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Relict benthic foraminifera in surface sediments off central east coast of India as indicator of sea level changes

Sanjay Singh Rana*, Rajiv Nigam & Rajani Panchang

Micropaleontology Laboratory, National Institute of Oceanography, CSIR, Dona Paula, Goa - 403 004, India
*[E-mail: sanjay@nio.org]

An attempt has been made to reconstruct sea-level variations along the central east coast of India during the late Pleistocene and early Holocene. A total of 39 surface sediment samples collected from water depth range of 27 – 2,777 m were studied for foraminiferal content. The samples within the depth range of 36-110 m showed presence of relict foraminiferal tests along with recent foraminifers. The relict foraminiferal assemblage of *Amphistegina, Operculina, Calcarina* and *Alveolinella* in the selected surface samples is characteristic of coral reef environment and has been inferred as evidence for past low sea levels. Based on extrapolation of previously published radiocarbon dates from the region, we propose a pliable sea level curve for the period between ~9,000 to ~14,000 years BP.

[**Keywords:** Sea level, Holocene, relict foraminifera, coral sclerites, coral reef]

Introduction

A general interest has been created worldwide in the current and future global sea-level change. This interest has grown along with the concern over global warming due to the increasing amount of greenhouse gases. Accelerated sea level rise and associated inundation of large chunk of land mass, modification of rainfall pattern and associated agricultural pattern, enhance frequency of storms as well as loss of coastal property are some of the consequences of global warming due to greenhouse gases which require our immediate attention. To develop predictive models for sea-level changes, a stage has reached where investigators of climate and sea-level relationships call for long-term records of sea-level changes in the past and more so since the end of the last glaciation. If a suitable site is chosen carefully, some information concerning the sea level can be derived from the foraminiferal assemblages, using indirect means[1,2].

In view of this, quite a few attempts have been made to decipher sea-level fluctuations along the west coast of India[3-5]as well as along the east coast of India[6-13]. However, the studies along the east coast of India have not been able to suggest a comprehensive picture of sea level fluctuation along the east coast of India during Holocene.

Oceanic sediments are one of the best archives of palaeoclimatic records. Bay of Bengal is one unique sedimentary basin in the Indian vicinity where, due to relatively higher influx of sediments, high resolution studies are possible. For the present study, foraminifera have been used to study the Bay of Bengal, its processes and variations in them through time and space. Foraminifera are eukaryotic unicellular organisms with the general characteristics of protists[14]. Their exoskeletons are commonly made of calcium carbonate, while the rest have agglutinated shells made up of sediments or shells of dead organisms. Due to their diversity, which is a function of their ecological adaptation, each environment is characterized by different foraminiferal assemblages. Their small size, sensitivity to slight changes in the environment and ability to preserve these changes in their hard part, give them an immense applicability in the field of palaeoclimatic reconstruction and environmental monitoring. The present work was taken up to understand the foraminiferal distribution and ecology to decipher the present and past environments along central east coast of India.

Materials and Methods

The central east coast of India forms the western boundary of Bay of Bengal, which is the northeastern

*Corresponding author:
Telephone: 0091-832-2450489
Fax: 0091-832-2450609

branch of the Indian Ocean (Fig.1). Huge fresh water and sediment influx from major rivers has profound influence on the Bay of Bengal. These eastward flowing peninsular rivers have relatively steep profiles in comparison to the rivers Ganges and Mahanadi. Majority of the submarine canyons in the Bay of Bengal have been reported along the east coast of India, mostly where break in slopes occur at water depths of 90-125 m. The origin of the fluvial channels identified as canyons on the mid to outer shelf has been related to the low sea-level stand. During the transgression phase, enlargement of some channels to continental slope turned them to active submarine canyons- active sites of slumping and gravity flow carrying sediments from shelf to rise[15]. Similarly, they have compiled various evidences of past low sea stands along the Bay of Bengal at various depths in the form of coarser sediments which are not associated with present-day near shore sediments, sands rich in heavy minerals, peat beds, carbonate sands and carbonate buildups.

Samples collected along central east coast of India (between 10°-15°N and 79°-81°E) during the *Sagar Kanya* cruise (SK-187) (Jan. 23- Feb. 17, 2003) under

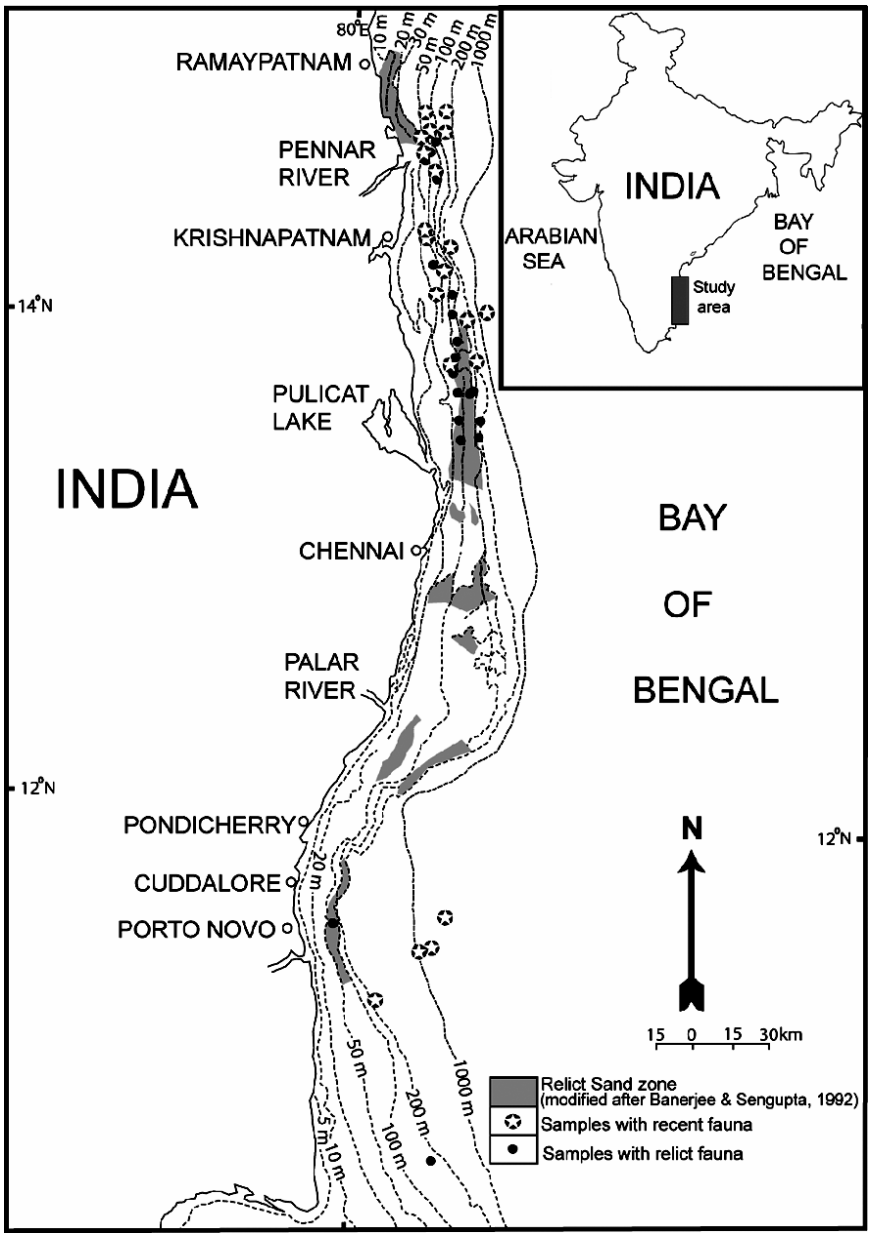

Fig. 1—Study area map showing the sampling locations in present study and the relict sand zone as mapped by Banerjee & Sengupta[23]

"BENFAN" project and surface samples (collected by Geological Survey of India, Marine Wing, Visakhapatnam), were used for the present study. The study is based on 39 surface samples (grabs, core tops of piston and gravity cores) collected from 27 to 2,777 m water depth (Fig. 1).

In the laboratory, the samples were processed using the standard procedure of drying, soaking, treatment with sodium hexa-meta phosphate and hydrogen peroxide to disintegrate clay and dissolve organic matter respectively. From the sand fraction (>63 µm sediment size), ~ 300 benthic foraminifera were picked to study their abundance and distribution.

Results

Out of the 39 surface sediment samples analyzed, 14 samples yielded some relatively larger foraminifera with peculiar tests apart from the normal recent benthic foraminifera which are comparatively smaller in size with glossy and smooth shells. The larger foraminifera, in contrast to recent foraminifera, are earthy and dull in appearance and identified as relict foraminifera. Apparently, lack of burial in the sediments is the reason that these tests remained exposed on sea bed/floor for thousands of years and so this dull appearance. The term 'relict foraminifera' is used for those foraminifera that remain exposed on the seafloor for long geological periods without any major transportation, and can be identified by their earthy colour, dull luster, broken parts with deposition of some secondary material[16]. The larger foraminiferal genera encountered in the present study mainly include *Amphistegina, Operculina, Calcarina* and *Alveolinella* (Fig. 2). In addition sclerites belonging to the soft coral assemblage, *Lemnalia, Chironephthya* and *Acalycigorgia* are also encountered.

Discussion

The larger foraminifera *Amphistegina*, *Operculina, Calcarina* and *Alveolinella* found in the present study are considered as typical fauna for coral reef environment[17]. Secondly the samples containing relict foraminifera also contain abundant soft coral sclerites (Fig. 2). Such relict foraminiferal and coral sclerite assemblage has also been reported along the west coast of India[18] and Myanmar[19], suggestive of presence of coral reefs in the past.

The sclerites found in the present study belong to the soft coral assemblage of *Lemnalia, Chironephthya* and *Acalycigorgia*, have a depth preference for 5 to 20 m and inhabit flat reefs[20]. The occurrence of these sclerites strengthens our postulation about the existence of former corals at a depth approximately between 60 to 80 m. Similar sclerite fauna has also been recorded along the west coast of Myanmar[19] and has been used to decipher the coral ecology in the region in the past.

Fossil coral reefs have been reported before[21,22] in the study area, off Mahabalipuram (115 m) and of Karaikal (125 m), and were suggested to represent the globally lowest sea level stand during the Last Glacial Maxima (LGM). Singh & Swamy[15] have compiled all the reports of relict sediments from east coast shelf and the records of low sea-level stand which includes heavy minerals enriched sands, peat beds, oolite, carbonate sand and carbonate buildups. These evidences of low sea stands have been assigned to three spatially pronounced depth zones[9,23], approximately 30 m, 60 m and 110 m. These different sea stands have been attributed to episodic events of sea level rise and stand. However, the samples containing relict fauna occur within a depth zone of ~36 to 110 m, though majority of the locations are within the water depth zone of 60 to 80 m. When these sample locations were plotted on the near shore bathymetric map (Fig.1), they coincided with relict sand zones deposited during the past low sea stands. Mohana Rao & Rao[9] had postulated the possible presence of a reef feature slightly buried under a thin veneer of sediment at ~60 m depth. The occurrence of abundant relict reef fauna at this depth in the present study confirms that postulation.

Five published radiocarbon dates[8,9,21,22] along the east coast of India were plotted as a function of the depth at which the samples dated were found, to get an approximation of the trend of the early Holocene sea level rise (Fig. 3). The age of the 14 samples with relict fauna was extrapolated on to this age curve. The samples located at a depth of 110 m can thus be assigned to age of ~13,600 years B.P. Similarly the samples located at 36 m water depth can be assigned to 8,900 years B.P.

To reconstruct the pliable sea-level curve in the study area, the ecology of the soft coral species (as interpreted from the sclerites) was used. The applicability of coral sclerites is due to the fact that different species of soft corals produce different forms of sclerites and thus serves as the basis of identification. The distribution of soft coral

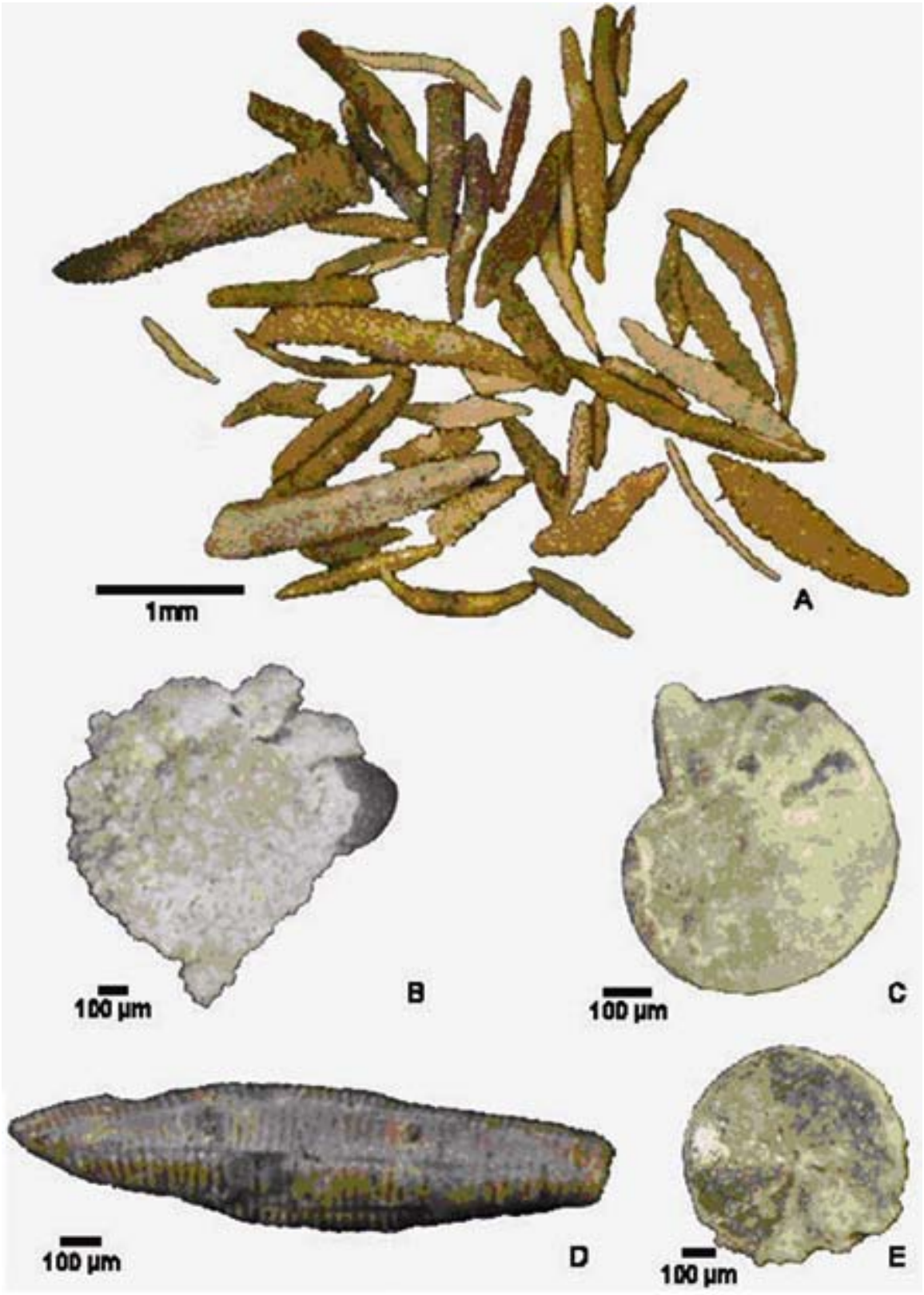

Fig. 2—Soft coral sclerites encountered in the study area (A) and Relict larger foraminiferal assemblage typical of coral reef: *Calcarina* (B), *Operculina* (C), *Alveolinella* (D) and *Amphistegina* (E), found in the study area.

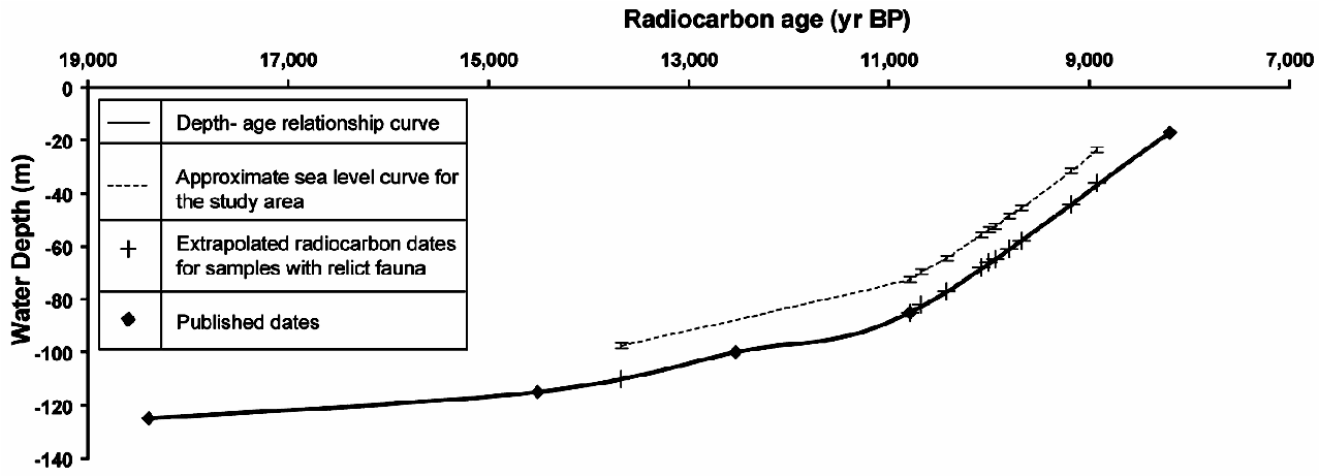

Fig. 3—Age-Depth relationship curve for the study area constructed on the basis of 5 published dates: Vaz[21,22]; Rao *et al.*[8] and Mohana Rao & Rao[9]. Dotted line represents pliable sea level curve during ~ 13,600-8,900 years BP as derived from extrapolating the dates for the samples containing relict fauna.

assemblages are depth dependant and thus in the present work can help in assigning the sea level. The soft coral assemblage found in this region suggests a depth preference of 5-20 m. Thus, considering 12.5 m as an average optimum depth for the proliferation of the coral fauna, a pliable sea level (dotted line in Fig. 3) is being proposed for the study area, representing the geological time between 8,900 and 13,600 years B.P. Based on this data, it can be said that the average rate of sea level rise during this period was ~1.5 cm/yr.

Due to lack of radiocarbon dates in the study area, this method of extrapolation of dates for the present samples, using published dates as a reference, has been adopted. Inferences drawn through this study are site specific and cannot be used generally to assign sea levels all along the east coast of India. The complex bathymetry of the region, heavy fresh water and terrigenous influx complicates the procedure for dating past sea level surfaces along east coast of India.

Conclusion

Occurrence of relict fauna at three different depths 110-80 m, 80 to 60 m and 30 m probably indicates different sea stands, suggesting episodic sea level rise during Late Pleistocene and early Holocene. A tentative sea level curve is also proposed for period between ~9,000 to ~14,000 years B.P. for central east coast of India. The reconstruction of paleosealevel variations over the Bay of Bengal region during the last few thousand years is still in its infancy. A comprehensive sea level curve for the Bay of Bengal similar to the one proposed for the eastern Arabian Sea[5] is need of the hour.

Therefore, more detailed work on marine sediments, based on many parameters from a number of core samples from different geographical locations is called for to account the hiatus in sea-level records, particularly <9,000 years BP. This also requires excellent geochronological control (preferably AMS radiocarbon dates). Consequently, paleoclimatic changes on the geological and historical time scales should continue to be investigated in order to provide a background of natural climatic variability over which human impact could be more easily evaluated. The results obtained from marine sediment studies need to be further supported by evidence from tree-rings, lake sediments, etc. which constitute continental paleoclimatic records.

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