Chapter 1

Introduction

*Climate change is the defining challenge of our age*

Ban Ki-moon

The knowledge of natural climatic variability during recent and geological past is important to evaluate anthropogenic impact on the natural processes. In view of the absence of written/instrumental records of climatic changes during geological past, reconstruction of paleoenvironment on geological time scale requires indirect indicators/proxies of climatic changes. Oceanic sediments are one of the best archives of palaeoclimatic records. The Bay of Bengal is one unique sedimentary basin 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.

1.1. Subject of the study: Foraminifera

Foraminifera are eukaryotic unicellular organisms with the general characteristics of protists. Their exoskeletons or ‘test’ are commonly made up 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. On the basis of habitat, foraminifera have been classified in two types, viz. benthic and planktic. Benthic foraminifera live on the sea floor or in upper few centimeters of oceanic sediments while planktic foraminifera float on sea surface or sea water columns. Because of their habitat, both types of foraminifera have different applications. Benthic foraminifera are used for bottom water and sediment studies and related processes.
while planktic foraminifera are used to study processes related to sea surface and upper water column. Abundance, diversity, shell weight, assemblage, isotopic and elemental ratio, etc are a few of the important parameters of foraminifera that have been extensively used all over the world to draw meaningful conclusions regarding paleoecology and paleoenvironment of the studied area. In this study also, foraminiferal distribution has been studied from the region off central east coast of India, in order to understand the relationship between foraminiferal characteristics and prevailing ecology of study area. This relationship has further been used to know the paleoenvironment history of the area off central east coast of India.

1.2. Previous work

A first few reported works on foraminifera from the Indian Ocean include that of Carter (1880), Chapman (1895), Murray (1889), Hofker (1927, 1930) and Stubbings (1939a, b). Gnanmuthu (1943) and Ganapati and Satyavati (1958) are the first published Indian works from the east coast of India. While former concentrated their work on Krusadi Island from Gulf of Mannar, later studied samples from littoral zones of Kolkatta (formerly known as Calcutta) to Chennai (formerly known as Madras) and reported 103 species. Some of the other notable studies from east coast are discussed below. Occurrence of *Asterorotalia trispinosa* was reported by Ghose (1966) from Digha beach, West Bengal. Bhalla (1968, 1970) studied beach fauna of Visakhapatnam and Madras and reported occurrence of four species for the first time from the Indian waters. Rao *et al.* (1979) recorded 124 benthic foraminiferal species from the Visakhapatnam shelf. Rao (1982) reported 284 species from the Visakhapatnam harbor complex. Naidu (1983) recorded 101 foraminiferal taxa from Sanidanigadda and Bendi lagoon. Reddy and Rao (1984) observed the relationship between living population of benthic foraminifera and salinity variation in Pennar estuary. Naidu *et al.* (1985) studied foraminifera as pollution indicators from Visakhapatnam harbor complex. Kumar (1988) recorded 108 species of foraminifera from the Palk bay. Rao *et al.* (1990) distinguished four factor assemblages responsive to environmental variables (substrate and organic matter content) from Q-mode factor analysis of 63 benthic foraminiferal species. Jayaraju and Reddi (1995) studied coastal and estuarine sediments of Kovalam- Kanyakumari- Tuticorin sector and presented 12 factor assemblages by factor analysis (Jayaraju and Reddi, 1996). Effect
of river discharge on the test morphology of benthic foraminifera was studied by

Jayaraju and Reddi (1997) in recent inner shelf region sediments off Pennikyal area. Rao et al. (1998) recorded 30 species of lagenid foraminifera from the shelf sediments off Karikkattukuppam. Kathal and Bhalla (1998) discussed significance of Rotorboides granulosum, collected from the recent littoral sediments along the Palk Strait and Kakinada bay. Glandulina spinata a rare foraminiferal species was reported
first time from the Indian waters by Rao et al. (1999) from Karikkattukuppam. Biozonation of benthic foraminifera of Oligocene to Pleistocene, from Krishna-Godavari and Cauvery basin was done by Dave (2000). Rao and Periakali (2001) reported a new foraminiferal taxon, *Cococarota madrasensis* from inner shelf of Bay of Bengal. Gandhi and Rajmanickam (2004a, b) studied foraminifera from Palk Strait sediments as a tool for siltation studies and identified 102 species. 24 deepwater benthic foraminiferal species were identified from Tuticorin coast by Nagendra et al. (2004). Saraswat et al. (2005) used abundance and mean proloculus size of *Epistominella exigua* from distal Bay of Bengal to study paleomonsoonal history of the area. Naidu et al. (2005) recognized benthic foraminiferal biofacies from Goguleru creek, Andhra Pradesh. Nagendra et al. (2005) studied tsunami sediment along Nagapattinam coast and assigned their habitat from coastal to inner shelf. Ramaswamy and Gaye (2006) studied mass flux of diatom opal, planktic foraminiferal carbonate and coccolithophorid carbonate in the Arabian Sea, Bay of Bengal and equatorial Indian Ocean. They noticed that due to high salinity changes in the northern and central Bay of Bengal, there is a reduction in planktic foraminiferal carbonate flux while diatom opal and coccolithophorid carbonate flux remain steady or increases slightly. Raghav and Malmgren (2006) have correlated abundance of *Globigerionoides ruber* with sea surface temperature in southeast Bay of Bengal. They identified five climatic events on the basis of depletion and abundance of *G. ruber*. All previous studies from the Bay of Bengal carried out till the year 2008 are described in detail in Khare et al. (2007) and Panchang et al. (2008) and are marked area-wise in Fig. 1.1. Recently, Ahmed et al. (2008) inferred surface and deep water characteristics for last ~60 thousand years from stable carbon and oxygen isotope records of benthic and planktic foraminifera from northeast Indian Ocean. Gadi and Rajshekhar (2009) studied intertidal foraminifera along the Indian Coast and Amini atoll of Lakshdweep Islands and prepared a scanning electron photomicrograph-illustrated catalogue.

1.3. Selection of the study area

While reviewing the previous foraminiferal studies from the region off east coast of India, it was observed that the studies are in patches and mostly centered around either big cities like Visakhapatnam, Chennai or on beaches, estuaries, lake and
mudflats (e.g. Pulicat lake, Gulf of Mannar and Pennar estuary). A very little emphasis has been given to the rest of the areas off central east coast of India. It can be attributed to the easy approach to the studied areas and may be due to the less financial aids. In recent years south east coast of India, especially the areas surrounding Nagapattiman has undergone various types of studies after tsunami effect. In view of the above, it was decided to carry out foraminiferal study from the central east coast of India. This area was especially chosen due to the influence of various rivers, which will help in understanding the effect of riverine discharge on the foraminiferal community. Besides Krishna and Godavari, other major rivers which drain along the central east coast of India are Cauvery, Pennar and Palar. Majority of rivers of Indian subcontinent drain in to Bay of Bengal bringing with them loads of fresh water and sediment. This low salinity water and suspended load significantly affects the biota of the area. During monsoon, high precipitation changes the properties of seawater, especially in the coastal areas, subsequently affecting the biota inhabiting these areas. As discussed earlier, due to their unicellular and minute size, foraminifera are very sensitive to the surroundings and their preservation potential makes it possible to record environmental changes, in their hard shell. Foraminifera have been effectively used to study paleoenvironment from the west coast of India. Therefore, it was decided to study the distribution of benthic foraminifera from the central east coast of India to understand their relationship with the prevailing environment and on the basis of these studies, the paleoenvironmental history of the area.

1.4. Objective of the study

In view of the above, present study was carried out with following objectives:

a) To study the surface distribution of benthic foraminifera off the central east coast of India.

b) To correlate the distribution of benthic foraminifera with the prevailing ecological factors.

c) To document subsurface distribution of foraminifera to reconstruct paleoclimatic changes.

d) To decipher pattern (including cylicity, if any) in the paleoclimatic changes.
The present study will help to fill the gap identified in foraminiferal study, during literature survey, from the region off central east coast of India. Study of surface sediments will help to understand the relation between benthic foraminifera and different ecological factor prevailing in the area. This relation can be used in subsurface sediments to carry out paleoenvironmental study of the area and to develop site specific proxies based on either taxonomic or morphological characters of the benthic foraminifera.