BENTHIC FORAMINIFERAL SPECIES DIVERSITY PATTERN
IN A LATE MIocene—EARLY PLIOCENE SEQUENCE
OF NEILL ISLAND, ANDAMAN SEA

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ABSTRACT—Species diversity of benthic foraminifera in the samples of a Late Miocene to Early Pliocene sequence at Neill Island, Andaman Sea, is determined using the Information Function technique. Plots of diversity show a decreasing value towards the younger part of the sequence. Paleobathymetric evidences suggest deepening of the basin during the deposition of the sequence. A discussion on the possible causes of species diversity pattern is provided, and it is suggested that the decrease in diversity towards the younger part of the sequence could have been the result of environmental instability, nutrient supply and predation.

Key words: Benthic foraminifera, species diversity, Late Tertiary Andaman–Nicobar Islands

INTRODUCTION

A remarkably well-developed deep-water marine sequence is present on Neill Island, Andaman Sea. The exposures occur on the western, northeastern and eastern coastal tracts. The present study is confined to two sections, viz., the East Coast Section and the Nipple Hill Section (Fig. 1). Benthic foraminiferal species diversity has been determined by quantitative methods and an attempt is made to understand the possible causes affecting diversity.

METHOD OF STUDY

The laboratory method included picking of all benthic foraminifera from an aliquot of washed residue (>74 μm size) of each sample. The aliquot was so chosen that it yielded about 300 individuals.

Species diversity, in the simplest term, is the number of species present in a specified sample. This measure, however, does not take into account the relative abundance of species. Also, diversity in different samples cannot be compared with one another because of variable sample size. To minimize such problems a number of mathematical expressions are used to measure the species diversity. The most commonly used is the Shannon-Wiener Information Function and this has been employed in this study. This is expressed as

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

where $p_i$ is the proportion of the $i$th species in a sample. For determining species abundance, i.e., equitability, a number of expressions are available. The expression proposed by Buzas and Gibson (1969) is used here and is expressed as:

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

Prior to the quantification of data to determine species diversity, Hurlbert's method (1971) for the expected number of species for sample of 100 individuals, $E(S_{100})$ was applied so that $H(S)$, $S$ and $E$ could be compared directly. Species diversity values are also determined using original data of distribution of species to see their relations with the diversity values after Hurlbert's method of quantification.

BENTHIC FORAMINIFERA:
SOME OBSERVATIONS

The assemblage consisting of 140 benthic foraminifera belongs to lower bathyal depths. Cluster analysis (Q-mode) recognized four thanatotopes (Fig. 2).

A comparison of distribution of fossil benthic foraminifera in the sequence with the depth distribution of these species in the Andaman Sea (Frerichs, 1970) indicated deepening during the deposition of sediments of the younger part of the sequence. Planktonic/benthic foraminiferal ratios also corroborate the deepening event. The changes in the environment brought about as a result of deepening of the basin are manifested in the form of four thanatotopes.

A large number of foraminiferal tests show signs of predation in the form of circular holes (Fig. 3). An examination of the size of the holes indicates that the predatory organisms possibly belonged to different species. However, the nature of the predators could not be ascertained.

RESULTS

Species diversity

The diversity values of benthic foraminifera vary from sample to sample, but an overall gradual decline is observed towards the upper part of the sequence (Fig. 4). The diversity is relatively high in samples N1 to N15. From N16 to N38, the values, in general, are low.

Values of $H(S)$, using original distributional data of
Fig. 1. Sample locality, stratigraphic position of samples and lithology of the studied sections. Age is based on planktonic foraminifera (Srinivasan, 1977, 1984).

Fig. 2. Q-mode dendrogram showing four sample groups identified in the sequence.
species, are relatively high (Fig. 4). The trend in species diversity values, however, is the same in both cases (with and without the use of Hurlbert’s method).

**Equitability**

Equitability is high in most of the samples; in 28 samples it is higher than 0.6. Samples N2, N20 and N25 have quite high values (0.70, 0.70 and 0.69 respectively), while sample N16 has the lowest value (0.49).

**Species number**

The species number ($S$) is higher in samples N1 to N17, ranging from 29 to 39. In samples N18 to N38, the values of $S$, in general, are lower, ranging from 32 to 34.

**Species diversity in deep seas**

A number of investigators have attempted to observe and understand the causes of species diversity in benthic organisms in modern oceans. Most of them have dealt with megafauna and found that diversity is a factor of environmental stability, productivity, spatial heterogeneity, predation and competition (Hessler and Sanders, 1967; Sanders, 1968, 1969; Rex, 1973, 1976, 1981; Menge and Sutherland, 1976). The areas of these investigations ranged from the intertidal zone to the deep-sea environment. Only a few of these workers studied species diversity in deep seas. Rex (1973), for example, noted increased diversity of gastropods from the continental slope to the abyssal rise but found a decreasing trend on the abyssal plain. He considered increased environmental stability to be the cause of increased diversity. Lower

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**Fig. 3.** Some benthic foraminiferal species showing predatory holes. 1, *Uvigerina gemmaiformis* Schwager; 2, *Sphaeroidina bulboides* d’Orbigny; 3, *Robula nikobarense* (Schwager); 4, *Proxifrons foliacea* (Schwager). Length of bar represents 200 μm.

**Fig. 4.** Plots of species diversity ($H(S)$), species number ($S$), and equitability ($E$). All samples are quantified at 100 individuals by Hurlbert’s method (1971). Plots of $H(S)$, based on original data, are also shown (joined by dashed line).
diversity on the abyssal plain was attributed by him to the extremely low productivity on the abyss.

Hessl and Sanders (1967) opined that the theory of climatic stability best explains high diversity in deep seas.

Rex (1981), who determined species diversity in a number of organisms, found a parabolic pattern of diversity. His observations showed maximum diversity at middle to lower bathyal depths which decreased with increasing distance seaward on the abyssal plain. He suggested that the level of species diversity in the deep sea is related to productivity, competition and predation.

Studies on species diversity in benthic foraminifera have been carried out by a limited number of workers (Gibson, 1966; Buzas and Gibson, 1969; Ikeya, 1971a, b; Murray, 1973; Gibson and Buzas, 1973; Sen Gupta and Kilbourne, 1974; Lagoe, 1976; Aoshima, 1978; Ingle et al., 1980). Among these, only a few, viz., Buzas and Gibson (1969), Gibson and Buzas (1973), Lagoe (1976) and Ingle et al. (1980) dealt with benthic foraminiferal species diversity in deeper parts of the sea. Observations by these investigators are of relevance to the present problem and are dealt with here.

Observations by Buzas and Gibson (1969) on the diversity of benthic foraminifera in the deep-water western North Atlantic show that maximum diversity occurs at abyssal depths of greater than 2500 metres. Their observation shows that the diversity rises sharply and reaches a maximum at about 5000 metres. According to them the high diversity in the deep sea is due to environmental stability which was acquired with time.

Gibson and Buzas (1973) studied diversity of modern benthic foraminifera of the eastern margin of North America in depths ranging from a few metres to more than 5000 metres. Their area of study extended from the Arctic to the Gulf of Mexico. The species diversity values in samples from deeper water along a number of traverses show that there is an overall increase in the diversity with depth. However, in the northwestern Gulf of Mexico, the diversity which increases up to a depth of about 100 metres steadily decreases below this depth.

Lagoe (1976) studied benthic foraminiferal species diversity in samples from the central Arctic Ocean in a depth range from about 1000 to 3700 metres. He observed a decrease in diversity with increasing depth. He ascribed low diversity at greater depths as possibly due to instability in resource supply and youthfulness of the marine environment.

Ingle et al. (1980) related species diversity and abundance of benthic foraminifera with water-mass properties. They observed that low diversity and abundance correlate with waters low in oxygen, higher salinity and high nutrient content, and high diversity and abundance correlate with waters high in oxygen and reduced salinity.

**PATTERN OF DIVERSITY IN THE STUDIED MATERIAL: DISCUSSION**

Various studies on diversity in deep seas point to the fact that the factors responsible for affecting diversity in the megafauna and benthic foraminifera are nearly the same. The foregoing discussions point out that these factors could be environmental stability, supply of nutrients, competition, predation and spatial heterogeneity. However, their relative importance varies from place to place and with depth. The task of understanding role of these factors in the case of fossil foraminifera becomes more difficult and one has to depend on evidences available within the sequence.

In the present study, the lowering of diversity is associated with the deepening of the depositional basin as already stated in the earlier part of the text. Thus, instability of the environment produced as a result of deepening seems to play a major role in affecting diversity. As pointed out by Valentine (1971), Lagoe (1976) and Rex (1981), the role of nutrients too is important at greater depths. The amount of nutrients will be lesser at greater depth and will affect benthic foraminifera as well as other microscopic organisms which form the food of the former. Lack of supply of nutrients with increasing depth could be another factor causing decrease in diversity towards the younger part of the sequence.

Extensive predation could have eliminated some species and be partly responsible for reduction in benthic foraminiferal diversity (Sharma and Kumar, 1987). Spatial heterogeneity, in the form of substrate, does not seem to play any role. Constant lithology from the base to the top of the sequence suggests homogeneity of substrate.

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