

# Planktonic Foraminifera in Sediment Samples from the Eastern Arabian Sea

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Twenty-two species of planktonic Foraminifera have been identified from the bottom sediments of the Arabian Sea off Bombay and their percentage occurrence has been studied. Species composition has shown that the sediments of the continental slope region off Bombay are represented by a larger number of species than the shelf sediments. The forms which are common in the eastern part of the Arabian Sea are: *Globigerina bulloides*, *Globigerinoides ruber*, *G. sacculifer*, *Globigerinita glutinata*, *Globigerinella aequilateralis*, *Orbulina universa*, *Pulleniatina obliquiloculata*, *Globorotalia menardii* and *G. tumida*. Concentration of the planktonic Foraminifera decreases from the offshore regions to regions towards the coast. In the slope sediments the per cent of CaCO<sub>3</sub> is proportional to the number of planktonic Foraminifera. The presence of high latitude cold water species along with the warm water species in the Arabian Sea off Bombay suggests the mixing of Antarctic water with other types of water found along the west coast of India. Similarity of the planktonic Foraminifera of the eastern Arabian Sea with that of Red Sea has been shown on the basis of species composition and dominance of certain species in both the seas. On the basis of this observation, it is concluded that Red Sea water has spread into the offshore region of Bombay.

**P**LANKTONIC Foraminifera in the Arabian Sea were first studied by Chapman<sup>1</sup> who reported 17 species from the Laccadive region. Stubbings<sup>2</sup> recorded 18 species from the Arabian Sea during John Murray Expedition. III the north-eastern part of the Arabian Sea which includes Gulf of Cambay, Kameswara Rao<sup>3,4</sup> found 9 species. Recently Be and McIntyre<sup>5</sup> reported the presence of an extinct subspecies *Globorotalia menardii flexuosa* (Koch), from the samples collected for the present investigation. From the forgoing account it is obvious that there is no thorough quantitative documentation of various species of planktonic Foraminifera present in the west coast of India; although their presence in different regions of the Arabian Sea has been noted.

In this paper the quantitative distribution of various planktonic foraminiferal species present in the bottom sediments of the Arabian Sea off Bombay is reported. Such a study has a bearing on oceanography conditions of the sea and also it will be useful for the comparison of the fauna with other region.

During a cruise sponsored by the Institute on board INS Darshak in January 1969 into the Arabian Sea off Bombay, several bottom sediment samples were collected using Lafond-Dietz snapper. Altogether 7 snapper samples were obtained and the sampling stations are shown in Fig. 1. The purpose of the collection of these samples is to determine species composition of planktonic Foraminifera and their quantitative distribution in the bottom sediments of the Arabian Sea off Bombay. The study area extends between longitudes 69°30.4'E and 72°22.0'E and latitudes between 18°33.5'N and 19°15.0'N. The water depths at the sites in the area range between 62 and 1820 m.

The continental shelf off Bombay coast has a maximum width of about 161 km. The inner shelf

is flat whereas the outer shelf is highly irregular all the way to its edge (140 m) being formed of pinnacles and knolls with intervening depressions. The continental slope of the west coast of India is gradual.

## Materials and Methods

Eight stations were covered during the said cruise. At the station 47 (lat. 19°15.0'N and long. 69°45.0'E), a pipe dredge was used and it came up with coral rocks and oolite limestone. The snapper did not get any sample at this locality and therefore for planktonic foraminiferal analysis only 7 samples were taken. The method of separating the Foraminifera from the samples is same as earlier<sup>4</sup>. Percentages of various planktonic species present in the samples have been calculated (Table 2). Station locations, sampling times and bottom character are given in Table 1 and data on water depths, Salinity, temperature, calcium carbonate and total number of Foraminifera are presented in Figs. 2 to 6. Calcium carbonate content of the sediment samples was determined using the method

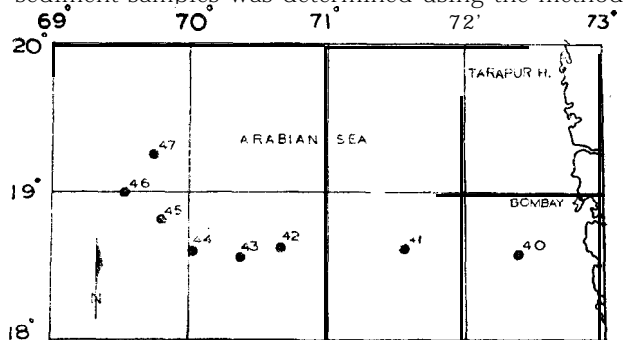


Fig. 1 — Station locations in the Arabian Sea off Bombay where sediment samples were collected

of Hutchinson and MacLennan as described by Barnes6.

**Results**

The bottom sediment samples can be classified into 5 categories, viz. silty clay, silty sand, sandy silt and silt. The sediments from the shore to a depth of 62 m are silty clay; from depth of 62 to 96 m the deposits are either silty sand or sand and from the outer shelf towards the sea the deposits are found to be sandy silt or silt. Seaward from 62 m to a depth of 96 m a calcareous zone is found. It is possible that the calcareous material must have been derived largely from the fragmentation of coral rocks as well as from oolite limestones. Evidence for this observation could be made on the basis of rock fragments and corals that were dredged from sites 42 and 47. The finding of the oolites and coral rocks at these stations

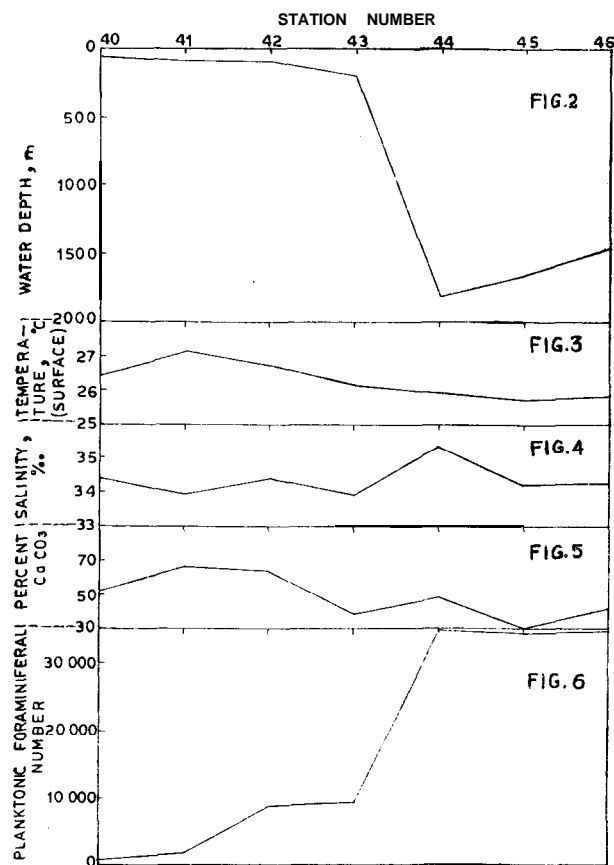
is of importance as it will give an idea on the problem of eustatic change5 in sea level along the west coast of India.

*Planktonic foraminiferal species* — Twenty-two species of planktonic Foraminifera belonging to 9 genera and 2 families, viz. Globigerinidae and Globorotaliidae, are identified. The fauna is dominated by warm water species and with the exception of *Globigrina bulloides*, all other cold water species reported in this paper are uncommon. The collection of planktonic Foraminifera in the Arabian Sea off Bombay is typical of Indo-Pacific region and the list of species is as follows:

- Hastigerina pelagica* (d'orbigny), Fig. 7
- Ovubina universa* d'orbigny, Fig. 8
- Globigerinoides conglobatus* (Brady), Fig. 9
- Globigrinoides ruber* d'orbigny, Fig. 11
- Globigevinoides sacculifer* (Brady), Fig. 10
- Globigerina rubescens* Hofker, Fig. 12
- Globigerina quinqueloba* Natland, Fig. 13
- Globigerina pachyderma* (Ehrenberg), Fig. 14
- Gloigerina falconensis* Blow, Fig. 15
- Globigerina bulloides* d'orbigny, Fig. 16
- Globigerina calida* Parker, Fig. 17
- Globigerinella aequilateralis* (Brady), Fig. 18
- Globigerinella adamsi* (Banner and Blow), Fig. 20
- Globigerinita glutinata* (Egger), Fig. 19
- Globoquadrina dutertrei* (d'orbigny), Fig. 21
- Globoquadrina conglomerata* (Schwager), Fig. 22
- Pulleniatina obliquiloculata* (Parker and Jones), Fig. 23
- Globorotalia truncatulinoidea* (d'orbigny), Fig. 24
- Globorotalia hirsuta* (d'Orbrgny), Fig. 25
- globorotalia menardii* (d'orbigny), Fig. 26
- Globorotalia tumida* (Brady), Fig. 27
- Globorotalia menardii flexuosa* (Koch), Fig. 28

TABLE 1 — DATA ON BOTTOM SEDIMENTS FROM THE ARABIAN SEA OFF BOMBAY

Station No.	Date (1969)	Latitude	Longitude	Bottom character
40	7/1	18°34.5'N	72°22.0'E	Silty clay
41	7/1	18°35.7'N	71°33.5'E	Silty sand
42	8/1	18°36.0'N	70°39.4'E	Sand
43	8/1	18°33.5'N	70°21.6'E	Sandy silt
44	8/1	18°35.0'N	70°03.0'E	Silt
45	8/1	18°49.0'N	69°47.5'E	do
46	8/1	19°03.0'N	69°30.4'E	do



Figs. 2-6 -- Ecological data and distributional trend of planktonic foraminiferal fauna

The total population of planktonic Foraminifera shows greater variation in abundance at varying depths in the continental shelf region of the Bombay coast and the sediments in the slope region are quite rich in planktonic Foraminifera. The area of greatest planktonic foraminiferal abundance (34750 specimens/g dry sediment) is the site No. 44. High concentrations of planktonic Foraminifera have been observed in the slope region off Bombay. In the shelf region concentration of planktonic Foraminifera varies from 750 to 9150 specimens/g dry sediment

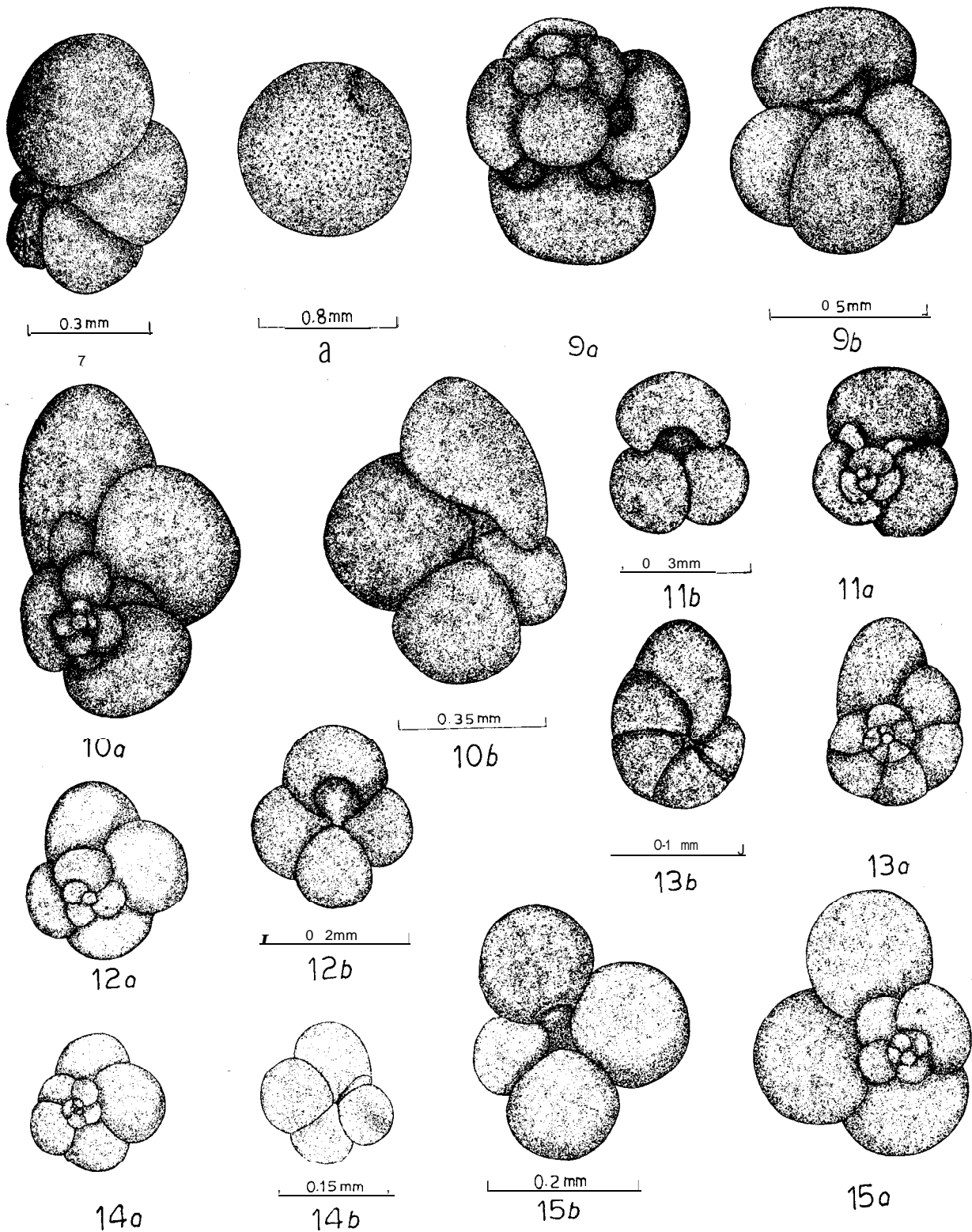
Planktonic foraminiferal species found in all the samples are *Hastigerina pelagica*, *Orbulina universa*, *Globigevinoides conglobatus*, *G. ruber*, *G. sacculifer*, *Globigerina falconensis*, *G. bulloides*, *Globigerinella aequilateralis*, *Globigerinita glutinata*, *Globoquadrina dutertrei*, *Pulleniatina obliquiloculata*, *Globorotalia menardii* and *G. tumida*.

Three of the 22 species recorded are found at 4 sites only, they being *Globigerina quinqueloba*, *G. calida* and *G. pachyderma*.

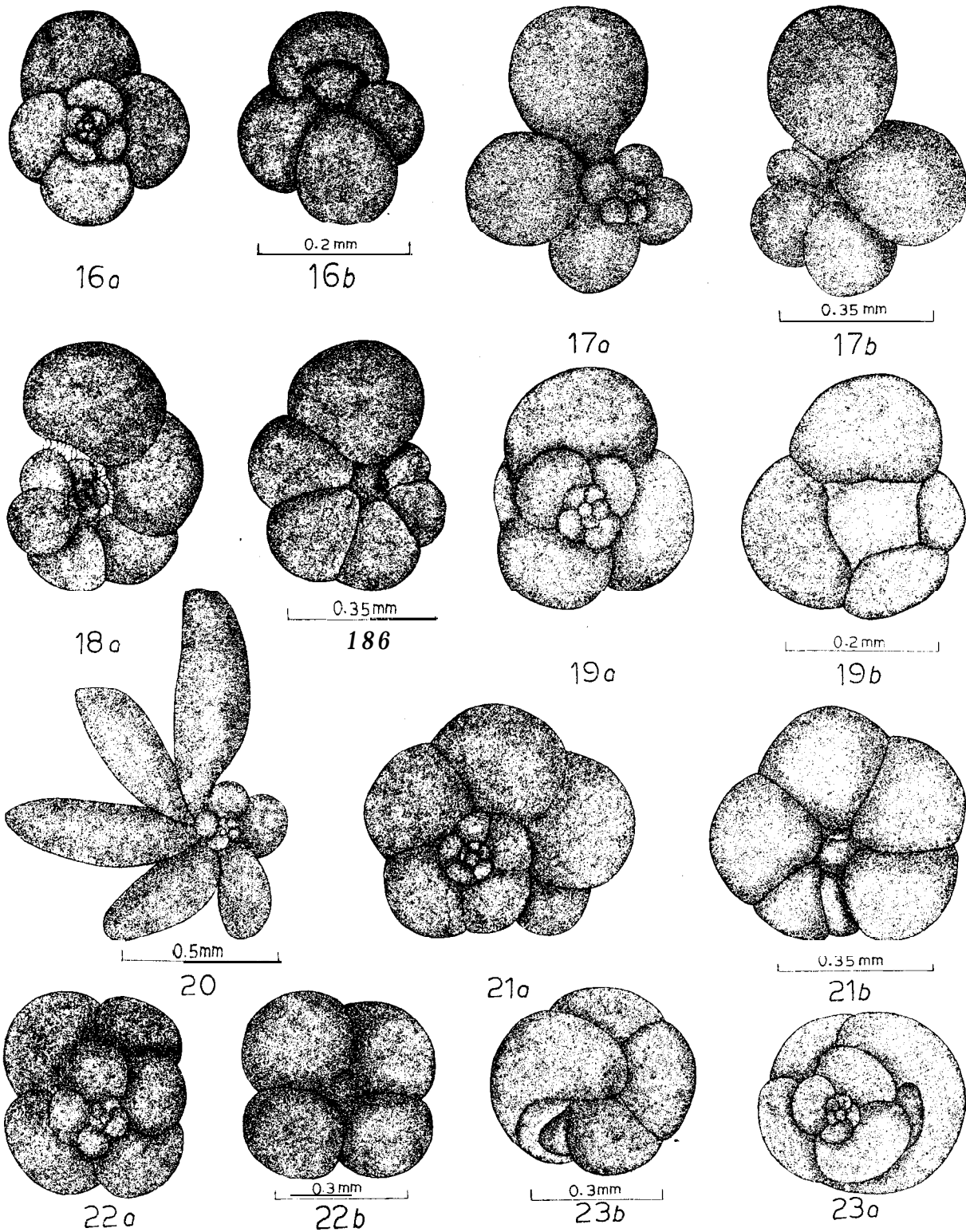
Planktonic foraminiferal species found at 2 sites are: *Globigerinella adamsi* and *Globorotalia hirsuta*.

Planktonic forms observed at one station only are: *Globorotalia truncatulinoidea* and *Globorotalia menardii flexuosa*

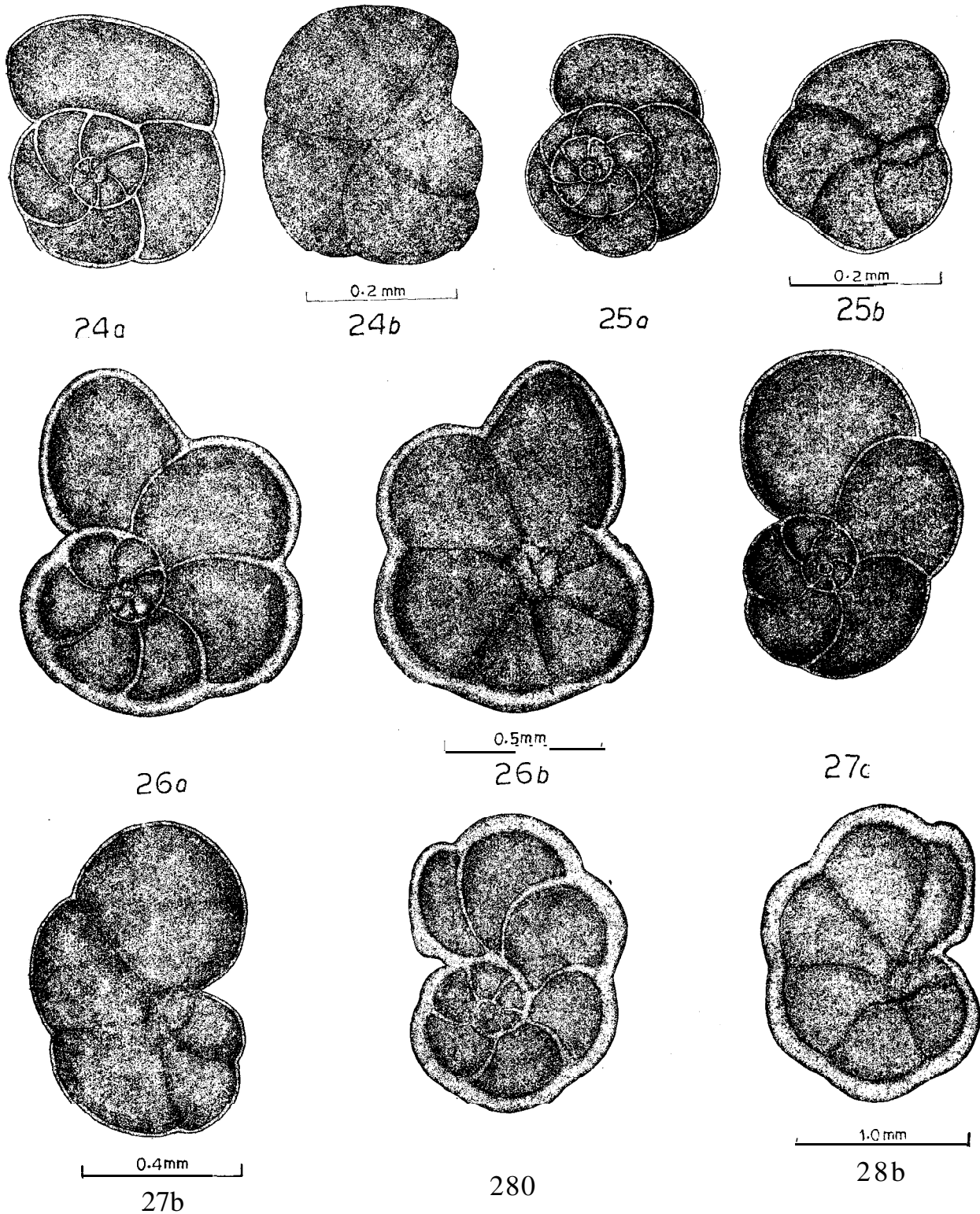
The general relationship between planktonic foraminiferal number (number of planktonic foraminiferal specimens present in one gram of dry sediment) and depth indicated that the number increases



Figs. 7-15 -Planktonic foraminiferal species [(7) *Hastigerina pelagica* (8) *Orbulina universa* (9) *Globigerinoides conglobatus*, (10) *Globigevinoides sacculifer*, (11) *Globigevinoides rubev*, (12) *Globigerina rubescens*, (13) *Globigerina quinqueloba*, (14) *Globigerina pachyderma* and (15) *Globigerina falconensis* a, dorsal view; and b, ventral view]



Figs. 16-23 -- Planktonic foraminiferal species (16) *Globigerina bulloides* (17) *Globigerina calida*, (18) *Globigerinella aequilateralis*, (19) *Globigerinita glutinata* (20) *Globigerinella adamsi*, (21) *Globoquadrina dutertrei* (22) *Globoquadrina conglomeraata* and (23) *Pulleniatina obliquiloculata* a, dorsal view; and b, ventral view



Figs. 24-28 — Planktonic foraminiferal species [(24) *Globorotalia truncatulinoides*, (25) *Globorotalia hirsuta*, (26) *Globorotalia menardii*, (27) *Globorotalia tumida*, and (28) *Globorotalia menardii flexuosa*. a, dorsal view; and b, ventral view]

TABLE ---PERCENTAGE OCCURRENCES OF PLANKTONIC FORAMINIFERAL SPECIES

Planktonic species	station number						
	40	41	42	43	44	45	46
Depth, m:	62	87	96	204	1820	1660	1460
<i>Hastigerina pelagica</i>	1.2	1.4	2.6	1.2	1.6	0.2	0.4
<i>Orbulina universa</i>	9.6	9.8	7.2	5.2	2.6	2.0	3.2
<i>Globigerinoides conglobatus</i>	3.2	3.0	3.4	1.0	1.0	1.0	1.2
<i>Globigerinoides ruber</i>	30.8	32.0	33.0	36.2	38.2	28.8	41.0
<i>Globigerinoides sacculifer</i>	4.6	3.0	1.0	1.2	11.2	3.6	5.0
<i>Globigerina rubescens</i>	0.6	0.6	0.4	0.6	0.4	0.2	—
<i>Globigerina quinqueloba</i>	—	—	1.0	1.0	0.2	0.4	—
<i>Globigerina pachyderma</i>	0.2	0.4	1.2	2.0	—	—	—
<i>Globigerina falconensis</i>	2.8	3.0	4.8	2.2	2.0	3.4	5.2
<i>Globigerina bulloides</i>	15.8	15.2	16.0	20.1	6.8	12.6	8.8
<i>Globigerina calida</i>	—	0.4	—	0.2	1.2	—	1.0
<i>Globigerinella aequilateralis</i>	4.8	4.4	3.6	5.0	5.2	1.8	3.0
<i>Globigerinella adamsi</i>	—	—	—	1.0	0.2	—	—
<i>Globigerinita glutinata</i>	14.8	15.4	16.2	16.6	10.8	18.2	12.8
<i>Globoquadrina dutertrei</i>	5.2	4.8	1.4	1.6	3.8	5.8	4.6
<i>Globoquadrina conglomerata</i>	1.6	—	0.8	—	1.0	0.4	0.2
<i>Pulleniatina obliquocutlata</i>	0.8	1.4	3.2	2.6	6.0	10.0	6.2
<i>Globorotulia truncatulinooides</i>	—	—	—	0.2	—	—	—
<i>Globorotalia hirsuta</i>	—	—	1.8	0.4	—	—	—
<i>Globorotalia menardii</i>	2.6	0.8	0.4	0.4	3.2	2.8	1.0
<i>Globorotalia tumida</i>	1.2	3.8	1.6	0.4	3.4	8.8	6.4
<i>Globorotalia menardii flexuosa</i>	—	—	—	0.4	1.2	—	—

with depth and distance from the shore (Fig. 6). The slope sediments are represented, by larger number of species.

Studies on this group have shown that in the slope sediments the percentage of CaCO<sub>3</sub> increases with the abundance of planktonic Foraminifera.

### Discussion

Quantitative analysis of planktonic Foraminifera from the sediments has shown that the silty sand and sand deposits contain only a few forms whereas the sandy silt and silt deposits are fairly rich in variety and numerical abundance. The sediments of the continental slope region are represented by a larger number of specimens of planktonic Foraminifera than those of the shelf. It can be inferred that low concentrations of planktonic Foraminifera in the shelf region is due to low 'productivity of this group in the shelf waters.

The sediments in the shelf region off Bombay are fairly rich in CaCO<sub>3</sub> and the content of CaCO<sub>3</sub> varies from 38 to 66%. Seaward from 62 m to a depth of 96 m, a calcareous sand zone exists and in this area CaCO<sub>3</sub> varies from 52 to 66% and the calcareous material is largely derived from the coral rocks and oolite limestones. From the edge of the continental shelf and continuing into the slope, CaCO<sub>3</sub> content in the deposits varies from 30 to 48%. The content of CaCO<sub>3</sub> in the pelagic sediments is actually the balance of the two processes, viz. productivity of calcareous organisms and the reaction of water on the deposited calcareous remains'. It has been found that in this region the source of calcareous material is dominantly from floating calcareous organisms, namely planktonic Foraminifera, and in the deposits of this area CaCO<sub>3</sub> content increases with the number of planktonic Foraminifera (Fig. 5). This confirms the observation of Correns<sup>8</sup> that the amount of CaCO<sub>3</sub> in the silt is proportional to the number of foraminiferal tests.

The planktonic foraminiferal species from the eastern part of the Arabian Sea can be classified into two categories: warm and cold water species. Some dominant warm water species in the Arabian Sea off Bombay are: *Hastigerina pelagica*, *Globigerinoides ruber*, *G. sacculifer*, *Globigerinella aequilateralis*, *Orbulina universa* and *Globorotalia tumida*. All the cold water species which are rare with the exception of *Globigerina bulloides* are *Globigerina pachyderma* and *G. quinqueloba*. The occurrence of cold water species with warm water species in the bottom sediments of the Arabian Sea off Bombay is an indication of the mixing of the Antarctic water with other types of water, viz. the Indian equatorial water, the Red Sea water and the Indian central water found along the west coast of India. It is also known that the upwelling of the cold bottom waters of the Antarctic comes to the surface in the Arabian Sea when confronted with the Carlsberg Ridge<sup>9</sup>.

In connection with the mixing of the two types of faunal elements, it is worth mentioning about an interesting species, namely *Globorotalia menardii flexuosa* (Koch). Ericson *et al.*<sup>10</sup> observed specimens of *Gl. m. flexuosa* at certain Quaternary levels of Atlantic deep-sea cores and it was considered by these authors on the basis of this observation that this subspecies became extinct after having lived about 90000 to 125000 years ago in a circumtropical belt in the Atlantic, Indian and Pacific Oceans during the warm Interstitial of the Wisconsin and the Sargamcn Interglacial. Furthermore, this subspecies has not been recorded so far in the recent deposits of the Atlantic and Pacific Oceans. Based on this available information that this subspecies is an extinct one, Bhatt<sup>11</sup> reported by the presence of forms resembling *Gl. m. flexuosa* along with other species of planktonic Foraminifera from a sample from the outer shelf region off the Visakhapatnam coast,

that the mixing of the two faunal categories is 'relict' in nature but this conclusion is not true in view of the fact that Be and McIntyre<sup>5</sup> could discover living specimens of the same species in the northern Indian Ocean which includes Bay of Bengal and Arabian Sea. From this report we can conclude that it is still living since its inception. Report of Be' and McIntyre<sup>5</sup> about the presence of *Gl. m. flexuosa* from the sediment samples of the present investigation is further an evidence of its presence in the Arabian Sea besides Bay of Bengal and other adjacent seas of northern Indian Ocean.

Our knowledge of planktonic Foraminifera present in the Red Sea is mainly from the contributions of Said<sup>12</sup>, Herman<sup>13</sup> and Berggren and Boersma<sup>14</sup>. Said<sup>12</sup> recorded 5 planktonic forms. Herman<sup>13</sup> reported 16 species from the samples of the Red Sea. Further studies on this group from the Red Sea by Berggren and Boersma<sup>14</sup> have shown that some species like *Orbulina univcrsa*, *Globigerinella acuilateralis*, *Globigerinoides ruber* and *G. sacculifer* are dominant. In the offshore region of Bombay, the above-mentioned species are quite abundant. *Globigerinoides ruber* which is known to tolerate high salinity conditions in the Red Sea is very dominant in the offshore region of Bombay. Out of the 16 species reported by Herman<sup>13</sup>, 14 of them are encountered in the samples of the study area. From the results of the present investigation and those of earlier studies by Chapman<sup>1</sup> and Stubbings<sup>2</sup> it is seen that there is some identity of the planktonic foraminiferal fauna of the Red Sea with that of Arabian Sea. This similarity of planktonic foraminiferal fauna in both the seas suggests that the Red Sea water has spread into the offshore region of Bombay. This finding, is of importance as it is the only available biological evidence so far for the mixing of Red Sea water with that of Arabian Sea. Physical evidence for this phenomenon is that of Rochford<sup>15</sup> who has shown the presence of Red Sea water along the

west coast of India on the basis of T-S characteristics.

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