Chapter 1
INTRODUCTION

1.1 General Introduction

The Quaternary period has been a time of great climatic and sea level oscillations. It is well established now that global climatic changes and sea level variations during the Quaternary had a direct impact on the circulation pattern, monsoonal system, coastal upwelling, coastal erosion and depositional processes. These changes have occurred on both the long (millennium to million years) and short (decade to century) time scales (International Geosphere-Biosphere Programme, 1990). Information related to paleoclimate and paleoceanography is stored in different forms in continental, coastal and oceanographic regimes. Depending upon the time span under consideration one can study different sources e.g. glaciers, rivers, lake-beds and desert on the continents besides coastal and open ocean bottom sediments. The marine sediments are one of the effective archives to study the paleoclimatic and paleoceanographic changes on different time scales depending upon the place of study.

In recent years, there has been growing realisation among the Quaternary researchers to study the last glacial-Holocene shallow marine and estuarine sediments in order to have better understanding of the past oceanographic and climatic changes with high resolution on global, regional and local scales. The late Quaternary changes can be recorded using biological, biogeochemical, geochemical and sedimentological proxies preserved in the marine sediments.
The sedimentary records from the continental margins provide a better source for gathering information on past variations because their various coastal processes, sea level fluctuations, biological productivity and high sedimentation constitute sediments.

The Arabian Sea is different than other oceanic areas because of its uniqueness in geographical setting, atmosphere and oceanic circulation system bearing tremendous impact on Asian monsoonal climate. As continental margins have sedimentation rates that are an order of magnitude higher than the pelagic areas, sediment cores from the former environment would be ideal to study past variations in oceanic and climatic conditions. The continental shelves of India provide excellent sedimentary records to document changes of environments and sea level during the late Quaternary. Since last ten years, a special attention has been paid by the marine geologists and micropaleontologists to examine marine deposits along the Indian coasts. But these were mainly limited to the few locations (off Kutch-Saurashtra, Maharashtra, Karnataka and Andhra) of the continental shelves. Some stratigraphic and paleontological details of the late Quaternary sediments along the Kerala coast are available based either on the inland exposed sequences or from bore wells. No serious attempt has been made so far to find out complete scenario of the oceanographic evolution along the Kerala coast during the late Quaternary.

The present micropaleontological investigation of the late Quaternary sequence off northern Kerala, employing multiple biological criteria (foraminifera
and pteropods) forms a part of the ongoing research programme "Late Quaternary climatic and sea level changes along the west coast of India" in the Department of Marine Geology & Geophysics, Cochin University of Science & Technology. A systematic transect-wise core sampling across the shelf will enable to record modern distribution pattern of microfauna in order to document their response to ecological conditions and to establish new biological proxy for better deciphering of past oceanographic history (Fig.1.1). The study would also yield new insights into the last glacial-Holocene variability pattern in sea level changes along the southwestern continental margin of India.

1.2 Objectives of the study

1. To study the spatial distribution of Recent foraminifera and pteropods in order to understand the relationship between the faunal distribution pattern and environmental conditions.

2. To develop new proxies for the paleoenographic and paleoclimatic interpretations based on the modern distribution pattern of microfauna.

3. To establish a precise chronostratigraphy for the examined core sections by integrating isotope stratigraphy, radiochronololgy, biostratigraphy and lithostratigraphy.

4. To study temporal distribution pattern of the foraminifera and pteropods in selected sediment cores and to assess their response to change in environment during the late Quaternary.

5. To decipher the oceanographic changes occurred during the late Quaternary based on the integrated microfaunal records.
1.3 Previous studies

With the advent of Deep Sea Drilling Project (DSDP) in the late sixties and subsequently Ocean Drilling Programme (ODP) in eighties, the Arabian Sea has become a center of activity amongst international marine geologists, micropaleontologists, sedimentologists, climatologists and oceanographers. Several studies have been carried out on the Quaternary paleoceanography and climates of the Arabian Sea (Frerichs, 1968; Vincent, 1972, 1976; Duplessy et al., 1981; Borole et al., 1982; Cullen and Prell, 1984; Prell and Van Campo, 1986; Srinivasan and Singh, 1991 and Singh and Srinivasan, 1993). Most of these investigations were based mainly on the deep-sea cores, thus providing a record of long term changes. Several international research programmes like the IGBP (International Geosphere-Biosphere Programme), PAGES (Past Global Changes), and CLIP (Climate of the Past) have emphasised the need for extensive and worldwide high-resolution study on the Quaternary (Prell and Kutzbach, 1987; Naidu, 1990; Zahn and Pedersen, 1991; Naidu et al.; 1992 and Naidu and Malmgren, 1995). These studies were based on foraminiferal data from a few sediment cores. A few significant contributions have also been made employing other sediment based climatic indices such as pollen grains (Van Campo et al., 1982; Prell and Van Campo, 1986 and Van Campo, 1991), geochemical tracers (Shimmield et al., 1990a,b; Clemens et al., 1991 and Shimmield, 1992) and isotopic composition of foraminifera (Prell and Curry, 1981; Duplessy, 1982; Kroon and Ganssen, 1989; Sirocko and Lange, 1991 and
Sirocko et al., 1991, 1993). Most of these results were derived from the western part of the Arabian Sea.

In recent years international scientific community paid special attention to understand the pattern of past sea level changes mainly on the local scale. The main focus of Quaternary sea level research has been on the continental shelves (Devoy, 1985; Belderson et al., 1986; Peterson, 1986; Fairbanks, 1989 and Austin, 1991) and information on former sea level stands can be derived from several established biological tools besides archeological, geological and geomorphological indicators (Wright, 1977, Singh et al; 1998).

Micropaleontological and paleoceanographic studies on coastal eastern Arabian Sea sediments are still in infancy. Several investigations on the carbonate sediments of the western continental shelf of India have been made in the last few decades. But, previous studies were mainly focused to record distribution of Recent foraminifera along the Indian west coast (Antony, 1968; Seibold, 1972; Setty, 1973, 1974; Gupta, 1974; Rao, 1974; Bhatia and Kumar, 1976; Nigam and Sarupriya, 1981; Setty and Nigam, 1982; Nigam, 1986,1987; Nigam and Rao, 1987; Naidu, 1990; Nigam and Henriques, 1992; Nigam and Sarkar, 1993 and Nigam and Khare, 1999). A few papers have been published on the late Quaternary biological and lithological response to climatic fluctuations and sea level changes in northern and central part of the western continental shelf (Nair, 1974; Nair and Hashmi, 1980; Nigam, 1986, 1988, 1989; Nigam and Nair, 1989; Nigam and Khare, 1992a,b and Rao et al., 1996). No serious attempt
was made to study foraminiferal assemblages from subsurface sediments of the
shelf of Kerala and their response to the late Quaternary oceanographic changes
occurred along the coast. Besides foraminifera, pteropods that have been known
to be very sensitive to a change in environmental condition also represent a
significant biogenic component of the sediments of Indian margins. Surprisingly,
study of pteropods from the marginal sediments of the Arabian Sea had been
neglected until recently (Singh and Rajarama, 1997; Singh, 1998; Singh et al.,

1.4 Geologic setting

The width of the western continental shelf of India is about 30Km off
Bombay and narrows down to about 60 km near 10°N latitude (Shrivastava and
Chandra, 1993). The southwestern shelf decreases southward from 75km to
55km (Shrivastava and Chandra, 1993). The Western Ghats mountain chains are
the major physiographic features along the southwest coast with elevations up to
~1000m. The coastal region consists of Plio-Miocene Warkalli and Quilon
Formations and Recent alluvium. The coastline of Kerala is an emergent type
and is formed by several long narrow banks running parallel to the shoreline.
There are often several rows of these and between them is a complicated system
of channels or backwaters. Although no major river traverses through this area,
there are several minor rivers and streams, seasonal in nature. Similar to the
northern part, the southwestern shelf of India is covered by three different types
of sediments (i) near-shore sand zone extending from shoreline to 5-10m depth,
(ii) silt and clay (muds) extending to depth of 50m (iii) biogenic carbonate rich sediments of the outer shelf (beyond >50 - 60m water depth).

1.5 Oceanographic setting

The strong seasonal variability in the monsoonal climate invokes large oceanographic changes in the Arabian Sea. During the southwestern monsoon, surface water flows from west to east and Equatorial Current (EC) shifts northward to join the Monsoon Current (MC). Southwesterly winds during the summer monsoon cause coastal upwelling offshore Somali, Oman and Yemen and open ocean upwelling to the northeast of Findlater Jet axis. A weak upwelling has been reported in certain areas off southwestern India (Wyrtki, 1973 and Singh and Rajarama, 1997). The northeastern monsoon is characterized by east to west water movement and highly variable airflow from the northeast. These northeastern winds produce weak upwelling and greater surface mixing in the northeastern Arabian Sea (Wyrtki, 1973).

The surface waters off the Kerala coast show a seasonal variation in hydrographic parameters. During the southwest monsoon from May to September, a season of heavy rainfall, strong winds and severe storm at sea prevail. During this season, surface temperature remains high and the thermocline (the greatest temperature with depth) extends almost to the surface. The salinity gradient in the top 100m decreases significantly. The coastal current flows southward associated with the Equatorial Surface Water (ESW) retreat and an upward movement of Arabian Sea Water (ASW) (Darbyshire, 1967). Between
July to August, the backwaters discharge very low salinity water and this extends seawards as low-salinity front at the surface. With the onset of winter monsoon (NE monsoon), the coastal current starts flowing northward bringing less saline Equatorial Surface Water and resulting sinking of the Arabian Sea Water and deepening of the thermocline. During the months of November to January, a weak coastal upwelling occurs (Darbyshire, 1967). Isohaline conditions are formed in February to April months. February to April is characterised by relatively stable hydrographic conditions. The thermocline remains between 100 and 200m. The current system becomes weak and condition remains similar to those in January.

Due to the high biological productivity, a pronounced mid-depth Oxygen Minimum Zone (OMZ) prevails in the Arabian Sea. The OMZ is recorded strongest between 300 and 700m water depth in the northeastern part of the Arabian Sea (Wyrtki, 1973). Along the southwest coast of India, extremely low oxygen concentration (<0.2ml/l) occurs approximately at 200m water depth downwards in the water column. The hydrographic data (temperature, salinity and dissolved oxygen: DO) recorded during the Sagar Sampada Cruise 162 from the study area and around are presented in Table. 1.1
Table 1.1: Hydrographical parameters recorded during Sagar Sampada Cruise 162 from the study area and around

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Latitude °N</th>
<th>Longitude °E</th>
<th>Surface waters</th>
<th>Bottom waters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Temp. (°C)</td>
<td>Salinity (%)</td>
</tr>
<tr>
<td>30</td>
<td>11°21.20</td>
<td>75°34.28</td>
<td>29°2512</td>
<td>34.6001</td>
</tr>
<tr>
<td>50</td>
<td>11°19.50</td>
<td>75°21.28</td>
<td>29°0968</td>
<td>34.4171</td>
</tr>
<tr>
<td>100</td>
<td>11°18.15</td>
<td>74°57.25</td>
<td>29°1366</td>
<td>34.2924</td>
</tr>
<tr>
<td>200</td>
<td>11°19.37</td>
<td>74°52.23</td>
<td>29°1915</td>
<td>34.2913</td>
</tr>
<tr>
<td>30</td>
<td>11°59.11</td>
<td>75°05.09</td>
<td>29°0506</td>
<td>34.6964</td>
</tr>
<tr>
<td>50</td>
<td>11°56.14</td>
<td>75°01.26</td>
<td>28°9515</td>
<td>34.4664</td>
</tr>
<tr>
<td>75</td>
<td>11°49.32</td>
<td>74°53.18</td>
<td>28°9804</td>
<td>34.3069</td>
</tr>
<tr>
<td>100</td>
<td>11°45.37</td>
<td>74°41.21</td>
<td>28°0438</td>
<td>34.2932</td>
</tr>
<tr>
<td>200</td>
<td>11°43.19</td>
<td>74°34.04</td>
<td>28°0825</td>
<td>34.2864</td>
</tr>
<tr>
<td>30</td>
<td>12°53.08</td>
<td>74°41.07</td>
<td>29°3769</td>
<td>35.0301</td>
</tr>
<tr>
<td>50</td>
<td>12°49.20</td>
<td>74°32.49</td>
<td>29°1559</td>
<td>34.9699</td>
</tr>
<tr>
<td>100</td>
<td>12°44.14</td>
<td>74°14.02</td>
<td>29°1355</td>
<td>34.6260</td>
</tr>
<tr>
<td>200</td>
<td>12°44.29</td>
<td>74°06.45</td>
<td>29°0893</td>
<td>34.6291</td>
</tr>
</tbody>
</table>