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PALAEOECOLOGY OF LATE MIOCENE SMALLER BENTHIC FORAMINIFERA FROM BARATANG ISLAND, ANDAMAN SEA

V. SHARMA and DEBASHIS MAZUMDAR
DEPARTMENT OF GEOLOGY, UNIVERSITY OF DELHI - 110 007

ABSTRACT

The Late Miocene smaller benthic foraminifera are reported from seven sections of Baratang Island, Andaman Sea. Various criteria used to understand the paleoecology of the fauna suggest that the depositional environment has been uniform throughout the deposition of the sediments. The deposition took place in the outer neritic zone, at a depth of about 200 meters.

INTRODUCTION

Within the Andaman-Nicobar region, Baratang Island is unique in its containing stratigraphic records of a long geological history. In spite of this uniqueness, it has not attracted many workers due to inaccessible terrain as a result of dense forests and hostile tribes. It is only in the recent times that better communication with this island was established as a result of human settlements.

Geologically, the island comprises rocks ranging in age from at least Late Cretaceous to Tertiary (Boileau, 1950; Sharma, Mukherjee and Bandopadhyay, 1969; Mukherjee, 1982). A major part of the island is covered by Palaeogene rocks. Neogene sediments occupy the southwestern part of the island.

The first known references on foraminifera of this island are by Badve, Ghare and Rajshekhar (1984) and Rajshekhar (1985, 1989), who reported foraminiferal species from the ejected material of mud volcanoes. In a later publication, Badve, Rajshekhar and Kundal (1989) identified a rich *Globotruncana* assemblage along with a few other species of planktic foraminifera in the cherty limestone. Mazumdar and Sharma (1991) studied planktic foraminifera from seven stratigraphic sections located in the southwestern part of the island and considered the Neogene sediments to belong to *Globorotalia (Globorotalia) plesiotumida* Zone (Late Miocene). Mazumdar and Sharma (1991) also briefly described the geological setting of the southwestern part of Baratang Island.

PRESENT WORK

Understanding the palaeoecology of benthic foraminifera has been possible by using a number of criteria which include both faunal and sedimentological approaches. One of the important faunal criteria is the comparison of the fossil fauna with the modern one from the same general area. This, in conjuction with other evidences can help to understand the depositional environment, including depth of deposition. For a relatively younger fossil fauna, this could be achieved with greater accuracy than with older ones, as the information loss is less.

In the present work, a number of criteria such as distributional characteristics of benthic foraminifera, planktic foraminiferal percentage and species diversity are employed to interpret palaeoecology of the studied foraminifera. Samples from seven stratigraphic sections have been used in the study. Lithologs and sample positions are shown in fig. 1. The same samples were used earlier (Mazumdar and Sharma, 1991) for studying planktic foraminifera and biostratigraphy.

PROCEDURE

All benthic foraminifera from an aliquot of washed residue were picked and identified. The aliquot was so chosen that it yielded about 300 individuals. Thanatotopes were identified with the help of cluster analysis. Planktic foraminifera, species diversity and species composition of each sample in a thanatotope were determined and used for palaeoecological interpretation.

The terminology as suggested by Berggren (1978), for the main divisions of marine environment, has been applied in the text. Accordingly, inner neritic = 0-30 metres, middle neritic = 30-100 metres, outer neritic = 100-200 metres, upper bathyal = 200-600 metres, middle bathyal = 600-1000 metres, and lower bathyal = 1000 and 2000 metres.

Thanatotopes

Distributional data of benthic foraminifera in the form of presence/absence of species is subjected to cluster analysis. Species with an abundance of 1.5%

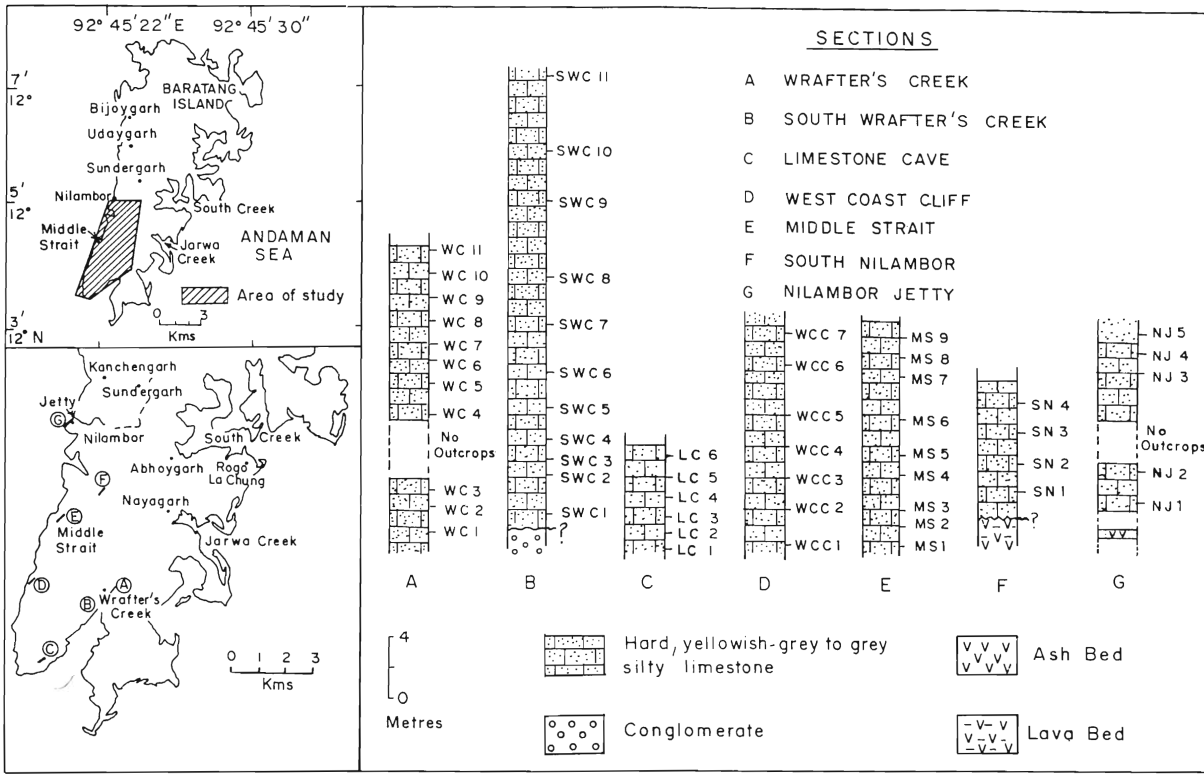

Fig. 1. Location and lithological columns of the studied sections with sample positions.

or more are used in the analysis. Among the available similarity coefficients, the Simple Matching Coeffecient and Jaccard Coefficeint are widely used in Cluster Analysis. The Q-mode technique of Weighted Pair Group using Arithmetic Averages of the Jaccard Coefficient Matrix (Sokal and Sneath, 1963; Mello and Buzas, 1968) is applied by the authors for finding similarity among samples. Relationship among samples is shown in the form of a dendrogram (fig. 2). Based on natural breaks in the dendrogram, seven thanatotopes (sample groups) have been identified. Seven samples do not join any cluster because of their joining at a relatively lower level of similarity.

Species composition of each thanatotope is shown in fig. 3.

Planktic Foraminifera

The fact that percentage of planktic foraminifera in a foraminiferal assemblage increases with depth (Grimsdale and Morkhoven, 1955) led a number of investigators to apply it as a useful index of understanding depth of deposition (Vella, 1962; Boltovskoy and Wright, 1976; Srinivasan and Azmi, 1976; Aoshima, 1978; Hayward and Buzas, 1979; Sharma and Takayanagi, 1982). The percentage of planktic foraminifera in the samples of each thanatotope is shown in fig. 4.

Species Diversity

In modern oceans, benthic foraminiferal species diversity has been observed by a number of investigators (Buzas and Gibson, 1969; Ikeya, 1971 a, b: Gibson and Buzas, 1973; Murray, 1973; Sengupta and Kilbourne, 1974; Lagoe, 1976; Aoshima, 1978; Ingle, 1980; Ingle and Keller, 1980). Change in ecological conditions are reflected in species diversity, and diversity measurement when applied in conjunction with other evidences can be a useful criterion to understand the environment.

In case of recent organisms, the simplest way of knowning species diversity of particular group is to determine the total number of species of that taxon inhabiting an area. In case of fossils, it is the number of species present in a sample. Such measurements, however, do not take into account the relative abundance of species which is important in understanding population structure of the group. For, in two samples, diversity (number of species) may be same but abundance of species may be quite different. Several mathematical expressions (Fischer, Corbett and Wil-

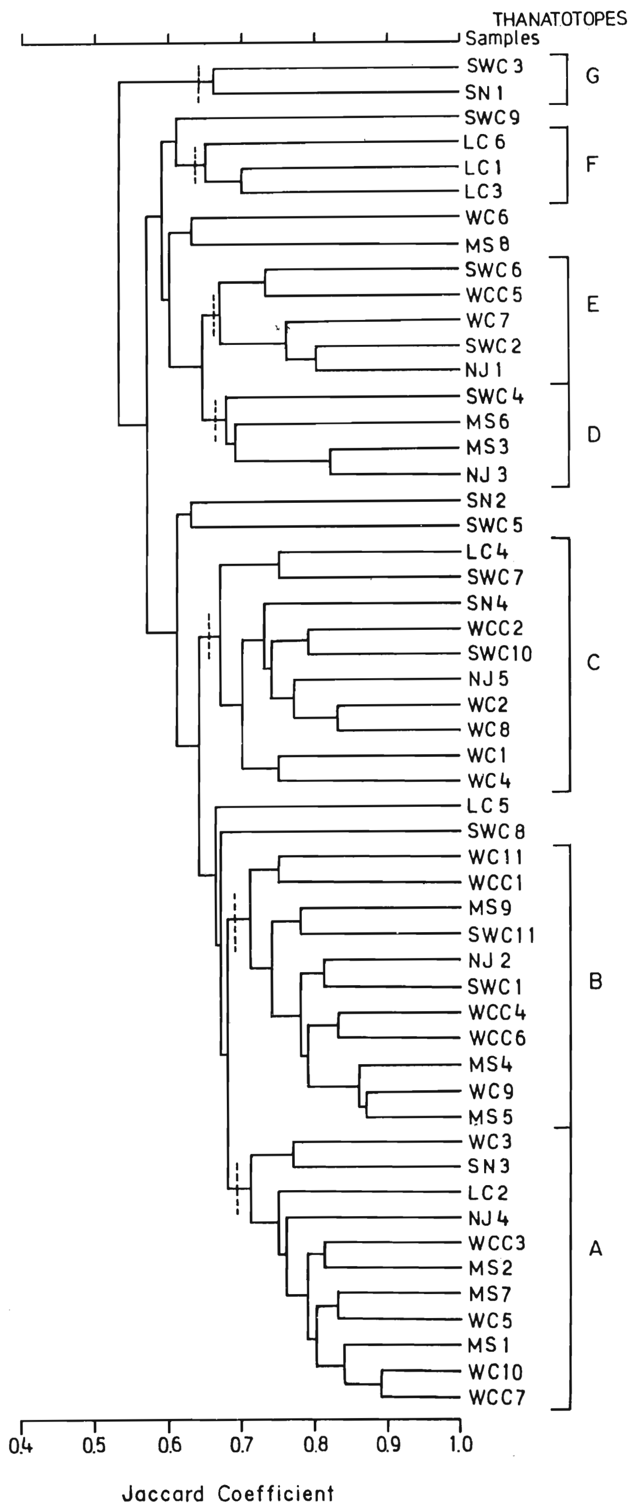

Fig. 2. Dendrogram based on Q-matrix of Jaccared Coefficient by using Weighted Pair Group Method Clustering Technique.

liams, 1943; Preston, 1948, 1960; Williams, 1964; Simpson, 1949; Shannon-Wiener, 1963; Murray 1973) are available, which also incorporate abundance of species in diversity measurements.

In this study, species diversity is measured by Shannon-Wiener Information Function. The Information Function is expressed as

$$H(S) = -\sum_{i=1}^{S} p_i \ln p_i,$$

where, p_i = proportion of the i th species in the sample

S = number of species.

Value of H(S) will be maximum if abundance of all species is same, that is, if they are evenly distributed. As a part of the diversity measurement, it is also desirable to know evenness or equitability of species. Here, equitability is determined by the formula suggested by Buzas and Gibson (1969), which is expressed as

$$E = \frac{e^{H(S)}}{S}$$

where H(S) = species diversity, and

S = number of species.

The values of species number (S), species diversity [H(S)] and equitability (E) in the sample of each thanatotope are shown is fig. 5.

Since number of species in a sample increases with the increase in sample size, it is essential that sample size should remain constant so that species diversity values could be compared with one another. Sanders (1968) presented method of rarefaction which allows an investigator to compare directly samples of different sizes. Hurlbert (1971) pointed out shortcomings in Sanders' method and proposed a mathematical expression for detecting number of species in each sample in a specified number of individuals. In the present study, following Hurlbert (1971), the population is equated at 100 individuals (E_{100}) for every sample before quantification of species diversity. The mathematical expression used is

$$Es_n = \sum_{i=1}^{S} 1 - \frac{\genfrac{}{}{0pt}{}{N-N_i}{n}}{\genfrac{}{}{0pt}{}{N}{n}}$$

All calculations were done with the help of IBM Compatible Computer at Computer Centre, University of Delhi, Delhi.

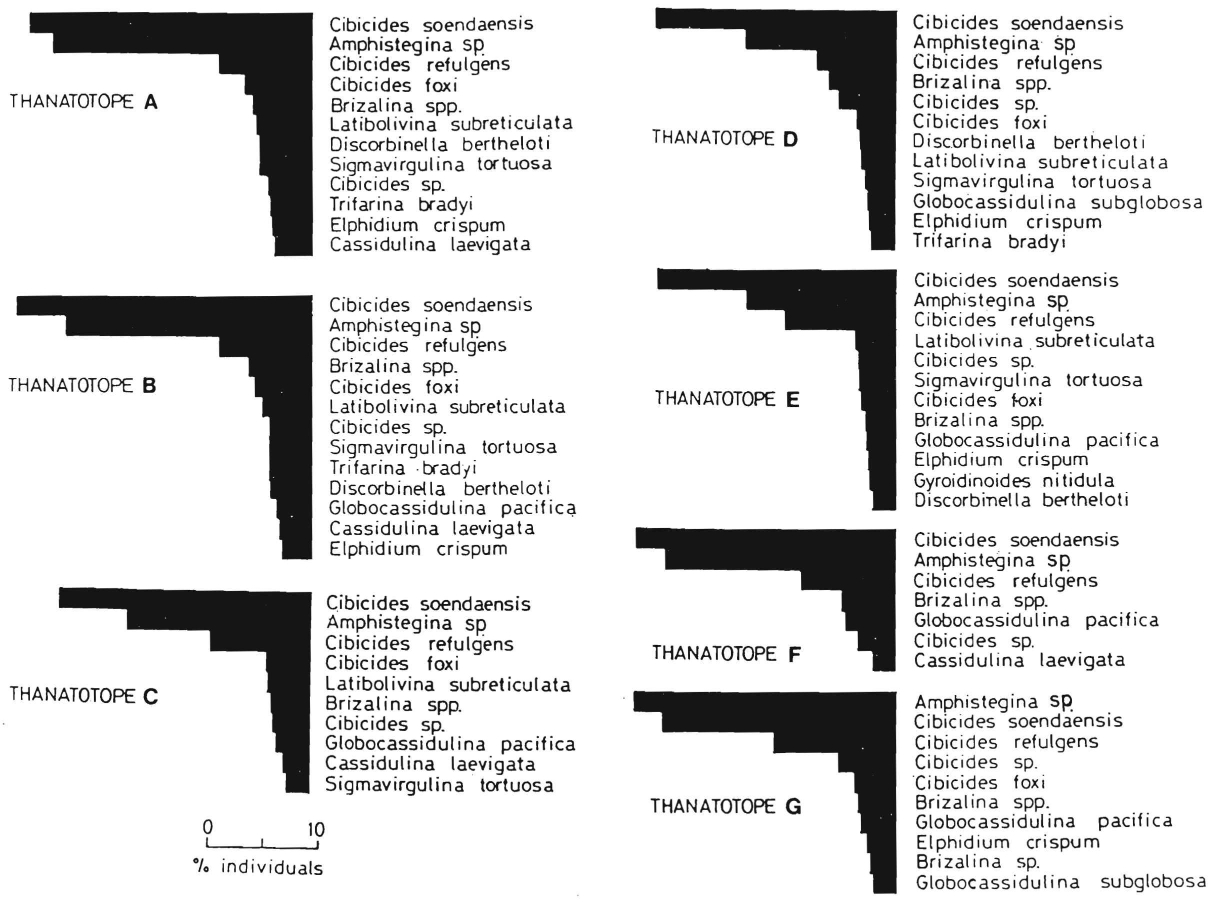

Fig. 3. Histogram of percentage occurrence of benthic foraminifera (>2%) in the identified thanatotopes (A to G).

REPOSITORY

The samples used in this study and the microfaunal slides of benthic foraminifera from each sample are lodged in the Department of Geology, University of Delhi, Delhi.

OBSERVATIONS

Thanatotope A

Benthic Fauna. Samples of thanatotope A (represented by 11 samples) are characterised by dominance of *Cibicides soendaensis* and *Amphistegina* sp., both together constituting about 36% of the total fauna. Other common species (>5%) include *Cibicides refulgens, Cibicides foxi, Brizalina* spp. and *Latibolivina subreticulata.* Six other species constituting 2% to 5% of the total fauna account for the remaining forms in this thanatotope.

Planktic Foraminifera. This varies between 56% and 70% with an average of about 62%.

Species Diversity. Values of H(S) vary from 2.26 to 2.82 with an average value of 2.74. A low species diversity in sample LC-2 seem to be as a result of low value of S. The average value of equitability in this thanatotope 0.48 (range from 0.38 to 0.58).

Thanatotope B

Benthic Fauna. This thanatotope is represented by 11 samples each containing *Cibicides soendaensis* and *Amphistegina* sp. in dominance. Species which are represented by more than 5% in this thanatotope are *Cibicides refulgens, Brizalina* spp. and *Cibicides foxi* Other species ranging between 2% and 5% are *Latibolivina subreticulata, cibicides* sp., *Sigmavirgulina tortuosa, Trifarina bradyi, Discorbinella bertheloti, Globocassidulina pacifica, Cassidulina laevigata* and *Elphidium crispum.*

Planktic Foraminifera. This varies between 55% and 72% with an average of about 63%.

Species Diversity. Values of H(S) vary from 2.26 to 2.95, with an average of 2.64. A low diversity in sample LC-2 seems to be as a result of low value of S. The average equitability value is 0.48 (range from 0.38 to 0.58).

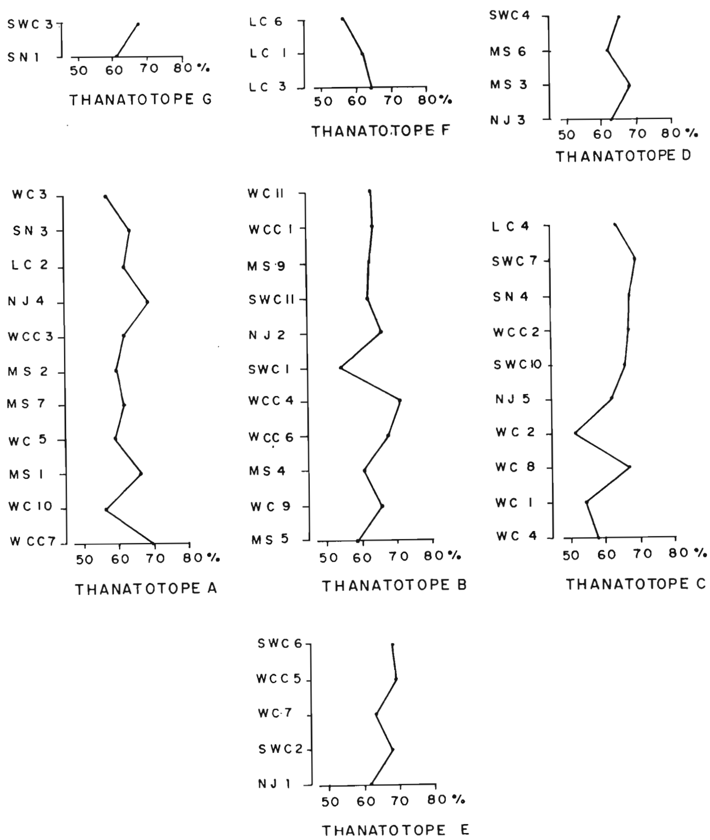

Fig. 4. Percentage of planktic foraminifera in the samples of each thanatotopes.

Thanatotope C

Benthic Fauna. This thanatotope with 10 samples also has a dominance of *Cibicides soendaensis* and *Amphistegina* sp. and to a lesser extent *Cibicides refulgens.* Species greater than 5% are *Brizalina* spp., *Cibicides foxi, Cibicides* sp. and *Latibolivina subreticulata.*

Planktic Foraminifera. The average value is 62% of the total foraminiferal fauna. Two samples WC-1 and WC-2 show relatively low values of planktic forminifera (54% and 51% respectively).

Species Diversity. In the samples of this thanatotope H(S) ranges from 2.34 to 2.91 with an average of 2.55.

Thanatotope D

Benthic Fauna. This thanatotope is represented by 4 samples. The species composition is similar to that in the samples of thanatotopes A, B and C with *Cibicides soendaensis, Amphistegina* sp., *Cibicides refulgens,Brizalina* spp., *Cibicides* sp. and *Cibicides foxi* constituting 5% and above of the total fauna; first two species being the most dominant.

Planktic Foraminifera. This averages about 64% (values ranging from 62.1% to 68.3%).

Species Diversity. Average species diversity, H(S), is 2.68 (range from 2.44 to 2.92) and is nearly the same as in thanatotopes A and B.

Thanatotope E

Benthic Fauna. This thanatotope is dominated by *Cibicides soendaensis* and *Amphistegina* sp. (each greater than 15%).

Latibolivina subreticulata, Cibicides sp. and *Sigmavirgulina tortuosa* each constitute greater than 5% of the total population.

Planktic Foraminifera. The planktic foraminiferal average (=66%) is nearly the same as seen in thanatotope D.

Species Diversity. Average species diversity, H(S), in this thanatotope is 2.69 (range from 2.62 to 3.09) a value very close to that in thanatotope D.

Thanatotope F

Benthic Fauna. This thanatotope is represented by 3 samples and comprises only 7 species. The average species composition is similar to those in the previously described thanatotopes. *Cibicides soendaensis, Amphistegina* sp (each represented by greater than 20%), and *Cibicides refulgens* (represented by greater than 10%) are the dominant forms, while *Brizalina spp., Globocassidulina pacifica, Cibicides* sp. are represented by more than 5%.

Planktic Foraminifera. The planktic foraminiferal percentage ranges from about 61% to 64% average being 62%.

Species Diversity. H (S) is low (average 2.37) as compared to those in other thanatotopes. This is partly due to low value of S and partly to low value of E.

Thanatotope G

Benthic Fauna. Only two samples constitute this thanatotope. The most dominant form is *Amphistegina* sp. followed by *Cibicides soendaensis* and *Cibicides refulgens* (each more than 10%). Species making 5% and above are *Cibicides* sp., *Cibicides foxi* and *Brizalina* spp. and *Globocassidulina pacifica, Elphidium crispum, Brizalina* sp. and *Globocassidulina subglogosa* constitute 2% to 5% of the total benthic foraminifera.

Planktic Foraminifera. Average percentage of planktic foraminifera (about 64%) is nearly the same as found in other thanatotopes.

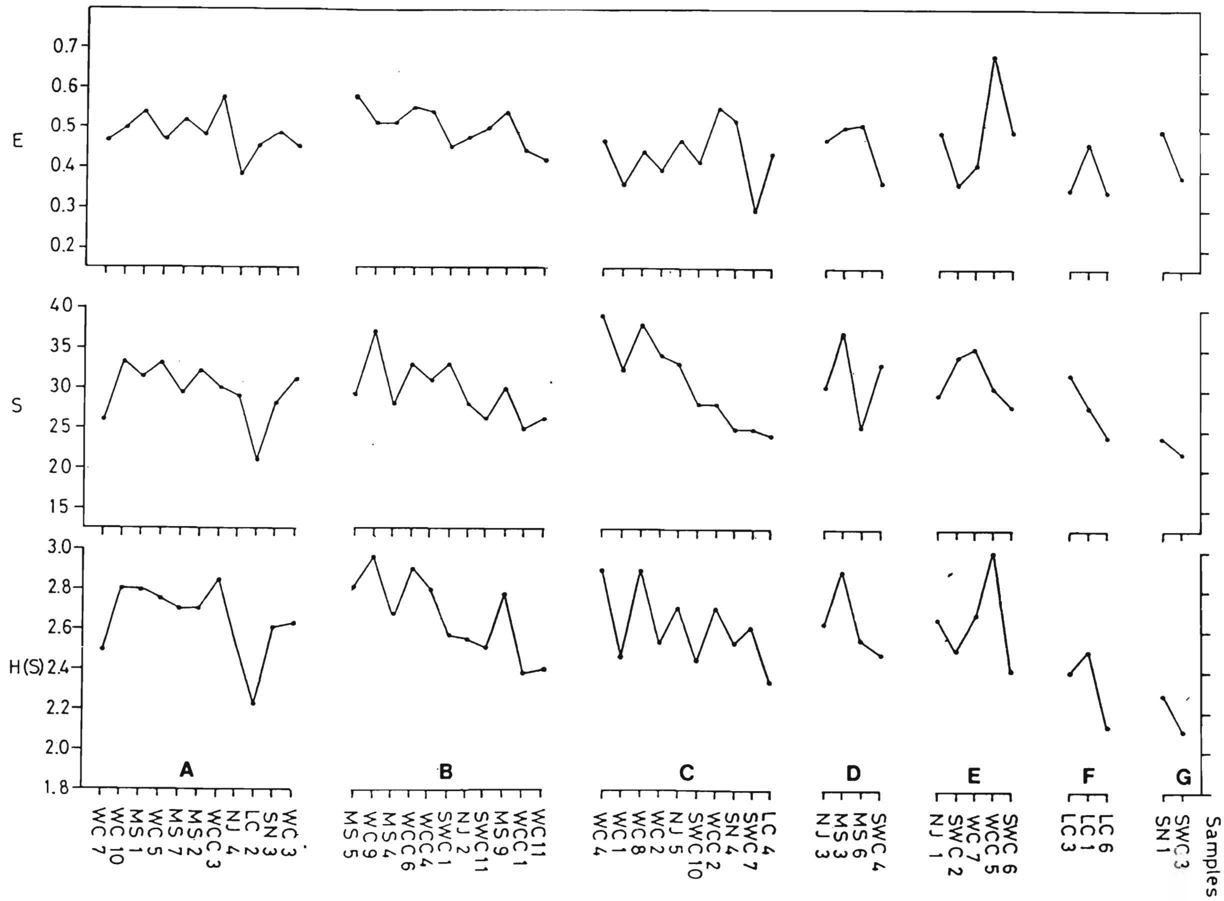

Fig. 5. Plots of species diversity [H(S)], species number [S] and equitability [E] in the samples of each thanatotope (A to G). To visualise the trend, the values are joined by a line.

Species Diversity. A low H(S) is seen in this thanatotope (=2.31). This is because of a relatively low (S) (average 23) and low E as compared to those in most other thanatotopes.

Ungrouped Samples

Benthic Fauna. 7 samples remained ungrouped with any of the clusters, as they join at very low levels. In all these samples, the most dominating forms are the same as found in the identified thanatotopes, i.e., *Amphistegina* sp. and *Cibicides soendaensis*. Benthic foraminiferal composition, H(S), E and percentage of planktic foraminifera in the ungrouped samples are shown in fig. 6.

DISCUSSION

The thanatotopes show striking similarity in faunal composition. In all the thanatotopes, *Cibicides soendaensis, Amphistegina* sp., *Cibicides refulgens, Latibolivina subreticulata, Sigmavirgulina tortuosa, Cibicides foxi* and *Cibicides* sp., are the common forms (>5%). Among these, *Cibicides soendaensis* and *Amphistegina* sp. are dominant (>10%) in all the thanatotopes: *Cibicides refulgens* dominates in thanatotopes E and F. Other species present in the thanatotopes are *Elphidium crispum* which constitute 2-5% of the total benthic fauna.

Amphistegina sp. and *Cibicides soendaensis* together constitute about 29% to 32% of the total benthic foraminiferal fauna in each thanatotope. *Amphistegina*, as a genus, is a shallow water form (Scott, 1970; Boltovskoy and Wright, 1976; Murray, 1973; Todd, 1976). The forms of *Amphistegina* sp. reported in Baratang Island are thin and small except in a few samples containing large forms. *Cibicides soendaensis* occurs between 25 and 1000 metres and is more abundant in depths shallower than 300 metres (Frerichs, 1970).

Maximum concentration of *Cibicides* is recorded today in outer shelf depths where it is one of the most prominent genera (Boltovskoy and Wright, 1976). Cumulative percentage of *Cibicides* in the thanatotopes

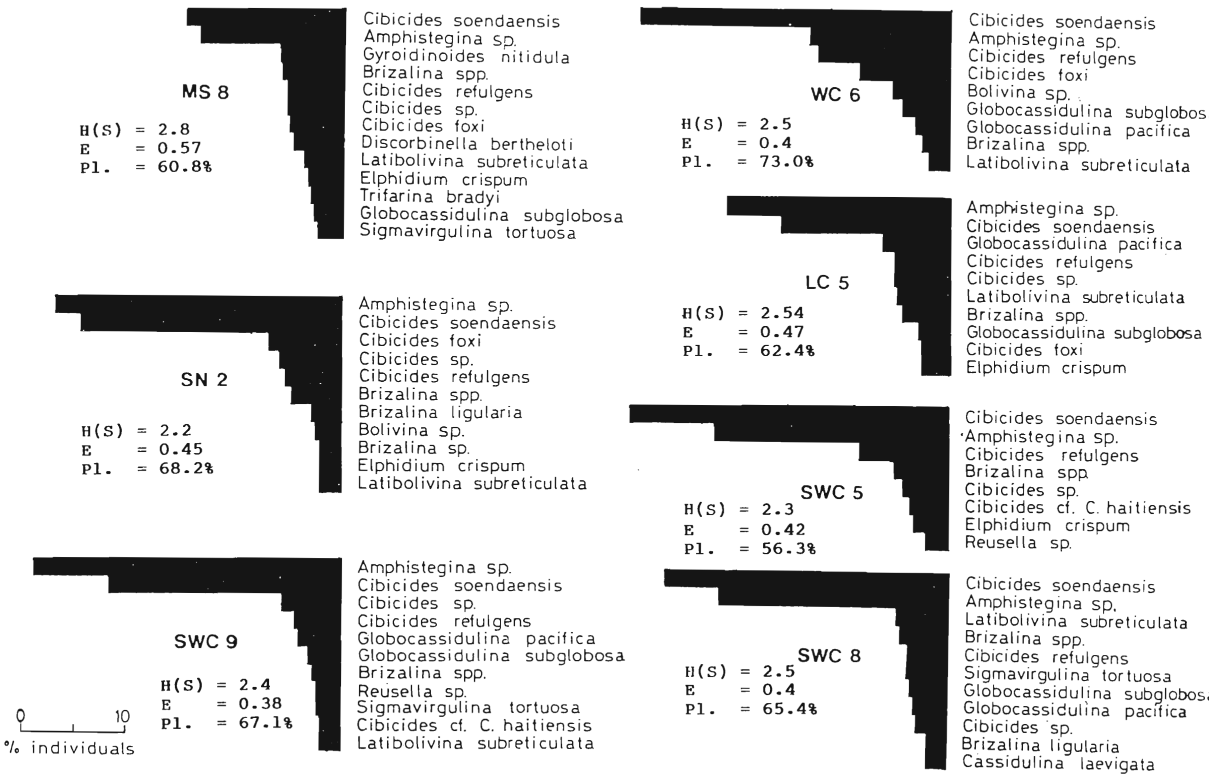

Fig. 6. Histogram of percentage occurrence of benthic foraminifera (>2%) in the ungrouped samples. Values of species diversity [H(S)], equitability [E] and planktic foraminiferal percentage [Pl.] are also indicated for each sample.

renges from about 33% to 40%. Among species of *Cibicides, Cibicides refulgens* is a well represented form, besides *Cibicides soendaensis*, and usually has an abundance of more than 5% and occassionally greater than 10%. In the Andaman Sea, it has a depth range of 78-210 metres (Frerichs, 1970). Pujos-Lamy (1973) found its maximum abundance in the outer shelf (outer neritic zone, as defined in this study) in the Gulf of Gascogne.

Other significant species of thanatotopes include *Latibolivina subreticulata, Cassidulina laevigata, Elphidium crispum* and *Discorbinella bertheloti. Latibolivina subreticulata* is found today up to a depth of about 320 metres in the Andaman Sea, with its maximum occurrence in the shallower part (up to about 50 metres) (Frerichs, 1970). *Cassidulina laevigata* is a common to abundant species in the shelf sediments (64-190 metres) off Vishakhapatnam (Subba Rao *et al.*, 1979) and between 63 and 105 metres in the Andaman Sea (Frerichs, 1970). *Elphidium crispum* shows its common occurrence (1%-5%) up to a depth of about 36 metres and rare occurrence (<1%) below this depth, in the shelf off Vishakhapatnam, Bay of Bengal (Subba Rao *et al.*, 1979). Similar depth occurrences for *Elphidium crispum* have been noted by Frerichs (1970) (67-225) metres) and by Setty and Nigam (1980) (below 50 metres) in the Andaman Sea and Arabian Sea respectively. Matoba (1970) and Akimoto (1990), too, reported its common occurrence in the shallow waters of continental shelf on the east coast of Japan. *Discorbinella bertheloti* is a common middle and outer neritic species (85-185 metres; Oki 1989).

As already pointed out, percentage of planktic foraminifera in samples has been used by a number of investigators to estimate depth of deposition. Study of Grimsdale and Morkhoven (1955) showed more than 80% of planktic species at a depth of 750 metres and more than 90% at 1000 metre depth. According to Phleger (1951), at depths more than 2000 metres, foraminiferal assemblage consists of 99% or more of planktic species. Data of Pflum and Frerichs (1976) from the Gulf of Mexico show that fewer than 50% planktics are found in the neritic zone; 50%-90% in the upper bathyal zone (200-1000 metres) and more than 90% in the mid and lower bathyal zone (1000-4900 meters). According to Boersma (1980), planktic foraminiferal fauna constitutes about 15%-30% of the total fauna in the middle shelf sediments, approximately 50% in the outer shelf and 50%-85% in the upper continental slope.

Average values of H(S) and percentage of planktic foraminifera in the thanatotopes vary within narrow limits. While in thanatotopes A to E, averge values of H(S) remain fairly constant (vary from 2.55 to 2.69), slightly lower values are seen in thanatotopes F and G (average 2.37 and 2.31 respectively). The low values are due to the presence of lesser number of species in the samples constituting these thanatotopes. Planktic foraminiferal average in different thanatotopes is nearly constant (ranging from 62.2% to 65.9%). These evidences, along with uniform lithology and striking similarity in the faunal composition of the thanatotopes suggest uniformity of environment of deposition, the depth remaining nearly constant throughout the deposition of sediments. Also, depth distribution of species constituting the thanatotopes as well as comparison of planktic foraminiferal percentage in the thanatotopes with the depth-percentage relation of planktic foraminifera in the modern oceans suggest deposition in the outer neritic zone, at about 200 metres.

The ungrouped samples have the same faunal composition as found in the thanatotopes with *Amphistegina* sp. and *Cibicides soendaensis* as the dominating forms, followed by species of *Cibicides*, including *Cibicides refulgens, Latibolivina subreticulata, Brizalina* spp. etc. The various criteria described earlier, when applied to the ungrouped samples, show same environment for these samples.

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