

Distribution, ecology and paleoenvironments of Benthic foraminifera - A case study off Manora, Palk Strait, Tamil Nadu

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A total of 21 benthic foraminiferal species and varieties belonging to 12 genera, 9 families, 6 **superfamilies**, and 3 suborder have been identified. From the total number of species, *Ammonia beccarri*, *A.tepida*, *P.calcar*, *P. nipponica* shows a higher abundance in this region. The following species are found only in few core samples, namely *Elphidium incertum*, *Spiroloculina communis*, *Spiroloculina orbis* and *T. agglutinans*. Size of the foraminifera in this region is very small. It may be due to the finer nature of sediments and high rate of sedimentation in this region observed by earlier workers. The OM values range from 0.54 to 1.37 %. CaCO_3 value ranges from 1 to 6%. Based on the sand-silt-clay ratio, the study area was predominated with silty sand and sand in majority of the region. From the coastal geomorphological studies it is observed that, the distribution of landforms between near Manora displays a paleo micro deltaic characteristic the beach ridges have width of 200m around Manora. The sediments of beach ridges lie directly above the mudflats suggesting that the beach ridges were deposited later to the formation of mudflats i.e. mudflats are older to beach ridges.

[**Keywords:** Benthic foraminifera, distribution, ecology and paleoenvironments, Palk Strait, Tamil Nadu]

Introduction

Foraminifera are first appeared in Cambrian and are enormously successful group of amoeboid protists. They live in the modern oceans right from paralic-environs to both planktic and benthic habitats of the deep oceans. Being exclusively marine, except a few species, highly abundant in deep-sea sediments/rocks, very sensitive to even minute change in environment foraminifera have wide applications in stratigraphic correlation, higher resolution biostratigraphy, oil exploration, environmental and paleoenvironmental interpretations. The Palk Strait ecosystem is endangered due to the shallowing of the bay resulted due to continuous siltation¹. Extensive mining of beach placers in the eastern coast of India and large number of illicit mining of coral banks along the Tuticorin

coast are pointed out as the causes for the large amount of siltation in the Palk Strait and gradual vanishing of pearl culture. Agrawal² has noticed significant changes within last thirty years in the bathymetry of Palk Strait. Only limited studies had been carried out in this region that too, in surface sediments. Hence an attempt has been made to delineate the depositional environment using vertical distribution of benthic foraminifera in this region.

Materials and Methods

The study area **Manora** in Palk Strait is located near Pattukkottai, Thanjavur district of Tamil Nadu (Fig.1) . The area is located in the southernmost end of the Cauvery delta along the coastal zone of Bay of Bengal and Palk Strait. The Palk Strait is the narrow channel connecting

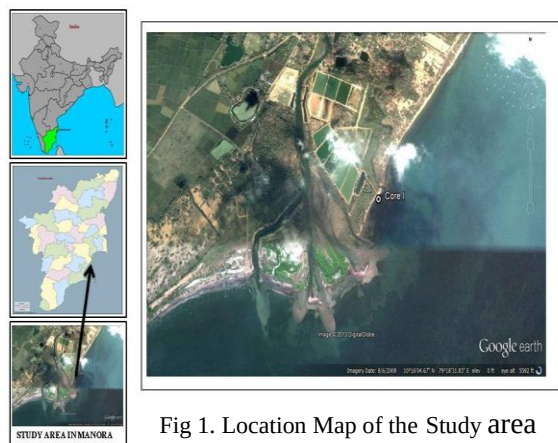


Fig 1. Location Map of the Study area

Table.1. Geographic locations of sampling stations in the Manora, Palk Strait.

S.No	Latitude	Longitude	Depth in Cm	Nature of Sample
1	10° 16' 05"N	79° 18' 37.5"E	0-5	Top Core
2	10° 16' 05"N	79° 18' 37.5"E	5-10	Top Core
3	10° 16' 05"N	79° 18' 37.5"E	10-15	Top Core
4	10° 16' 05"N	79° 18' 37.5"E	15-20	Top Core
5	10° 16' 05"N	79° 18' 37.5"E	20-25	Top Core
6	10° 16' 05"N	79° 18' 37.5"E	25-30	Top Core
7	10° 16' 05"N	79° 18' 37.5"E	30-35	Middle Core
8	10° 16' 05"N	79° 18' 37.5"E	35-40	Middle Core
9	10° 16' 05"N	79° 18' 37.5"E	40-45	Middle Core
10	10° 16' 05"N	79° 18' 37.5"E	45-50	Middle Core
11	10° 16' 05"N	79° 18' 37.5"E	50-55	Middle Core
12	10° 16' 05"N	79° 18' 37.5"E	55-60	Middle Core
13	10° 16' 05"N	79° 18' 37.5"E	60-65	Middle Core
14	10° 16' 05"N	79° 18' 37.5"E	65-70	Middle Core
15	10° 16' 05"N	79° 18' 37.5"E	70-75	Bottom Core
16	10° 16' 05"N	79° 18' 37.5"E	75-80	Bottom Core
17	10° 16' 05"N	79° 18' 37.5"E	80-85	Bottom Core
18	10° 16' 05"N	79° 18' 37.5"E	85-90	Bottom Core
19	10° 16' 05"N	79° 18' 37.5"E	85-95	Bottom Core

Gulf of Mannar and Bay of Bengal and is about 75 km wide between Sri Lanka and India. It includes coastal area from Rameshwaram in the south west corner to Point Calimere in the north eastern corner.

Geologically the study area can be broadly divided into four geological zones viz. 1. The western and southern zones from a laterite country. The laterites/latertic soil occur places at places over the crystalline rocks viz. magnetite genisses and also sedimentary formations comprising fossil ferrous sandy calcareous clay and limestone of upper age and cretaceous age and grits, ferruginous sandstone gravel of miopliocene age. 2. The fluvial deposits (flood plains) of Cauvery and Agniyar rivers. 3. The fluvio marine deltaic sediments. 4. The coastal sediments of marine/Aeolian regions fringing the Palk Strait.



Fig 2. Core sample collection using PVC pipes

In order to study the distribution of Recent benthic foraminifera, subsurface (core sample) sediment samples were collected from the Manora, Palk Strait near Pattukkottai, Thanjavur district in Tamil Nadu, with the help of PVC pipe. The locations of sub surface samples are recorded using GPS. One core sample were collected up to a depth of 90cm (core I) by using PVC pipe (fig.2), and it core sample are sub sampled at an interval of 5cm . Thus, a total of 19 samples were obtained. Geographical co-ordinates are recorded using GPS for the core collections are in table.1 respectively. All the sediment samples were subjected to standard micropaleontological techniques, so as to record the occurrence of foraminifera.

Calcium carbonate, organic carbon and organic matter in the sediment samples were determined by adopting a methodology suggested by Piper³, Gaudette *et al.*⁴ Walkey- Black method, adopted and modified from Jackson⁵ respectively. Sand, silt and clay percentages were calculated using a combination of sieving and pipette procedure, the later in accordance with Krumbein and Pettijhon⁶. Trilinear plots were prepared and description has been given based on Trefethen's (1950)⁷.

The sediment samples (19 nos) were dried in an oven at 60° C to remove the moisture. From the dried samples 100 gm was removed by repeated process of coning and quartering to ensure uniformity and avoid errors in analysis. The samples were soaked in water for overnight, were stirred up by mechanical stirrer to disaggregate the samples and to remove the clay fractions. The stirred samples were decanted repeatedly using distilled water until a clear column of water, without any turbidity, was obtained. During that process, wherever necessary, the samples were frequently rubbed by hand to eliminate the attached clay particles.

The samples were dried and weighed. The weight loss was taken note of. The handpicked faunal specimens from each sample (25 ml of wet sediment) were transferred to 24-chambered micropaleontological slides and mounted over a thin layer of tragacanth gum according to the family, genus and species, wherever possible. The different genera and species were identified; type specimens of each species were selected and transferred to round punch microfaunal slides with cover slips. Later, they were mounted on brass stubs (1 cm in diameter) using a double-sided adhesive carbon tape and coated with palladium for about 90 to 120 seconds (JEOL: JFC) ion sputtering device) to render the surface of the foraminiferal tests conductive for scanning.

To obtain lucid illustrations, microphotographs of different views of all the foraminifera species present were taken using a Scanning Electron Microscope (JEOL JSM-6360). All the foraminifera species described and illustrated

here are deposited in the Department of Geology, University of Madras, Chennai.

Results and Discussion

The foraminiferal taxa belong to three Suborders such as ROTALIINA, MILIOLINA and TEXTULARIINA, and 9 families, 12 genus and 21 species are identified (Table.2). The MILIOLINA and ROTALINA occupy the dominant place in the study area.

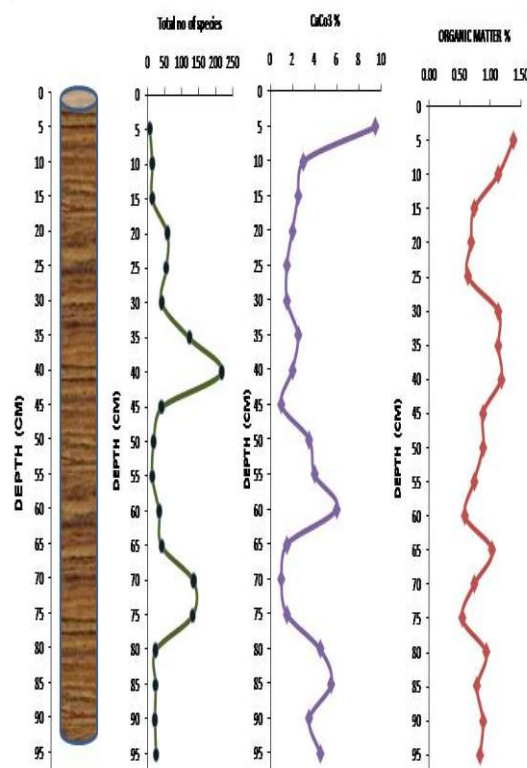


Fig 3. Vertical distribution of total number of species, CaCO₃ and Organic matter in %

A total of one core sample subsampled into 19 sediment samples were collected nearshore region of Manora for foraminiferal studies. The genus *Ammonia*, *Elphidium*, *Pararotalia*, are dominates the total assemblages followed by *Quinqueloculina*, *Triloculina* and *Spiroloculina* in the study region. The following species are widely distributed in the core sample namely *Ammonia beccarii*, *A. dentata*, *A. tepida*, *A. trispinosa*, *S. communis*, *Q. elongatum*, *Q. lamarckiana*, *Q. seminulum*, *T. trigonula*, *E. crispum*, *P. hispidula*, and *A. ammonoides*. The figure.3 shows the vertical distribution of total species with respect to depth. Distribution of

total foraminiferal species brings out an appreciable raise and fall in different depths. The vertical distribution of foraminifera shows that from 0- 15 cm lesser amount of foraminiferal species diversity observed. Similarly from 15 cm to 30 cm the gradual increase of foraminifera was observed. From 35 to 40 cm the foraminifera species are more dominant. Similarly from 65 to 75 cm an appreciable amount of foraminifera species increase in abundance. It is clearly noticed that, wherever the calcium carbonate content increases the total species also increased. Further, with in the 95 cm the two different rises of foraminifera is observed, probably tidal influences in this region may increases the foraminiferal distribution in the particular depth. Moreover, the higher rate of sedimentation and littoral drift action may not give the room for deposition of foraminifera in other depths, frequently⁸⁻¹⁰.

The top core was typified by such species as *A. beccarii*, *P. nipponica* and *E. crispum*, all of which have been recorded in shallow waters worldwide¹¹. Few tests of *A. dentata* with long, slender spines were observed, but only in the relatively deeper water sediment samples, an observation also made by earlier workers¹³⁻¹⁴; *A. dentata* with short, blunt spines is more common in the near shore waters. Moreover, the smaller size of foraminifera is observed in the sampling locations may be due to the fine sediment nature¹⁵⁻¹⁶ in the bottom core such as *Bolivina*, Nonion suggest that these assemblages *Elphidium* are characteristics of mid-low tidal, moderately sheltered environment. *E. discoidale* is common under sheltered situations, often in low salinity zones in the inner shelf. *Nonion* are found in moderately quiet, fine sediment environment at deeper inner shelf, sheltered from oceanic water circulation. *A. beccarii* is wide spread in shallow subtidal and intertidal lower estuarine environment. Murray¹² found several species of this assemblage associated with muddy sand namely *A. beccarii* and *E. crispum*. It can be speculated that long-shore transport by littoral drift and tidal currents mix benthic Foraminifera species that do not necessarily occupy the identical shallow-marine substrates.

In our study area this assemblage is limited to the outer part of the inner shelf. In terms of wave energy this area is only influenced by storm waves. Many of the species tolerant to oxygen deficiency are typical of muddy environments sometimes containing high amounts of organic carbon¹². Abundances higher than 5% of some genera normally associated with oxygen deficient environments might be found in oxygen-depleted environments. The families *Bolivinidae* and *Buliminidae*, well represented in this deeper depth are associated with upwelling phenomena¹⁷. Beach ridge and mudflat sediments dominate the region near shore (Fig.4). They are bordered in the west by deltaic sediments.

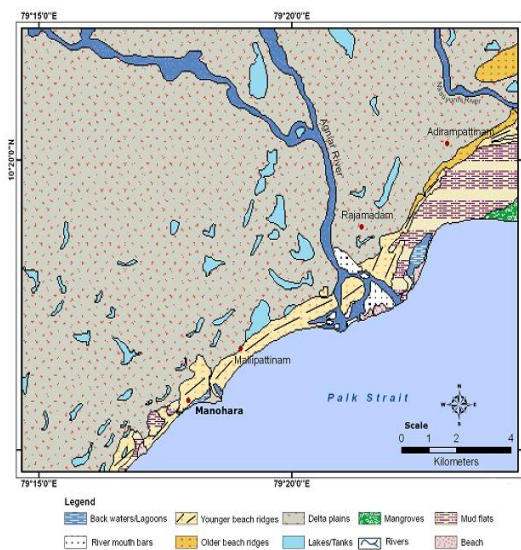


Fig 4. Coastal Geomorphology of the study area (after Prabakaran, 2012)

The occurrence of mudflat along the shoreline suggest that area was under lagoon or backwaters or back barrier environment that facilitated for the deposition of silt and clay sediments. The mudflat is underlain by a sand layer that outcrops as beach ridges west of mudflats. The beach ridges have width of 200m around Manora. The sediments of beach ridges lie directly above the mudflats suggesting that the beach ridges were deposited later to the formation of mudflats i.e. mudflats are older to beach ridges. The beach ridges are bordered in the west by vast delta plain. The delta plain is made up of mainly clay, silt and sand with natural levee and other over bank sediments.

Table.2. Distribution of foraminifera in the study area

Name of Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
<i>Ammonia beccarii</i>	2	8	11	40	32	20	102	150	22	8	8	12	18	90	102	14	12	9	11
<i>A.tepida</i>	1	4		5	10	5		6							4		6		
<i>A.dentate</i>								8											
<i>Bolivina nobilis</i>								3											
<i>Cibicides lobatulus</i>							1	4											
<i>E.discoidale</i>								4											
<i>E.crispum</i>				3				2						2	2	2		7	6
<i>E.incertum</i>			2							1								1	
<i>E.norwangii</i>	1			2			3		2					2					
<i>Globorotalina</i>		1			2														
<i>Pararotalia calcar</i>				1	3	3	3	12	6	4	2	8	4	12	4	3		2	3
<i>P.nipponica</i>				2	3	6	12	14	4			8	12	8		4			2
<i>Parrellina hispidula</i>													2	4	12				
<i>Quinqueloculina seminulum</i>			2		2	1		2				2	2	2					
<i>Q.elongatum</i>					1	3		2				3	3	10	4				
<i>Q.agglutinans</i>										2	1			3	2		5	3	2
<i>Rosalina globularis</i>	2			5		3			6		2			2					
<i>Spiroloculina communis</i>					1					3									
<i>S.orbis</i>							2								2				
TOTAL	6	13	15	58	54	41	123	207	40	18	13	33	41	135	132	23	23	22	24
Individual species	4	3	3	7	8	7	6	11	5	5	4	5	6	10	8	4	3	5	5

Table. 3. Results of ecological parameters

Depth in Cm	CaCO ₃ %	Organic matter %	Sand %	Silt %	Clay %	Total no of Foraminifera
1-5	1	1.37	96.4	3.3	0.3	6
5-10	3	1.13	92	7.8	0.2	13
10-15	2.5	0.74	94.7	5	0.3	13
15-20	2	0.69	92.7	7.1	0.2	58
20-25	1.5	0.64	86.6	13.2	0.2	54
25-30	1.5	1.13	87.4	11.8	0.8	41
30-35	2.5	1.13	85.4	13.9	0.7	123
35-40	9.5	1.18	81.3	17.9	0.8	217
40-45	1	0.88	89.7	9.7	0.6	40
45-50	3.5	0.88	79.4	19.9	0.7	17
50-55	4	0.74	89	10.5	0.5	13
55-60	6	0.59	87.7	11.7	0.6	33
60-65	1.5	1.03	88.2	11.4	0.4	41
65-70	2	0.74	94.2	5.4	0.4	135
70-75	2.5	0.54	82.2	17.3	0.5	132
75-80	4.5	0.93	92.5	7	0.5	23
80-85	5.5	0.78	91.9	7.6	0.5	23
85-90	3.5	0.88	90.7	8.7	0.6	21
90-95	4.5	0.83	91.8	7.7	0.5	24

The sediments of mudflats overlie the deltaic sediments. Hence the delta plain represents the oldest sediments of Manora region followed by mudflat and beach ridge sediments.

Ecology is the study of the reciprocal between organisms and their surroundings; the influences of the environment on the physiological activity of the organisms and vice versa. It thus embraces the study of the environmental limits in which a species exists¹⁸. The results of ecological parameters and total species are shown in table 3.

Silty and muddy substrates are often rich in organic debris and the small pore spaces contain bacterial blooms. Such substrates are, therefore, attractive to the foraminiferal species and support large populations. The larger pore spaces of sands and gravel contain fewer nutrients and, therefore, support less diverse populations. A number of studies have revealed a close correlation between the nature of the sediments especially the texture (sand-silt-clay-ratio) and the foraminiferal population. Suresh Gandhi and Rajamanickam¹⁹ investigated in the distribution of certain ecological parameters and

foraminiferal distribution in the depositional environment of Palk Strait, east Coast of India and observed from the sand/silt/clay ratios, it is inferred that the sediments are normally sandy in nature but silty sand dominates at deeper depths. The vertical distribution of Sand, silt and clay is shown in Fig.5.

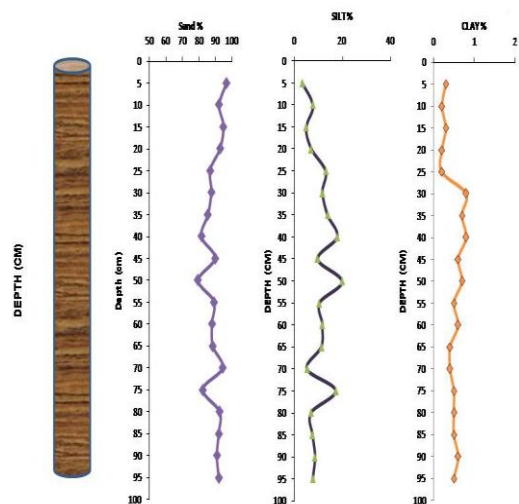


Fig 5. Vertical distribution of Sand-Silt-Clay (in %)

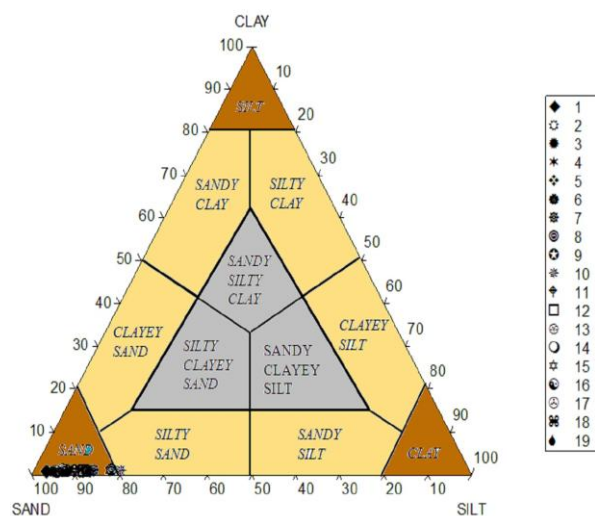


Fig 6. Trilinear plots of Sand-Silt-Clay ratio of Manora, Palk Strait

The relative abundance of sand, silt and clay in the sediments of surface has been plotted on trilinear diagrams (Fig.6). Trefethen's⁷ textural nomenclature has been used to describe the

types of the present area. In the study region, the Sand is dominant in maximum samples. The top, middle and bottom core are dominant with sand (Fig.6). The foraminifera size is medium in nature may be due to the sandy nature of fine sediment occupied the entire core.

Organic carbon is composed of elements such as carbon, hydrogen, oxygen, nitrogen and sulphur. Organic carbon has a significant role in geochemical and biological cycles that accumulate in the sediments. The organic carbon may be used as an index of depositional environment and sedimentary process. The detrimental effect of organic matter in sediment on foraminifera is restricted to areas where acidic conditions are created. Mostly, however, organic material enhances the nutritive content of the water and substrate and thus favours the development of foraminifera.

The organic matter content ranges from 0.54 to 1.37% (fig.3). The higher OM content is observed at the top of the core sample 0- 5 cm. Whereas, from 10- 25 cm a gradual decrease in organic matter content is observed. From 25 to 65 cm an appreciable amount of OM content is observed. Over all, a rise and fall of organic matter content is observed in 95 cm core samples.

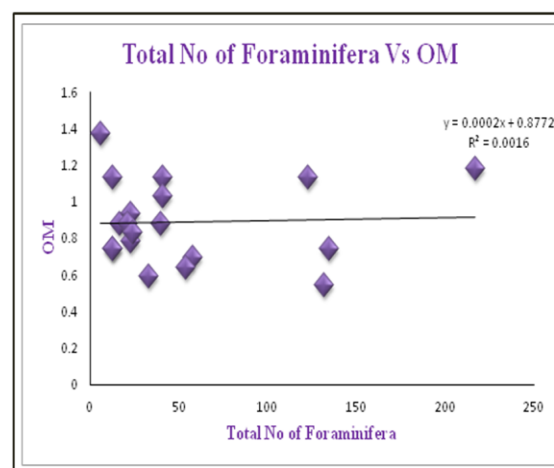


Fig 7. Showing the relation of Total no. of Species Vs OM

The scatter plot of organic matter Vs total species shows positive correlation (Fig 7). Organic matter Vs Depth shows positive correlation.

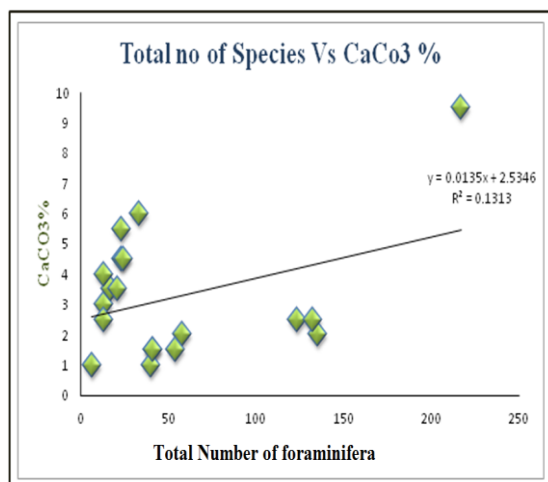


Fig 8. Showing the relation of Total no. of Species Vs CaCO_3 %

Deeper the depths decreasing the organic matter. Further, the trend of organic matter Vs Carbonate shows positive correlation pictures that due to littoral drift activities the drifting of sediment brought from the inner shelf regions have played a great role in the contribution of dead species as well as carbonate shells.

The carbonate content of the sediment is an important parameter governing foraminiferal abundance, especially spatial distribution. The amount of calcium carbonate that can be dissolved in sea water is a function of temperature, salinity and pressure. Salinity increases with temperature and enhances the solubility of the bicarbonate ion. Majority of the foraminifera have calcareous tests and, therefore, calcium carbonate becomes an important factor that controls the abundance of foraminifera.

The calcium carbonate ranges from 1.00 to 9.5% (Fig 3). The higher calcium carbonate is observed at a depth of 35- 40 cm whereas; from 1- 30 cm a gradual decrease is observed. From 45 to 65 cm & 75 – 90 cm an appreciable amount of Calcium carbonate is observed.

In the study area lower amount of carbonate content in the top of the core samples is noticed. The scatter plot of carbonate content vs total species shows the positive correlation (Fig.8).

It means that strong relation is being maintained between carbonate and total species. But, now

carbonates must have been the product originated from the other factors, probably the drifted shells from elsewhere or from the coral reef region in the in situ. It indicates that the carbonate present in this region is from *in situ*.

A total of 21 benthic foraminiferal species and varieties belonging to 12 genera, 9 families, 6 super families, and 3 suborder have been identified. Calcium carbonate content is generally found to be directly proportional to the population size in the study area. The sand-silt-clay ratios were estimated and silty sand and sand substrates have been predominantly found in the study area. From 50 to 75 cm depth silty sand is predominant whereas in the remaining depths it is sandy in nature. The sand-silt-clay, organic matter and carbonate content studies clearly indicate the nature of deposition environments. From the overall distribution of the fauna in the present area, it observed that the calcium carbonate is the major controlling factors for the thriving of foraminifera fauna in this region. From the total number of species, *A.beccarri*, *A.tepida*, *P. calcar*, *P. nipponica*, shows a higher abundance in this region. The size of the foraminifera in this region is very small. It may due to the finer nature of sediments and high rate of sedimentation in this region observed by earlier workers^{1,8}.

The vertical distribution of foraminifera is higher at top core 0 to 35 cm and 35-40 cm middle core, 70- 75 cm in the bottom core is observed. It is clearly noticed that, within the core sample two times of appreciable raise in foraminifera distribution is observed in the core samples. Further due to the higher rate of sedimentation at the particular depths may lead the favor for higher number of dead species distribution is observed where as in the remaining depths a lesser number of dead foraminifera species are present indicates the lower rate of depositions during that time. Further, the occurrence of species in the core samples is mainly due to transport by tidal currents. Based on the foraminifera distribution it is observed that the top core is tidal environment, middle core is mixed environment and the bottom core indicate the shallow marine environment.

Conclusion

Based on ecological parameters it is concluded that the, low organic matter, Calcium carbonate and fine sediment nature is observed in the bottom core. Further the species are small in size. Finer the sediments, favorable for enrichment of species are observed in this region.

From the coastal geomorphological studies it is observed that, the distribution of landforms between near Manora displays a paleo micro deltaic characteristic the beach ridges have width of 200m around Manora. The sediments of beach ridges lie directly above the mudflats suggesting that the beach ridges were deposited later to the formation of mudflats i.e. mudflats are older to beach ridges. Occurrence of beach ridges and mudflats denotes that Quaternary sea level changes have played a role in the genesis of the landforms around this region.

PLATE-I



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