMMONIA* Briinnich, 1772

*Ammonia dentata* (Parkar and Jones)

Plate 1, figures 8a-c

*Rotalia beccarii* (Linnaeus) var. *dentata* PARKER and JONES, 1865, Philos. Trans., vol. 155, pp. 387, 422, pl. 19, figs. 13a-c.


Remarks.—This is a well-known Indo-Pacific species and occurs abundantly in the present material. Both sinistrally and dextrally coiled tests are present. The specimens show a wide range of variation in shape, size, and convexity of the test.

From the Indian region, it has been recorded by Bhatia (1956) and Bhatia and Bhalla (1959).

Genus *ASTEROROTALIA* Hofker, 1950

*Asterorotalia trispinosa* (Thalmann)

Plate 2, figures 1a, b
Fig. 1. Asterorotalia trispinosa (Thalmann), X 36.
Fig. 2. Pseudorotalia Schroeteriana (Parker and Jones), X 36.
Fig. 3. Elphidium simplex (Cushman), X 72.
Fig. 4. Elphidium crispum (Linne), X 36.
Fig. 5. Elphidium adenum (Cushman), X 72.
Fig. 6. Elphidium cf. E. minutum (Reuss), X 72.
Fig. 7. Elphidium indicum (Cushman), X 36.
Fig. 8. Poroeponides lateralis (Terquem), X 36.

Streblus trispinosa (Thalmann), ISHIZAKI, 1954, Taiwan Tigaku Kizi, vol. 14, nos. 3-4, p. 57, pl. 2, fig. 4.


Remarks.—Only two specimens of this well-known, shallow-water, Indo-Pacific species were found in the present material. The specimens are well developed but have broken spines. The ventral sutures have characteristic covering of thin plates which have openings at their distal ends.

Huang (1964) made a detailed study of the genus Asterorotalia and allied genera and described A. trispinosa in some detail. Bhatia and Bhalla (1959) recorded it from the Puri beach sands. Recently, Ghose (1966) made a detailed statistical study of A. trispinosa from the beach sands of Digha, southern Bengal.

Genus PSEUDOROTALIA Reiss and Merling, 1958

Pseudorotalia schroeteriana (Parker and Jones) Plate 2, figure 2

Rotalia schroeteriana PARKER and JONES, 1862, in Carpenter, Intr. Foram., p. 213, pl. 13, figs. 7-9.


Streblus schroeteriana (Parker and Jones) ISHIZAKI, 1940, Taiwan Tigaku Kizi, vol. 11, no. 2, p. 56, pl. 3, figs. 5, 9; pl. 4, figs. 7-8.

Pseudorotalia schroeteriana (Parker and Jones) REISS and MERLING, 1958, Geol. Surv. Israel Bull., no. 21, pp. 13-14, pl. 1, figs. 15-17, pl. 5, fig. 15.

Remarks.—This is the first record of Pseudorotalia schroeteriana from the Indian region. The Indian specimens are smaller and less developed than typical specimens of this species. The present specimens show the characteristic conical shape of the species with double row of alternating sutural canals on both the dorsal and ventral sides of the test. A detailed description of this species is given by Reiss and Merling (1958) who selected it as the type species of a new genus Pseudorotalia, proposed by them.

Pseudorotalia schroeteriana is an Indo-Pacific species and is commonly found in shallow, tropical, waters. It is common in the present material. The known geological range of this species is from Miocene to Recent.

Family: ELPHIDIIDAE Galloway, 1933

Subfamily ELPHIDINAE Galloway, 1933

Genus ELPHIDIIDUM de Montfort, 1808

Elphidium advenum (Cushman) Cushman

Plate 2, figures 5a, b
**Polystomella subnodosa** BRADY (Münister), 1884, *Challenger* Rept., Zool., vol. 9, p. 734, pl. 110, figs. 1a-b.

**Polystomella advena** CUSHMAN, 1922, Carnegie Inst., Washington, Publ. 311, p. 56, pl. 9, figs. 11, 12.


**Remarks.**—This cosmopolitan species of *Elphidium*, occurs commonly in the present material. It is commonly found in warm, shallow, agitating waters, like those of open-sea beaches, and has been widely recorded from Atlantic and Pacific Oceans. Todd and Low (1960) discussed the difference between *E. advenum* and *E. striatopunctatum*. The same authors (Todd and Low 1961) recorded *E. advenum* from harbors and inlets of Martha’s Vineyard Island, U.S.A., in 20°C to 21°C temperature and 30.6% to 31.6% salinity range.

**Elphidium advenum** has been recorded by Bhatia (1956), Sethulekshmi Amma (1958) and Bhatia and Bhalla (1959) from the Recent sediments of Indian coasts. The known geological range of this species is from Miocene to Recent.

**Elphidium crispum** (Linné) Cushman and Grant

Plate 2, figures 4a, b

**Nautilus crispus** LINNÉ, 1758, Systema Naturae, ed. 10, p. 709, ed. 13 (Gmelin’s), 1788, p. 3370. FICHTEL and MOLL, 1798, Test. Micr., p. 40, pl. 4, figs. d-f.


**Remarks.**—It is a well-known species of *Elphidium* and is present in abundance in shallow waters of different parts of the world. The studies of Myers (1943) show that *E. crispum* is a ‘hard’ foraminifer as it can remain buried for 2 to 3 months under an overburden of 1 cm of sediment and can still come up alive. Parker (1958) recorded it in 11°C to 21°C temperature and 38% to 39% salinity range in less than 25 m depth from eastern Mediterranean. However, Colom (1950) reported it at a depth of 726 m off the coast of Africa. Recently, Murray (1963) made a detailed study of *E. crispum* in cultures and pointed that it does not prefer a clay substratum; with decrease in salinity, the feeding rate also decreases; and it can survive in subsaline waters if the temperature is low.
A significant contribution to our knowledge of some members of Elphidiidae, especially their internal structure, has been made by Ujiie (1956). He gave a detailed account of the internal structure of *E. crispum*. According to him, while *E. crispum* has well-developed canal system and septa-spirothecal stolons, *E. advenum* has only well-developed canal system and this he considers as one of the bases for distinguishing the two species.

From the Indian region, *E. crispum* has been recorded by Bhatia (1956) from western India and by Sethulekshmi Amma (1958) from the Travancore coast. It is abundantly found in the present material. The geological range of this species is from Miocene to Recent.

*Elphidium indicum* Cushman
Plate 2, figures 7a, b


Remarks.—The type of *E. indicum* is from the shore sands at Bombay. In the present material, only two specimens were found which show characteristic costae of the species. A comparison with the topotypes was made and the present specimens were found to be similar to the Bombay forms. It ranges from Miocene to Recent.

*Elphidium cf. E. minutum* (Reuss) Cushman
Plate 2, figures 6a, b


*Polystomella discrepans* REUSS, 1864, Akad. Wiss. Wien Sitzungsber, vol. 50, pt. 1, p. 478, pl. 4, figs. 7a, b.


Remarks.—A solitary but well-developed specimen of *Elphidium*, which can be compared with *E. minutum*, was found in the present material.

*Elphidium simplex* Cushman
Plate 2, figures 3a, b


Remarks.—It is a characteristic Indo-Pacific species and occurs commonly in the present material. It has been recorded in Pacific quite often. Bhatia (1956) recorded it from shore sands of western India and Bhatia and Bhalla (1959) from beach sands at Puri, facing the Bay of Bengal.
Superfamily ORBITOIDACEA Schwager, 1876  
Family EPONIDIDAE Hofker, 1951  
Genus POROEPOINIDES Cushman, 1944  
Poroeponides lateralis (Terquem)  
Plate 2, figures 8a, b


Remarks.—This, shallow-water, cosmopolitan species, has been frequently reported from beach sands. However, it is abundantly found in shallow, tropical waters of the different parts of the world.

Poroeponides lateralis is a highly variable species, especially in the shape of it's last formed chamber. Closs and Barberena (1962) reported a complete range of variation from open to closed condition of umbilicus in P. lateralis.

Todd and Low (1961) recorded P. lateralis in 19° C to 23° C temperature and 31.1 %₀ to 32.1 %₀ salinity range from open-sea beaches of Martha's Vineyard Island, U.S.A.

Poroeponides lateralis has been recorded from Indian coasts by Bhatia (1956), and Bhatia and Bhalla (1959). Its known geological range is from Miocene to Recent.

DISCUSSION OF THE FAUNA

The foraminiferal assemblage of the Vishakapatnam beach is typical of tropical waters and comprise several species of Foraminifera, a majority of which are low in frequency.

As stated elsewhere in the present paper, not much work has been done on the Recent Foraminifera of the Indian region. Gnanamuthu (1943) reported a large number of foraminiferal species from Krusadi Island in the Gulf of Mannar but due to inadequate descriptions and illustrations, not much can be made out from his paper. However, the following species seem to be common to both Krusadi and Vishakapatnam areas: Quinqueloculina seminulum, Triloculina trigonula, Poroeponides lateralis, and Spiroloculina communis. Out of fourteen species of Foraminifera described and illustrated by Bhatia and Bhalla (1959)
from Puri beach, facing the Bay of Bengal, following are also present in the Vishaka- 
patnam beach sands: Q. seminulum, Q. tropicalis, T. trigonula, Elphidium advenum, 
E. simplex, P. lateralis, and Asterorotalia trispinosa. Rao (1961) listed four species 
of Foraminifera from off Vishakapatnam coast. From his list, only *Elphidium crispum* 
is found at the Vishakapatnam beach. *A. trispinosa* reported by Ghose 
(1966) from Digha beach, also occurs both in Puri and Vishakapatnam assem-
blages.

Bhatia (1956) described numerous species of Foraminifera from the Recent 
shore sands of western India. Quinqueloculina seminulum, Triloculina terquemiana, 
T. tricarinata, Ammonia dentata, E. advenum, E. crispum, E. indicum, E. simplex, 
and P. lateralis, are common to both Vishakapatnam and western India assemblages. 
In recent years, another paper describing Recent Foraminifera from the West 
Coast is by Sethulekshmi Amma (1958), who described and illustrated one hundred 
and fourteen species of Foraminifera from Travancore coast. Following species 
from her list, also occur in Vishakapatnam beach sands: Spiroloculina antillarium, 
S. communis, T. tricarinata, T. terquemiana, E. crispum, and E. advenum.

A comparison of the foraminiferal fauna of the East Coast and the West 
Coast reveals that only a few species are common to both the regions. Ammonia 
dentata and Elphidium crispum which are abundant on the East Coast, occur rarely 
or frequently on the West Coast. Pseudorotalia Schroeteriana which is commonly 
found on the East Coast, is totally absent from the West Coast. Another Indo-
Pacific species which frequently occurs on the East Coast but absent from the West 
Coast, is Asterorotalia trispinosa. It is a characteristic Indo-Pacific species and has 
been widely reported from Malaya, Indonesia, Taiwan, Japan, and other areas. 
Similarly, Spiroloculina communis and Quinqueloculina tropicalis are also not re-
presented on the West Coast.

An important fact that emerges from a comparison of East and West coast 
foraminiferal assemblages is that both the faunas are somewhat different and that 
the number of foraminiferal species on the East Coast is markedly less than that 
on the West Coast. Another feature worth noting is that the East Coast fauna 
increases in frequency southwards and at the southern tip of India, where both 
Bay of Bengal and Arabian sea meet, abundant Foraminifera—qualitatively as 
well as quantitatively—have been recorded by different workers. This would, 
then, suggest that there are probably two fairly distinct, faunal provinces—the 
Eastern, covering the major part of the Bay of Bengal and, the Western, covering the 
Arabian sea. However, more data from shore and off-shore samples are needed 
before the above suggestions can be confirmed.

The reason why the East Coast foraminiferal crop is poor in comparison to 
that on the West Coast, is not definitely known but some indirect clues are available 
which could possibly help in understanding and, perhaps, solving this problem. 
Wiseman and Bennett (1940) pointed out that the coastal areas of Arabian sea 
are rich in organic matter (more than 1.5% of organic carbon). The studies of 
Subba Rao (1960) on the Bay of Bengal show that the shore sediments of the East
Coast of India are poor in organic matter in comparison to that in Arabian sea. He recorded 0.77% of organic carbon in the shelf sediments of the East Coast. Subba Rao (1960) attributes this low percentage of organic carbon in the Bay of Bengal, to two main factors: (1) low production of plankton in the Bay of Bengal and, (2) "... extreme dilution of land humus by the inorganic detrital matter attended by intense oxidation conditions which is a common feature in tropical seas" (Subba Rao 1960, p. 1712). A large amount of organic matter in the Arabian sea as compared to that in the Bay of Bengal, might well be one of the factors responsible for luxuriant growth of Foraminifera on the western coast of India. However, temperature does not appear to play a significant role in the high production of Foraminifera on the West Coast as both the coasts are almost in the same latitudinal zone.

The foraminiferal fauna of the Vishakapatnam beach is a characteristic warm-water assemblage. Cushman (1950) divided the Recent warm-water foraminiferal fauna of the world into four main geographical provinces, namely, East African, Indo-Pacific, West Indian, and Mediterranean. His East African province includes the West Coast of Indian and a small portion of the southern part of the East Coast. The major part of the East Coast, including Vishakapatnam beach and almost entire Bay of Bengal, is covered by a zone containing an admixture of the East African and Indo-Pacific faunas. This 'mixed zone' extends from Bay of Bengal up to Great Australian Bight, passing through the western coast of Sumatra and Java (Fig. 2). Towards the East of this zone, lies the Indo-Pacific foramgeographical province.

**Fig. 2. Major Warm Currents in the Indian Ocean together with the broad distributions of warm-water foraminiferal fauna.**

True to its geographical setting, the foraminiferal assemblage of the Vishakapatnam beach is a 'mixed' one as it includes several species of Foraminifera belonging to East African as well as Indo-Pacific province. Heron-Allen and Earland (1915) described several species of Foraminifera from the Kerimba Archipelago.
and the following species also occur in the Vishakapatnam assemblage: *Q. seminulum*, *S. antillarium*, *S. communis*, *T. tricarinata*, *R. trigongula*, *T. terquemiana*, *E. advenum*, *E. crispum*, and *P. lateralis*. Braga (1960) made a detailed study of the foraminiferal fauna from the coast of southern Mozambique and the following species are also present in the Vishakapatnam assemblage: *S. communis*, *T. tricarinata*, *T. trigongula*, *E. crispum*, and *P. lateralis*. Recently, Albani (1965) recorded foraminiferal fauna comprising of forty-three species, from the Durban Bay. The species common to Durban Bay and Vishakapatnam assemblages are: *Q. seminulum*, *S. antillarium*, *S. communis*, *T. tricarinata*, *T. trigongula*, *E. advenum*, *E. crispum*, and *P. lateralis*. Thus, a comparison of Vishakapatnam and East African coast foraminiferal assemblages, reveals that *Q. seminulum*, *S. antillarium*, *S. communis*, *T. tricarinata*, *T. trigonula*, *E. advenum*, *E. crispum*, and *P. lateralis* are common to both the regions. The well-known Indo-Pacific species of Foraminifera present in the Vishakapatnam assemblage are: *S. communis*, *Q. tropicalis*, *Ammonia dentata*, *Asterorotalia trispinosa*, *Pseudorotalia schroeteriana*, *E. indicum*, and *E. simplex*. In the present material, *S. communis* is, perhaps, the only characteristic Indo-Pacific species which has also been recorded from the East African region. From the above discussion, it is found that the foraminiferal assemblage of the Vishakapatnam beach includes the elements of both Indo-Pacific and East African forageographical realms.

In the establishment of zoogeographical provinces, the role of ocean currents, besides temperature and salinity, must not be overlooked. In the Indian Ocean, there are a few major warm-water currents (Fig. 2). One such current is the seasonal SW & NE Monsoon Drift. During the summer season, the SW Monsoon Drift skirting along the East Coast of Africa, passes through the West Coast of India via Arabian sea, and then takes a swing at the southern tip of Ceylon and joins the Indian Counter current at a short distance towards the East. A rather weak branch of the Drift enters into the Bay of Bengal from the eastern side of Ceylon, follows a curved path into the northern part of the Bay, passes through the coast of Burma, and gradually dies out between Malaya and Sumatra. This tongue of the Drift helps in contaminating the Bay of Bengal, including the East Coast of India, with the East African fauna. The North Equatorial and Indian Counter currents circulate water between Sumatra and East Coast of Africa and influence the water-mass with the Indo-Pacific fauna.

Johnson and Brinton (1963) noted that different water-masses develop their characteristic fauna but at their margins, where the blending of the two water-masses takes place, a mixed fauna may be present. In the present study, the 'mixed zone' appears to be a similar case. The waters of the East African and Indo-Pacific regions, aided by ocean currents, intermingle in the 'mixed zone' and a 'mixed fauna', comprising of the elements of both the realms, is present in it. A major part of the Bay of Bengal, including the Vishakapatnam beach, comes under this 'mixed zone'.
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REFERENCES


391. FORAMINIFERA FROM MARINA BEACH SANDS, MADRAS, AND FAUNAL PROVINCES OF THE INDIAN OCEAN

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ABSTRACT

The Marina beach sands, Madras, have yielded fifteen species of foraminifera, including four indeterminate species. Of these, four species are recorded for the first time from Indian waters. The species are very low in frequency. The foraminifers do not appear to be indigenous but have probably been swept in by strong tidal currents and surf-action—a characteristic feature of the Marina beach.

The foraminiferal assemblage is typical of tropical waters and includes seven cosmopolitan and four provincial species. The Indo-Pacific element dominates over the East African one. The intermixing of the foraminifera of the two realms suggests that the "mixed zone" of Cushman should be extended south to Madras.

INTRODUCTION

Following James Hutton's time-honored principle that "the present is the key to the past," more and more attention is now being paid to the study of the Recent so that the knowledge thus gained may be applied in understanding the history of the earth. In India, marine formations are fairly well-developed along coasts and the main aim of the present study is to advance our knowledge of the Recent foraminifera from Indian shores which would contribute towards our understanding of the coastal formations of the sub-continent.

The foraminifera from Indian waters have been studied only in a cursory way. From the Madras area, apparently the only record of foraminifera is by Ganapati and Satyavati (1958), who recorded twenty-two species from two stations off Madras.

The Marina beach of Madras is an open sea beach facing the Bay of Bengal (text fig. 1). Marina is a coarse sand beach with a comparatively steep slope and is noted for the surging waves which constantly attack it. It is about three and a half miles long and is flanked by Cooum River in the north and Adayar River in the south. Both the rivers are rather small and empty into the Bay of Bengal. The detailed hydrological conditions around Marina are not known. However, Rao and Murty (1968) studied the shelf sediments off the Madras coast and observed that while the calcium carbonate content at 6 fathoms depth near Madras is 1.75%, it increases progressively with depth and, at 90 fathoms off Madras, it is 37%.

The present work is based on four samples collected in January, 1968 from the exposed part of Marina beach. It is of a qualitative nature and all the species, whether rare or abundant, have been identified and illustrated. The assemblage is characteristic of warm waters and includes cosmopolitan as well as provincial species of foraminifera. It consists of a total of fifteen species which are very low in frequency—generally represented by a few, or solitary, specimens. Following is a checklist of the species recovered; of these, only Quinqueloculina vulgaris and Elphidium crispum were earlier reported from the Madras area.

Quinqueloculina cf. Q. seminulum (Linnaeus)
Q. vulgaris d'Orbigny
Q. sp. indet.
Triloculina trigonula (Lamarck)
Glabratella sp. indet.
Ammonia annectens (Parkar and Jones)
Ammonia cf. A. hozanensis (Nakamura)
Pararotalia nipponica (Asano)
Elphidium crispum (Linne)
E. minutum (Reuss)
Elphidium sp. A
Elphidium sp. B
Poroeponides lateralis (Terquem)
Amphistegina madagascariensis d'Orbigny
Florilus scaphum (Fichtel and Moll)

In the present paper, the classification of foraminifera as proposed by Loeblich and Tappan (1964) has been followed. Synonymies have been considerably cut and the words et syn. follow those references in which satisfactory synonymies have already appeared. However, important shifts in the generic names and all possible references from Indian waters have been included. The species are alphabetically arranged and brief taxonomic as well as ecological remarks have been added. Plate figures were drawn by the author.

SYSTEMATIC DESCRIPTIONS

Order FORAMINIFERIDA Eichwald, 1830
Suborder MILIOLINA Delage and Herouard, 1896
Superfamily MILIOLACEA Ehrenberg, 1839
Family MILIOLIDAE Ehrenberg, 1839
Subfamily QUINQUELOCULININAE Cushman, 1917
Genus Quinqueloculina d'Orbigny, 1826
Quinqueloculina cf. Q. seminulum (Linne)
Plate 20, figures 1a, b
Serpula seminulum LINNE, 1767, Systema Naturae, ed. 12, p. 1264.
TEXT FIGURE 1
Index map showing sample localities.


A solitary, slightly broken, specimen referable to *Q. seminulum* was found in the material from Marina beach. On its four-chambered side, the present specimen shows some resemblance to *Q. suborbicularis* d'Orbigny, described from the Recent of the Mediterranean Sea but, unlike *Q. suborbicularis*, the tip of its last-formed chamber is rounded.

*Q. seminulum* is a cosmopolitan species ranging from Eocene to Recent. It has been frequently reported from near-shore waters where it is found in association with other thick-walled foraminifers. It tolerates wide range of salinity and temperature fluctuations. Kane (1967) recorded it from estuarine to truly marine conditions.

Quinqueloculina vulgaris d'Orbigny, 1826
Plate 20, figures 3a, b

Only two specimens of this small and rather broad species of *Quinqueloculina* were found. They somewhat resemble *Q. triloculiniforma* McLean, 1956, except that the middle chamber on the three-chambered side is easily visible.

*Q. vulgaris* is a cosmopolitan species and has been recorded from cold as well as warm waters at various depths ranging from beach to several fathoms. From Indian waters, it has been reported by Sethulekshmi Amma (1958) from the Travancore coast and by Ganapati and Satyavati (1958) from off the coast of Madras in a 12-97 fathoms depth and 71°-80°F. temperature range.

Quinqueloculina sp. indet.
Plate 20, figures 2a, b

A solitary, rather worn, specimen having a smooth, porcelaneous, long oval test with slightly depressed sutures, bifid tooth, and bluntly triangular outline was found which could not be referred to any known species of *Quinqueloculina*. More well-preserved specimens are required before a trivial name can be assigned.

Genus Triloculina d'Orbigny, 1826

Triloculina trigonula (Lamarck)
Plate 20, figures 4a, b
Milolites trigonula Lamarck, 1804, p. 351, Pl. 17, fig. 4.

Triloculina trigonula (Lamarck). d'Orbigny, 1826, p. 229, Pl. 16, figs. 5-9. Bhata and Bhalla, 1959, p. 79, Pl. 1, figs. 5a, b. Bhalla, 1968, p. 382, Pl. 1, figs. 2a, b.

Two tests with a bluntly angled periphery were found in the material from Marina beach. Originally described by Lamarck from the Eocene of France, this species was later recorded from Eocene to Recent elsewhere. *T. trigonula* has been recorded from the Recent sediments of both the east and west coasts of India.

Suborder ROTALIINA Delage and Hérouard, 1896
Superfamily DISCORBACEA Ehrenberg, 1838
Family GLABRATELLIDAE Loeblich and Tappan, 1964
Genus Glabratella Dorreen, 1948
Glabratella sp. indet.
Plate 20, figures 7a, b

Test high-spired with flat umbilical side; umbilical surface ornamented with minute beads arranged in radial rows; sutures acute on dorsal side but radial on ventral side; aperture a small crescentic opening on umbilical side.

A solitary, broken, specimen of *Glabratella* was found which could not be referred to any known species. This is the first record of *Glabratella* from Indian waters.
Superfamily ROTALIACEA Ehrenberg, 1839
Family ROTALIIDAE Ehrenberg, 1839
Subfamily ROTALINAE Ehrenberg, 1839
Genus Ammonia Brunnich, 1772
Ammonia annectens (Parker and Jones)
Plate 20, figures 8a-c
Rotalia becarii (Linne) var. annectens Parker and Jones, 1865, p. 387, 422, Pl. 19, figs. 11a-c.
Streblus annectens (Parker and Jones). Ishizaki, 1940, p. 58, Pl. 3, figs. 12, 13. Bhatia and Bhalla, 1959, p. 79, Pl. 2, figs. 1a-c.
Ammonia annectens (Parker and Jones). Huang, 1964, pp. 50-52, Pl. 2, fig. 3; Pl. 3, figs. 1, 2, text-fig. 3.
Only two, slightly broken but well-developed, specimens of this species were found. Both are sinistrally coiled.
Ammonia annectens is a characteristic Indo-Pacific species and has been described from different areas in the Pacific. From the Indian region, it has been recorded from the west coast by Bhatia (1956) and from the east coast by Bhatia and Bhalla (1959). The known geological range of this species is from Miocene to Recent.
Ammonia cf. A. hozanensis (Nakamura)
Plate 20, figures 5a-c
Rotalia hozanensis Nakamura, 1937, p. 141, Pl. 12, fig. 4.
Ammonia hozanensis (Nakamura). Huang, 1964, p. 53, Pl. 1, fig. 4.
A few specimens which may be questionably referred to Ammonia hozanensis were found. Our specimens with a low spire and characteristic apertural view are similar to those figured and described by Huang (1964) and apparently come well within the range of variation of A. hozanensis. However, the Indian specimens have a slightly greater number of chambers in the last whorl and their periphery is comparatively more lobulate but these features come within the range of variation of the species.
P. nipponica has been reported from Japan, Taiwan, Philippines, and other areas in the Pacific but not previously from Indian waters. The known range of this species is from Miocene to Recent.
Family ELPHIDIIDAE Galloway, 1933
Subfamily ELPHIDIINAE Galloway, 1933
Genus Elphidium de Montfort, 1808
Elphidium crispum (Linne) Cushman and Grant
Plate 21, figures 1a, b
Nautilus crispus Linne, 1758, Systema Naturae, ed. 10, p. 709; ed. 13 (Gmelin's), 1788, p. 3370; Fichtel and Moll, 1798, p. 40, Pl. 4, figs. d-f.
Bhalla: Recent Madras Beach Foraminifera
Bhalla: Recent Madras Beach Foraminifera

A few specimens of this well-known, cosmopolitan species of Elphidium were found. Of all the species of Elphidium, this is, perhaps, the best studied species. It is known to tolerate a wide range of salinity and temperature variations and is commonly found in shallow, turbulent waters. Cushman and McCulloch (1940), however, recorded it from a depth of 2 to 130 fathoms. The range of this species is from Miocene to Recent.

E. crispum has been recorded from the west coast of India by Bhatia (1956) and Sethulekshmi Amma (1958) and from the east coast by Bhalla (1968). An indeterminate species of Elphidium was recorded by Ganapati and Satyavati (1958) off Madras from 39 to 50 fathoms depth and 71° to 80°F. temperature range, appears to be E. crispum. However, the types were not seen and, as such, no conclusions can be drawn.

Elphidium minutum (Reuss) Cushman
Plate 21, figures 2a, b
Polystomella minuta Reuss, 1864, p. 478, Pl. 4, fgs. 6a, b.
Polystomella discrepans Reuss, 1864, p. 478, Pl. 4, fgs. 7a, b.

This species was represented by only three specimens. It was recorded from Indian waters by Bhalla (1968) from the beach sands at Vishakhapatnam, facing the Bay of Bengal.

The types of Elphidium minutum are from the Late Oligocene of Germany. Its known range is from Oligocene to Recent.

Elphidium sp. A
Plate 21, figures 3a, b
Test somewhat compressed; umbilicus depressed; periphery broadly rounded; margin slightly lobulate in later chambers; sides nearly parallel in apertural view; eleven chambers in last whorl, gradually increasing in size as added; sutures slightly curved, a little depressed, limbate, with a few, rather indistinct, retral processes.

A solitary, broken, specimen of Elphidium was found which could not be referred to any known species. It resembles Elphidium incertum (Williamson) (= Elphidium florentinae Shupak) described by Shupak (1934) from the Recent and Pleistocene of Long Island and New York Harbor, U. S. A., but differs in having a more rounded periphery and in the nature of sutures and retral processes. More specimens are needed before it can be identified at the species level.

Elphidium sp. B
Plate 21, figures 4a, b
Test compressed; umbilical regions flat with clear shell material extending slightly towards aperture; periphery sharply angular, strongly lobulate; chambers distinct, thirteen in last whorl, increasing gradually with growth, last chamber broken; sutures distinct, slightly curved, deeply excavated with a few, rather transverse, retral processes.

A single specimen was found. The striking character of the specimen is its deeply excavated sutures and incised margin. The present specimen somewhat resembles Elphidium argenteum, originally described by Parr (1945) from the Victoria shore sands, but differs in having a strongly lobulate margin, fewer chambers in the last whorl, less curved but deeply cut sutures, and in lacking the beaded surface and parallel sides. It is likely that the present specimen represents a new species of Elphidium but more, well-preserved, specimens are required before a new name can be assigned.

EXPLANATION OF PLATE 21

Figs. Page
1a, b. Elphidium crispum (Linne), 159, X50. 158
2a, b. Elphidium minutum (Reuss), X50. 159
3a, b. Elphidium sp. A, X100. 159
4a, b. Elphidium sp. B, X100. 159
5a, b. Florilus scaphum (Fichtel and Moll), X100. 160
6a, b. Poroepipus lateralis (Terquem), X36. 160
7a, b, c. Amphistegina madagascariensis d'Orbigny, X100. 160
Superfamily ORBITOIDACEA Schwager, 1876
Family EPONIDIDAE Hofker, 1951
Genus Poroeponides Cushman, 1944
Poroeponides lateralis (Terquem)
Plate 21, figures 6a, b

Rosalina lateralis Terquem, 1878, p. 25, Pl. 2, fig. 11.
Pulvinulina lateralis (Terquem). Brady, 1884, p. 689, Pl. 106, figs. 2, 3. Heron-AIlen and Earland, 1915, p. 714, Pl. 53, figs. 6-11.
Eponides lateralis (Terquem). Cushman, 1931 (1918 etc.), p. 47, Pl. 10, fig. 5.
Poroeponides lateralis (Terquem). Cushman, 1944, p. 34, Pl. 4, fig. 23. Bhata, 1956, p. 23, Pl. 3, figs. 3-5. Bhata and Bhalla, 1959, p. 80, Pl. 2, figs. 3a, b. Bhalla, 1968, p. 387, Pl. 2, figs. 8a, b.

Only one specimen belonging to Poroeponides lateralis was found. This species has been recorded in the Recent sediments of both the east and west coasts of India.

P. lateralis is a well-known species with a worldwide distribution. It has been commonly recorded from shallow, warm waters. By virtue of its thick test, it is able to withstand abrasion and consequently, it frequently occurs in shore sands. However, it is also found rather sporadically in deep waters. Said (1949) recorded it from a depth of 24 to 400 m in the Gulf of Suez and the Red Sea. Its known range is from Miocene to Recent.

P. lateralis shows a wide range of variation. Resig (1962) observed that Eponides repandus is a juvenile stage in the ontogenic development of Sestronophora. Loeblich and Tappan, with Poroeponides as an intermediate stage. On the basis of priority, Resig (op. cit.) suggested the suppression of Poroeponides and Sestronophora in favor of E. repandus (= Nautilus repandus Fichtel and Moll, 1798)—the type-species of Eponides Demontfort, 1808. Cushman et al. (1954) were also of the view that the basis of differentiating Poroeponides from Eponides is not sound but, in the absence of adequate data, continued to recognise both genera. However, McLean (1956) is of the view that Eponides and Poroeponides should be distinguished.

Closs and Barberena (1962) noted that P. lateralis exhibits considerable variation, especially in the shape of its last-formed chamber and umbilical region and preferred to include Eponides repandus in Poroeponides lateralis. Todd (1965), following Resig (1962), suppressed Poroeponides lateralis in favor of Eponides repandus. Loeblich and Tappan (1964, p. 684), however, maintain Eponides, Poroeponides, and Sestronophora as distinct genera and their main argument is that the "... adult stages must be used in classification, and as the type-species of Eponides and Poroeponides do not have a Sestronophora-like adult, the three genera are regarded as distinct." If Resig (1962) is followed, then, there will be far reaching implications in the systematics of foraminifera as several foraminiferal genera show biformed stages in their ontogenetic growth. The author agrees with Loeblich and Tappan (1964) and, therefore, Poroeponides has been maintained as a distinct genus in the present work.

Family AMPHISTEGINIDAE Cushman, 1927
Genus Amphistegina d'Orbigny, 1826
Amphistegina madagascariensis d'Orbigny
Plate 21, figures 7a-c

Amphistegina madagascariensis d'Orbigny, 1826, p. 304. Todd, 1965, p. 34, Pl. 11, fig. 3; Pl. 12, figs. 1, 2. et syn.

Only two, rather worn, specimens were found. This is the first record of Amphistegina madagascariensis from the Indian waters. Our specimens with reflex but rather obscure sutures and thick tests come well within the range of variation of the species. However, ours exhibit slightly raised umbilical knobs and the periphery is abraded due to intensive surf-action at the beach.

A. madagascariensis is considered to be an Indo-Pacific species. It prefers a shallow, warm water, environment and shows considerable variation. According to Todd (1965), A. madagascariensis varies with the environment. In beach and near-shore environments, the tests are generally thicker, sutures are rather obscure, and more abundant than in deep waters. However, in lagoon environments, the test is large and compressed, and has better marked sutures. The types of this species are from off Madagascar.

Superfamily CASSIDULINACEA d'Orbigny, 1839
Family NONIONNIDAE Schultze, 1854
Subfamily NONIONNINAE Schultze, 1854
Genus Florilus de Montfort, 1808
Florilus scaphum (Fichtel and Moll)
Plate 21, figures 5a, b

Florilus scaphum (Fichtel and Moll)
Plate 21, figures 5a, b

Nonionina scapha (Fichtel and Moll). Brady, 1865 (1867), p. 106, Pl. 12, figs. 10a, b.
Nonion scaphum (Fichtel and Moll). Cushman, 1930 (1918 etc.), p. 5, Pl. 2, figs. 3, 4. Bhata, 1956, Pl. 5, fig. 15. Bhata and Bhalla, 1959, p. 79, Pl. 1, figs. 6a, b.

The present specimens show flaring tests with depressed umbonal regions filled with calcite gran-
ules and have been, therefore, put under the genus *Florilus* de Montfort.

Only three broken specimens of this widely distributed species were found. *Florilus scaphum* is found in shallow as well as deep waters. From the west coast of India, it has been recorded by Bhatia (1956), and from the east coast, by Bhatia and Bhalla (1959). The known geological range of this species is from Eocene to Recent.

**DISCUSSION**

Foraminifera are rare in Marina beach sands. The reasons for this paucity of foraminifera are not known but some indirect evidence may help solve this problem.

Marina beach is bounded by rivers on its northern and southern extremities. These rivers appear to play a decisive role in controlling the growth of local foraminiferal populations. The fresh-water brought in by the rivers intermingles freely with the marine-water of the bay resulting in the decrease of salinity of the water around Marina. This blending also locally lowers the concentration of calcium carbonate of the sea-water. Rao and Murty (1968) noted that the percentage of calcium carbonate is low near Madras. Although these authors did not offer any reason for this low percentage, the influence of fresh-water may well be one of the causes for it. In addition, the detritus brought in by the rivers dilutes the foraminiferal population in the locality. Under such conditions, the growth of algae and other water plants which supply food to foraminifers, is also checked. The sediments of Marina beach are coarse-grained and poor in organic matter, and this, combined with great surf-action, provides an inhospitable site for the foraminifers to thrive. It is believed that beach foraminifera do not live on the beach itself but reside very near to the shore-line and are washed into the beach region by waves. According to Dietz and Menard (1951), the waves are normally effective down to a depth of about 30 feet. The studies of McMaster (1954) on the New Jersey coast, Logvinenko and Remizov (1964) along the sea of Azov, Thompson (1937) in California, Nanz (1955) and Miling and Behrens (1966) in Texas, and others, show that the beach sediments are derived from the continental shelf. This may hold true for foraminifers also. In view of the foregoing, it is surmised that the foraminifera of the present assemblage are not indigenous but were washed in from nearby shallow depths by strong waves. This would also, perhaps, explain the presence of normal foraminifers in an environment which is low in salinity and deficient in calcium carbonate content.

Prolific foraminiferal assemblages have been described from the west coast of India by Bhatia (1956) and Sethulekshmi Amma (1958). Bhalla (1968) pointed out that the east coast foraminiferal assemblage is different from that of the west coast and surmised that the Bay of Bengal and the Arabian Sea are two distinct faunal realms. A comparison of the foraminiferal fauna from the Marina beach with that from the west coast of India reveals that *Q. seminulum, Q. vulgaris, T. trigonula, A. annectens, E. crispum, P. lateralis,* and *F. scaphum* are common to both. Except for *A. annectens,* all these species have a world-wide distribution. The well-known Indo-Pacific species in the Marina assemblage are: *Ammonia annectens, Ammonia cf. A. hozanensis, Pararotalia nipponica,* and *Amphis- tegina madagascariensis.* Except for *A. annectens,* none of these species have previously been recorded from the west coast of India. The present study, therefore, gives credence to the contention of the author (Bhalla, 1968) that the Bay of Bengal and the Arabian Sea represent two faunal provinces. The occurrence of *A. annectens, A. cf. A. hozan­ ensis,* *P. nipponica,* and *A. madagascariensis* is of considerable interest in relating the Marina assemblage with the known foram-geographical provinces in the Indian Ocean (see text fig. 2).

The Recent warm water foraminiferal assemblages of the world have been grouped by Cushman (1950) into four main provinces, viz., Mediterranean, West Indian, Indo-Pacific, and East African. The Madras assemblage contains the elements of Indo-Pacific as well as East African realm. Of the fifteen species of foraminifera from Marina beach, *A. annectens, A. cf. A. hozanensis,* and *P. nipponica* are characteristic Indo-Pacific forms. The types of *A. madagascariensis* are from Madagascar but the species has also been reported from the Indo-Pacific realm. Prolific foraminiferal assemblages have been reported from the east coast of Africa. *Q. seminul­ um, E. crispum,* and *P. lateralis* are common to

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**TEXT FIGURE 2**

Major warm currents in the Indian Ocean and distribution of warm-water foraminiferal faunas.
Marina and East African assemblages. However, the elements of Indo-Pacific province dominate the foraminiferal fauna of the Marina beach. The Marina assemblage does not seem to be a true representative of this portion of the eastern coast line of India because several characteristic species which were recorded by Ganapati and Satyavati (1958) from off Madras, are absent in the present assemblage. This is mainly due to the prevailing ecological conditions which inhibit the growth of foraminiferal species in the area.

According to Cushman (1950), the entire west coast of India and a small portion of the southern part of the east coast fall under the East African province. The rest of the east coast and almost all the Bay of Bengal are covered by a zone formed by the blending of East African and Indo-Pacific provinces. This 'mixed zone' extends from the Bay of Bengal to the Great Australian Bight and forms the boundary between the two provinces. Bhalla (1968) discussed the formation of the 'mixed zone' and opined that the major warm-water currents in the Indian Ocean are instrumental in its development. In the Madras assemblage, representatives of Indo-Pacific and East African provinces are present and it would be reasonable to extend the 'mixed zone' of Cushman south at least to Madras.

ACKNOWLEDGEMENTS

The samples for the present study were collected by Professor F. Ahmad, Head of the Geology Department, Aligarh Muslim University, from Marina beach, in January, 1968, and were subsequently handed over to me for a study of their foraminiferal content. I am grateful to Professor Ahmad for his kind gesture. I feel pleasure in placing on record my sincere thanks to Dr. V. K. Srivastava, Reader in the Geology Department, Aligarh Muslim University, for several helpful suggestions.

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SOME OBSERVATIONS ON THE TAXONOMIC STATUS OF PARAROTALIA NIPONICA (ASANO) AND ALLIED SPECIES OF FORAMINIFERIDA

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During the course of an investigation of Recent Foraminiferida from the Indian waters, the author (Bhalla, 1970) recovered a few well developed specimens of *Pararotalia nipponica* (Asano) (= *Rotalia nipponica* Asano, 1936) from the east coast of India. While working out the taxonomy of this species, it was realised that a certain amount of confusion exists in the nomenclature of *P. nipponica* and allied species of *Pararotalia*; and a discussion on *P. nipponica* and related species, which have been often referred to in the literature on the Indo-Pacific region, is needed in order to clarify their taxonomic positions. The necessity for such a treatment is all the more important since some of them have been used in stratigraphical correlations in certain countries. In view of this, the following discussion has been attempted which tries to tackle the problem.

It is often difficult to make a distinction between the different members of the family Rotaliidae and *Pararotalia* is one of them. In the past, identical species were assigned to different genera by various workers. In recent years, there has been a vigorous effort on the part of systematists to evolve a workable criterion for distinguishing various rotaliid genera. Although the situation has greatly improved, it is still not completely satisfactory.

The genus *Pararotalia* was erected by Y. Le Calvez in 1949 with *Rotalia inermis* Terquem, 1882, as its type species. It is widely distributed both in space and time. *Pararotalia* ranges from Upper Cretaceous to Recent but is generally found in the sediments of Cenozoic era and is cosmopolitan in occurrence. An excellent account of the genus is given by Loeblich and Tappan (1957), and the details of internal structure and taxonomic position have been discussed by Reiss (1963) and Reiss and Merling (1958), among others. In recent years, a significant contribution towards the proper understanding of this genus has come from Ujiie (1966) who has emended it also.

*Pararotalia nipponica* has been widely recorded from the Indo-Pacific region. The other species of *Pararotalia* which either occur with *P. nipponica* or could be mistaken for it, are *Pararotalia taiwanica* (Nakamura) (= *Rotalia taiwanica* Nakamura, 1937) and *Pararotalia ozawai* (Asano) (= *Rotalia ozawai* Asano, 1951). Both these species have also been reported from the Indo-Pacific province.

A comparison of *P. nipponica* with *P. taiwanica* reveals that the only difference between the two is the smooth periphery and larger number of chambers in the former. According to Ujiie (1966), *P. taiwanica* is perhaps conspecific with *P. nipponica*. *P. nipponica* is also closely related to *P. ozawai* and both of them generally occur together (fide Ujiie, 1966). In comparison to *P. nipponica*, *P. ozawai* is small in size and bears spiny projections on its peripheral margin. However, Ujiie (1966) noted that, in thin-sections, these spines could be seen in the early coils of *P. nipponica* also. This led him to believe that the disappearance of peripheral spines from the later coils of *P. nipponica* is perhaps due to degeneration in the process of ontogeny and that *P. ozawai* represents the juvenile stage of *P. nipponica*. Except for the size and the peripheral projections, both the species are identical. The only character which distinguishes *P. taiwanica* from *P. ozawai* is the...
presence of spiny projections on the peripheral margin of the latter. Todd (1965) recorded *P. ozawai* from the shallow waters at Fiji and Rotonga in the Pacific and found it to be highly variable species. She observed a full spectrum of variation between the specimens with peripheral spiny projections (*ozawai*-type) and those without spines and almost entire periphery (*taiwanica*-type). Although she did not offer comments on the taxonomic implications of this feature, she seems to have considered, inter alia, *P. ozawai* and *P. taiwanica* to be conspecific.

From the foregoing discussion, it is evident that *P. nipponica* is a highly variable species. It is commonly found in association with *P. ozawai* (Ujiie, 1966) which, in turn, occurs with *P. taiwanica* (Huang, 1964). It has not been possible to ascertain their true relationship as the types were not available for study; but judging from their morphological features, certain generalizations can be made which may pave the way for their final taxonomic settlement.

Several authors have studied the above mentioned three species of *Pararotalia* from different angles, viz.; morphological characters, microstructures, etc., but none seems to have noticed dimorphism in these species. Dimorphism is an important phenomenon in the life history of foraminiferids and has played a vital role in the evaluation of foraminiferal genera and species. The presence of lobulated periphery and less number of chambers in *P. taiwanica* in comparison with *P. nipponica*, are the characters sometimes used in distinguishing megaspheric from the microspheric generation in several rotaliids. The lobulated periphery and less number of chambers in *P. taiwanica* are not sufficient enough to distinguish this species from *P. nipponica*. Possibly, *P. taiwanica* represents a megaspheric generation of *P. nipponica*. Similarly, the characters which distinguish *P. nipponica* from *P. ozawai* are also not well-marked. In comparison to *P. nipponica*, the test of *P. ozawai* is small and exhibits spiny projections on the periphery. Such projections have also been observed in the early coils of *P. nipponica* (Ujiie, 1966) and, are therefore not of much significance from taxonomic point of view. The small size of *P. ozawai* in comparison to *P. nipponica* is too insignificant a character to distinguish it from the latter. In view of this, it is more likely that *P. ozawai*, perhaps, represents one of the stages in the ontogenic development of *P. nipponica*. *P. ozawai* has been observed to grade into *P. taiwanica* through a series of transitional forms (Huang, 1964) and, during this process, the spiny projections of *P. ozawai* are lost giving rise to smooth margined test of *P. taiwanica*. This, in turn, would indicate that the two species are inseparable and are simply a case of intra-specific variation.

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**Figure 1.**

Diagram showing the developmental stages of *Pararotalia nipponica*.
Boltovskoy (1965) in his thought provoking article on Foraminiferida cautioned against the indiscriminate erection of new species without observing their natural variability. In recent times, a number of studies have been made on foraminiferal species to demonstrate the effect of temperature, salinity, latitudinal variations, etc., on them. A significant contribution in this direction has come from Lewis and Jenkins (1969). These authors have studied the control of environment on the development of Nonionellina flemingi (Vella) (= Nonion flemingi Vella, 1957) in Recent waters off New Zealand. They observed that N. flemingi behaves differently in different surroundings. Near Auckland islands, while the juvenile specimens of the species were found to be trochospirally coiled with a few chambers in the last whorl, the adult forms were planispiral with comparatively more number of chambers in the final coil. The effect of latitudinal variation was also pronounced; with the decrease in latitude, the size of the foraminifer also decreased.

From the above discussion, it becomes evident that in order to arrive at a correct taxonomic solution, materials of P. nipponica, P. taiwanica, and P. ozawai from different geographical locations should be examined and variation, coupled with dimorphism and microstructure, should be thoroughly studied. In all probability, it seems likely that only P. nipponica is valid whereas P. taiwanica and P. ozawai are its junior synonyms. All the three species are found in Recent waters and provide good scope for culture study also.

References


ABSTRACT—Fourteen species of foraminifera are recorded and illustrated from the beach sand at Puri. These include many characteristic Indo-Pacific species.

INTRODUCTION

The paper is based on samples collected by the senior author from the beach sand at Puri (19°84′: 85°52′), Orissa, in January 1959. Fourteen species of foraminifera are recorded and illustrated from these samples. Of these fourteen species, the following are the characteristic Indo-Pacific forms:

- Quinqueloculina tropicalis? Cushman
- Elphidium simplex Cushman
- Streblus annectens (Parker & Jones)
- S. denticus (Parker & Jones)
- Asteroecidina trispinosa (Thalmann)
- Dentostomina agglutinans (d’Orbigny)?
- Elphidium advenum (Cushman)

Dentostomina agglutinans (d’Orbigny) and Elphidium advenum (Cushman) have been recorded both from the Indo-Pacific and the Atlantic regions. The remaining identifiable species have a world-wide distribution.

PREVIOUS WORK

There are no specific records of foraminifera from the beach sand at Puri, Orissa. Perhaps the only paper dealing with recent foraminifera from the east coast of India is by Gnanamuthu (1943). This paper records the foraminiferal fauna of the Krusadai Island in the Gulf of Manaar. Although a large number of species are recorded from this area, a majority of them are poorly illustrated and lack proper description. As such, the paper can hardly be utilized for comparing the faunas of the two areas. As far as can be made out from Gnanamuthu’s paper (op. cit.), the only species which appear to be common in both the areas (Puri and the Gulf of Manaar) are the following (the figures in parenthesis refer to Gnanamuthu’s paper):

- Quinqueloculina seminulum (Linnaeus) (Plate II, figs. 4a-f)
- Triloculina sp. (Plate III, figs. 2a, b) = T. trigonula (Lamarck)
- Eponides repandus (Plate IV, figs. 19a-c) = Poroeponides lateralis (Terquem)

Some of the Lenticulina and Rotulida appear to be spiny Streblus. This can only be verified after careful restudy of the type specimens.

SYSTEMATIC DESCRIPTION

Family MILIOLIDAE

Genus QUINQUELOCULINA d’Orbigny, 1826

Quinqueloculina seminulum (Linnaeus) (Pl. I, figs. 1a, b)

Serpula seminulum Linnaeus, 1758, Systema Naturae, 10th Edn., p. 786.

This species is rare in our material and seems to come within the range of variation of *O. tropicalis*.

**Genus DENTOSTOMINA Carman, 1933**

*Quinqueloculina agglutinans* d’Orbigny, 1893, *Foram. Cuba*, Pl. xii, figs. 11-13, p. 168.

*Quinqueloculina agglutinans* d’Orbigny, 1893, *Foram. Cuba*, Pl. xii, figs. 11-13, p. 168.


We have three specimens of this agglutinate miliolid. The aperture is obscure. Bermudez (loc. cit.) placed the species under *Dentostomina*. According to Barker (1960, p. 16) forms figured by Brady (1884, Pl. 8, figs. 6, 7) probably represent a different species from d’Orbigny’s Cuban forms. As our specimens are closer to those figured by Brady (loc. cit.) we have followed Barker in assigning them questionably to *Dentostomina agglutinans* (d’Orbigny).

**Genus TRILOCULINA d’Orbigny, 1826**


This species is rare in our material and only one specimen was found.

**Family NONIONIDAE**

**Genus NONION Montfort, 1808**

*Nonion scaphum* (Fichtel & Moll) (Pl. 1, figs. 6a, b)


This is a well-known species having worldwide distribution. Bhatia (loc. cit.) recorded it from shore sands of western India. The species is common in our material.

**Genus ELPHIDIUM Montfort, 1808**

*Elphidium advenum* Cushman (Pl. 1, figs. 9a, b)


There are many records of this species from the Recent and Tertiary of the Atlantic and Pacific regions. Bhatia (loc. cit.) recorded it from shore sands of western India.

*Elphidium simplex* Cushman (Pl. 1, figs. 7a, b)


This is a diminutive species which cannot be assigned to any known species. Only two specimens were found and more specimens are needed before any definite identification is made.

**Family ROTALIIDAE**

**Genus STREBLUS Fischer, 1817**

*Streblus annectens* (Parker & Jones) (Pl. 1, figs. 8a, b)


This is a characteristic Indo-Pacific species with a somewhat lobulate periphery, slightly depressed sutures and small spiny projections running from the umbonal region to the apertural face. Common in occurrence.

*Streblus sp. indet.*

(Pl. 1, figs. 8a, b)

This is a diminutive species which cannot be assigned to any known species. Only two specimens were found and more specimens are needed before any definite identification is made.

**Genus ROTALIA* Linnaeus, 1767**


This is a characteristic Indo-Pacific species. Bhatia (loc. cit.) recorded the species from the west coast of India and discussed the taxonomic aspects of the genus *Streblus*. 
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**Streblus dentatus** (Parker & Jones)
(Pl. 2, figs. 2a-c)

*Rotalia beccarii* (Linnaeus) var. *dentata*


This is again an Indo-Pacific species. Rare in our material.

**Genus POROEPONIDES** Cashman, 1944

**Poroeponides lateralis** (Terquem)
(Pl. 2, figs. 3a, b)


Bhatia (loc. cit.) recorded the species from the west coast and discussed the taxonomic status of *P. lateralis* and *P. cribreopandus*. The specimen from the Puri beach sand is identical with the west coast forms.

**Genus ASTEROROTALIA** Hofker, 1951

*Asterorotalia trispinosa* (Thalmann)
(Pl. 1, figs. 10a, b)


This is the first record of this species from the Indian region. Our specimens come within the range of variation of the species. They have a distinctly triangular outline, with seven chambers in the last whorl. The sutures on the dorsal side are raised and limbate, while those on the ventral side have a narrow covering of a porous plate, characteristic of the genus *Asterorotalia*. Rare in occurrence.

**Family ANOMALINIDAE**
**Subfamily CIBICIDINAE**

**Genus CIBICIDES** Montfort, 1808

**Cibicides sp. indet.**
(Pl. 2, figs. 4a, b)

This is an indeterminate species. The number of chambers in the last whorl varies from 8 to 9. The ventral sutures are limbate. The periphery is keeled. Common in occurrence.

**ACKNOWLEDGEMENT**

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**EXPLANATION OF PLATE 1**
(All figures ×65 unless stated otherwise)

1a, b. *Quinqueloculina seminalis* (Linnaeus): a, side view; b, apertural view.
2a, b. *Quinqueloculina tropicalis* ? Cashman: a, side view; b, apertural view.
3a, b. *Denticostomina agglutinans* (d’Orbigny): a, side view.
4a, b. *Biloculina sp. indet*: a, side view; b, apertural view.
5a, b. *Triloculina trigona* (Lamarck): a, side view; b, apertural view.
6a, b. *Nonion scaphum* (Fichtel & Moll): a, side view; b, peripheral view.
7a, b. *Eplphidium simplex* Cashman: a, side view; b, peripheral view.
8a, b. *Elphidium sp. indet*: a, side view; b, peripheral view.
9a, b. *Elphidium advenum* (Cushman): a, side view; b, peripheral view.
10a, b. *Asterorotalia trispinosa* (Thalmann). × 125: a, dorsal view; b, ventral view.
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EXPLANATION OF PLATE 2

(All figures x65 unless stated otherwise)

1a-c. Streblus annectens (Parker & Jones): a, dorsal view; b, ventral view; c, peripheral view.

2a-c. Streblus dentatus (Parker & Jones), x125: a, dorsal view; b, ventral view; c, peripheral view.

3a, b. Pororoportoides lateralis (Terquem): a, dorsal view; b, ventral view.

4a, b. Cibicides sp. indet: a, dorsal view; b, ventral view.