Chapter 7

SUMMARY

The sedimentary record of western continental shelf offers an excellent opportunity to investigate the late Quaternary foraminiferal and pteropod assemblages and their response to the past oceanographic changes. In the present work, a detailed micropaleontological investigation of foraminiferal and pteropod records in the late Quaternary sequence from the shelf of northern Kerala was carried out with the specific objectives: (i) to study the distribution pattern of Recent foraminifera and pteropods and to identify new proxies useful for the paleoenvironmental interpretations (ii) to establish a precise chronostratigraphy for the late Quaternary core sections and (iii) to study temporal distribution of the foraminifera and pteropods in order to evaluate their response to the late Quaternary oceanographic and climatic changes occurred along the shelf of northern Kerala. To achieve these scientific objectives, a systematic transect-wise core sampling across the shelf of northern Kerala (covering innershelf, mid-shelf and outershelf regimes) was done and total fourteen cores were recovered. Of these sediment cores, two coming from the outershelf represent complete record of the last glacial and the Holocene. The foraminifera (benthic and planktic) and pteropods were examined both qualitatively and quantitatively. An emphasis was given on the detailed investigation of benthic foraminiferal and pteropod assemblages. In total 59 benthic foraminiferal, 18 planktic foraminiferal and 14 pteropod species were recorded. All the benthic foraminifera and pteropods were briefly discussed with their systematic positions and salient morphological features.
and illustrated by scanning electron micrographs. A preliminary qualitative palynological study was also carried out on one core section recovered from the outershelf regime, which enabled to record 13 types of pollen and spores. Quantitative data of microfaunal assemblages were generated on split samples (>125µm) consisting >300 specimens of benthic foraminifera and 200-300 individuals of planktic foraminifera and pteropods. Whole sample was analysed in case of a rare occurrence of foraminifera and pteropods. Planktic component of foraminiferal assemblages was used mainly for estimating absolute abundance.

Core-top samples were used for recording spatial distribution pattern of foraminifera and pteropods. The record of numerical foraminiferal abundance suggests that the benthic population richness across the shelf is controlled by the nature of the substrate in association with the nutrient content, bathymetric and other hydrographic parameters. The study reveals a bathymetric control on benthic/planktic (BF/PF) foraminiferal and pteropods/planktic foraminiferal (Pt/PF) abundance ratio. Bathymetric distribution pattern of BF/PF ratio is opposite to the Pt/PF ratio with decreasing trend of former from the shore across the shelf. Quantitative benthic foraminiferal record in the surficial sediments reveals a positive correlation between the diversity and bathymetry. R-mode cluster analysis performed on 30 significant Recent benthic foraminifera, determines three major assemblages, Assemblage I (>115m W.D., outershelf), Assemblage II (115-50m W.D., mid-shelf) and Assemblage III (<50m W.D., innershelf). And these assemblages correspond to three distinct outershelf, mid-shelf and innershelf lithofacies. The three benthic foraminiferal biofacies are in association with the three characteristic pteropod assemblages identified across the shelf of northern Kerala.
An attempt was made to document the relationship of Recent benthic foraminiferal
distribution with nature of substrate, nutrient content in sediments, bathymetry and
hydrographic condition. Recent benthic foraminiferal assemblages recorded from
the study area comprise mainly of rotaliids, elphidiids, nonionids, miliolids, bolivinids
cibicids, uvigerininiids, lagenids and agglutinated taxa. The present investigation
suggests a positive correlation between abundance of rotaliids as well as nonionids and nature of substrate, organic matter. The present observation further reveals that the bolivinids in the study area prefer coarse substrate and avoid an environmental condition with seasonal salinity fluctuations. It is noticed that *U. peregrina* prefers muddy substrate richer in organic matter and normal marine condition. The maximum concentration of miliolids and cibicids recorded from the mid-shelf region indicates their preference for coarse substrate with low organic matter and relatively high salinity condition. The agglutinated taxa are conspicuously absent in the innershelf samples and showing their maximum concentration in the outershelf region having fine substrate, high organic carbon and normal marine condition.

Bathymetric distribution pattern of pteropods indicates that certain species (*Limacina inflata, Creseis acicula, C. chierchiae* and *C. virgula*) are highly sensitive to change in water depths. The present observation validates the idea "pteropods as bathymetric indicator" proposed by the previous workers. An attempt has been made to prepare a model on relationship between abundance change of depth sensitive species and variation in present bathymetric condition. The proposed model was applied to decipher the late Quaternary sea level history of this region based on the temporal variation of the depth sensitive pteropods.
A precise chronological framework for the late Quaternary sequence is a prerequisite for the better record of faunal succession and deciphering the past environmental conditions. The chronostratigraphy with high precision of a sediment core section is established by integrating biostratigraphy with lithostratigraphy, radiochronology and oxygen isotope stratigraphy. The conventional planktic foraminiferal criteria are found to be not applicable for biostratigraphic subdivision in shallow marine cores of the continental shelves. Moreover, sedimentary records across the shelf vary in their faunal assemblages in space and time because sedimentation herein is mainly controlled by the sea level transgressive/regressive cycles. Therefore, biostratigraphic markers applicable for one region (e.g. outershelf) may not be useful for the other regions across the shelf. In the present work, cores from all the three regimes (outer-, mid- and innershelf) were studied. An attempt has been made to establish integrated bio-litho-radio-chronostratigraphy for the two best suitable cores of the outershelf regime. Both the cores represent complete record of the last glacial and the Holocene period (one represents the last 36,000 years and another 23,000 years). The present study also enabled to recognise the important foraminiferal criteria, which could be useful in biostratigraphic subdivisions in the outershelf, the mid-shelf and the innershelf sedimentary records. 

Globorotalia menardii and Globigerinoides sacculifer (tropical planktic foraminifera) are found to be applicable in demarcating Holocene/Pleistocene boundary in outershelf core sections. The study suggests that the quantitative occurrence of certain benthic foraminifera such as Hanzawaia mexicana, Nonion spp. can be considered as
important criteria for the biostratigraphic division of shallow marine sections (mid- to
innershelf).

For vertical pattern study of the late Quaternary foraminiferal and pteropod
assemblages, four cores were chosen: two from the outershelf and one each from
the mid- and the innershelf regimes. Foraminiferal records in the examined core
sections indicate variations in absolute abundance of planktic and benthic
components. The major fluctuations in benthic foraminiferal assemblages are
reflected in diversity, abundance of epifaunal, infaunal taxa, relative abundance of
rotaliids (mainly *Ammonia beccarii* s.l.), miliolids, bolivinids and uvigerinids. Benthic
foraminiferal record of the last 23,000 yrs shows an increased abundance of
epifaunal taxa (preferring muddy substrate and higher organic carbon) during 18-14
Ka BP and at around 5 Ka BP. High abundance of infauna during these intervals
has been suggested to reflect eutrophication and high productivity condition
associated with the enhanced upwelling. A general increase in abundance of
bolivinids (*B. marginata* and *B. perseinsis*) and uvigerinid (*U. peregrina*) occurring
frequently in eutrophic condition is also documented during this interval. The
change in bathymetry at the depositional site and the nature of sediments
(substrate) resulted due to sea level fluctuations during the late Pleistocene –
Holocene period, has been considered as probable reason for the downcore
variation in relative abundance of *H. mexicana*, miliolids and *Ammonia beccarii*.s.l. .
Additionally, a change in hydrographic condition linked with the last glacial-
Holocene climatic variation might have also influenced the benthic foraminiferal
assemblages. The benthic foraminiferal record of the innershelf region reflects
prominent downcore variation in relative abundance of *Nonion* spp. (infauna), *H.*
mexicana, Ammonia beccarii s.l., Cancris, Elphidium and agglutinate taxa (epifauna). The benthic foraminiferal assemblage in the upper portion of the core is distinct from the lower portion. The lower stratigraphic unit (late Pleistocene) is characterised by the dominance of epifaunal taxa (H. mexicana, Ammonia beccarii s.l., Cancris spp., Elphidium and the agglutinated taxa) in benthic population. The estuarine-lagoonal near-shore epifaunal benthic foraminiferal population was gradually replaced by the typical innershelf infaunal nonionids in the upper stratigraphic unit representing the Holocene period. A gradual rise of sea level during the post LGM period probably resulted in change of depositional environment and consequently in bio-litho facies.

The downcore variation of the depth sensitive pteropods (Limacina inflata and Creseis spp.) in two cores retrieved from the outershelf, was investigated in order to reconstruct the late Quaternary bathymetric changes in the study area. The paleo-depth estimate was made based on the record of L. inflata/Creseis spp. ratio in the cores using the proposed model on abundance – depth relationship of these bathymetric indicators. The paleobathymetric records obtained from the two cores indicate compliant consistency in terms of changing pattern (amount, timing and rate) in paleo-water depth. Sea level curves for both the core sites were drawn using the paleo-water depth records. The present investigation reveals that the sea was below 25m than Present Mean Sea Level (PMSL) around 36Ka BP. A gradual lowering with slow rate occurred from 36 to 25 Ka BP. The rate of sea level lowering increased from 22 Ka BP. During the last glacial maximum, sea level was approximately 100m below than PMSL. The study indicates that the rate of sea
level rise was maximum between 15 and 10 Ka BP. The sea level continued rising after 10 Ka BP but with the reduced rate. The inferred sea level record shows that the sea level rise has been very slow since 5 Ka BP. This study provides first time sea level data along the western continental shelf of India for the period prior to the LGM (Last Glacial Maximum).