

Effect of River Discharge on the Morphology of Benthic Foraminiferal Test

RAJIV NIGAM AND NELOY KHARE

Geological Oceanography Division, National Institute of Oceanography, Dona Paula, Goa 403 004

Abstract : Twenty one surface sediment samples collected from the inner shelf region off Karwar at 22-52 m water depth range have been studied for foraminiferal content. Based on the external test morphology the entire foraminiferal population (148 species) can be placed into two broad morpho-groups namely angular-asymmetrical and rounded-symmetrical morpho-groups. The surficial distribution of these groups revealed that angular-asymmetrical morpho-group gets adversely affected by high turbulence associated with increased fresh water river discharge, whereas, rounded-symmetrical morpho-group responded in a reverse manner. Since areal extent of river induced turbulence depends upon fresh water discharge due to monsoonal rains, the results show high potential in generating proxy data for the reconstruction of paleomonsoonal history through the study of morpho-groups in sub surface sediments of coastal regions.

Keywords : Foraminifera, morphology, palaeoclimate, West Coast, Arabian Sea.

INTRODUCTION

Foraminifera have proved their utility in paleoclimates and environmental studies. However, most of these techniques are based on species identification of foraminifera. Out of 38,000 species of foraminifera around 10,000 to 12,000 species are still living in modern oceans. Numerous taxonomic shifts made the job of identifications confined to highly trained researchers and thus making the application limited. In view of the foregoing, it is visualized that if coarser taxonomic group or other morphological variations based techniques are developed, they will serve as powerful tools to obtain first order estimates of paleoclimates.

Based on external morphology of foraminiferal tests, entire population can be classified into certain morpho-groups (Severin, 1983). Attempts were made to establish relevance of these morpho-groups for example, Kaiho (1991) utilized morpho-groups to discriminate between oxygenated and anoxic conditions. Recently Widmark and Malmgren (1992) reported abundance towards the K/T boundary in infaunal benthic foraminiferal taxa in the south Atlantic sites.

Besides, the infaunal and epifaunal taxa are usually recognized as productivity indicators (Corliss, 1985; Corliss and Chen, 1988; Corliss and Emerson, 1990; Widmark and Malmgren, 1992).

This paper, based on foraminiferal studies from shelf region off Karwar presents the potential of morpho-group of benthic foraminifera to be used as a technique for reconstruction of paleomonsoonal precipitations. Usefulness of this method lies with the fact that species level identification is not required for proposed paleoclimatic method.

Other aspects of foraminiferal studies of the study area have already been covered in the earlier publications (Nigam, 1987, 1988 a and b, 1993; Nigam and Nair, 1989; Nigam and Khare, 1992 a and b; Khare, 1990).

WORKING HYPOTHESIS

Severin (1983) by reanalyzing Phleger's (1956) data observed that on the basis of the external test morphologies species count data can be classified into a few morpho-groups. He explained that sediment turbulence controls the distribution of various

morpho-groups of foraminifera in modern sediments. He found that "overall angular and asymmetrical forms tend to occur in deeper water, while rounded and symmetric forms tend to occur in shallower water" and the same "may be due to decrease in sediment turbulence with increasing water depth".

However, in Indian context dependence of morphologies on turbulence can also serve as a key to fresh water discharge through rivers and thus key to monsoonal rainfall. It has been well established that monsoon periods which are generally accompanied by increased wind speed, lithogenic flux and precipitation (Neelakantan *et al.*, 1988; Naik and Neelakantan, 1989; Naik *et al.* 1990; Nair *et al.*, 1989) enhance the turbulence in coastal regions. It is observed that the periods of monsoonal precipitation are apparently associated with an increase in the turbulence which is more pronounced at the river mouths. Areal extent of turbulence within coastal zone depends upon amount of fresh water discharge through rivers. Therefore, if we study foraminifera in modern sediments in coastal areas, we should get higher concentration of turbulence resistant assemblage (i.e. rounded-symmetric foraminiferal forms) near river mouths, gradually decreasing with distance from river mouth. The same ecological conditions should have an adverse effect over turbulence susceptible assemblage (i.e. angular-asymmetrical foraminiferal forms).

The above hypothesis is tested by studying foraminiferal content of modern sediments off Karwar, west coast of India. This area is selected because of the fact that Kali river in this area is by far the largest river among the number of small estuaries, which are strongly influenced by the annual monsoonal precipitation. It is well known that river carries a large amount of suspended load along with fresh water discharge. These factors create a highly turbulent environment in and around river mouth. However, in the chosen area of study such an increase in turbulence is confirmed by Rivonker and Reddy (1990)

who reported to have obtained higher values (0.8) of extinction coefficient 'K' (a turbidity index) during monsoons in coastal areas near Karwar and ascribed it due to inland drainage through Kali river discharge.

MATERIALS AND METHODS

21 surficial sediment samples were collected from the inner shelf region off Karwar, adjoining Kali river mouth (Fig.1) during the cruise of DSV Nand Rachit from water depth ranging from 22 to 52 m using Peterson grab sampler.

All samples were washed through a 63 μ m sieve and oven dried. About 300-500 foraminifera were picked from weighed sample. Based on external test morphologies these species are kept broadly into two distinct morphological groups, following the criterion of Severin (1983), 1. angular-asymmetrical and 2. rounded-symmetrical irrespective of the taxonomic level (Plate 1).

Angular-asymmetrical morpho-group

This group incorporates elongate flattened forms which are oval to compressed in apertural view and have either parallel or sub-parallel sides, straight cylindrical forms which are rounded in apertural view and have generally parallel sides in side view and tapered forms which are either rounded or angular in apertural view and are tapered throughout their length in side view (Plate-1-8).

Rounded-symmetrical morpho-group

This group includes trochospiral forms which have both a flattened and a more rounded side when viewed in profile and those trochospiral and planispiral forms which do not have readily distinguished spiral and umbilical sides in apertural view (Plate-9-16).

RESULTS

A total of 148 species of benthic foraminifera have been identified and are

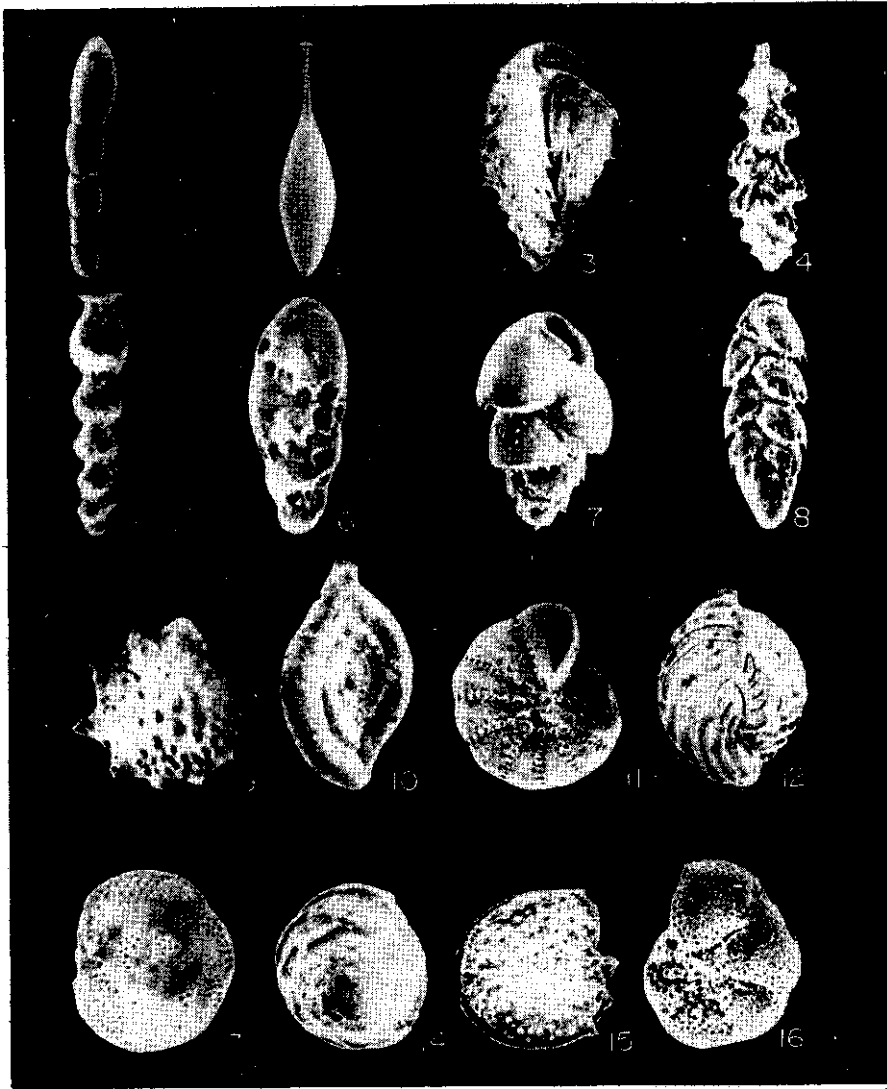


Plate: Representative species different morpho-groups

- | | |
|---|---|
| 1. <i>Dentalina communis</i> d'Orbigny X 120 | 2. <i>Lagena laevis</i> (Montagu) X 105 |
| 3. <i>Reussella simplex</i> (Cushman) X230 | 4. <i>Siphouvigerina porrecta</i> (Brady) X220 |
| 5. <i>Siphogenerina virgula</i> (Brady) X 225 | 6. <i>Virgulinitella pertusa</i> (Reuss) X 215 |
| 7. <i>Bulimina marginata</i> d'Orbigny X 215 | 8. <i>Bolivina durandii</i> Millett X 200 |
| 9. <i>Pararotalia calcar</i> (d'Orbigny) X 200 | 10. <i>Spiroloculina depressa</i> d'Orbigny X 105 |
| 11. <i>Elphidium discoidale</i> (d'Orbigny) X 160 | 12. <i>Quinqueloculina kerimbatica</i> (Heron-Allen and Earland) X 90 |
| 13. <i>Rosalina floridana</i> (Cushman) X 235 | 14. <i>Hetrolepa praecincta</i> (Karrer) X 135 |
| 15. <i>Operculina granulosa</i> Leymerie X 120 | 16. <i>Protelphidium</i> sp. X 210 |

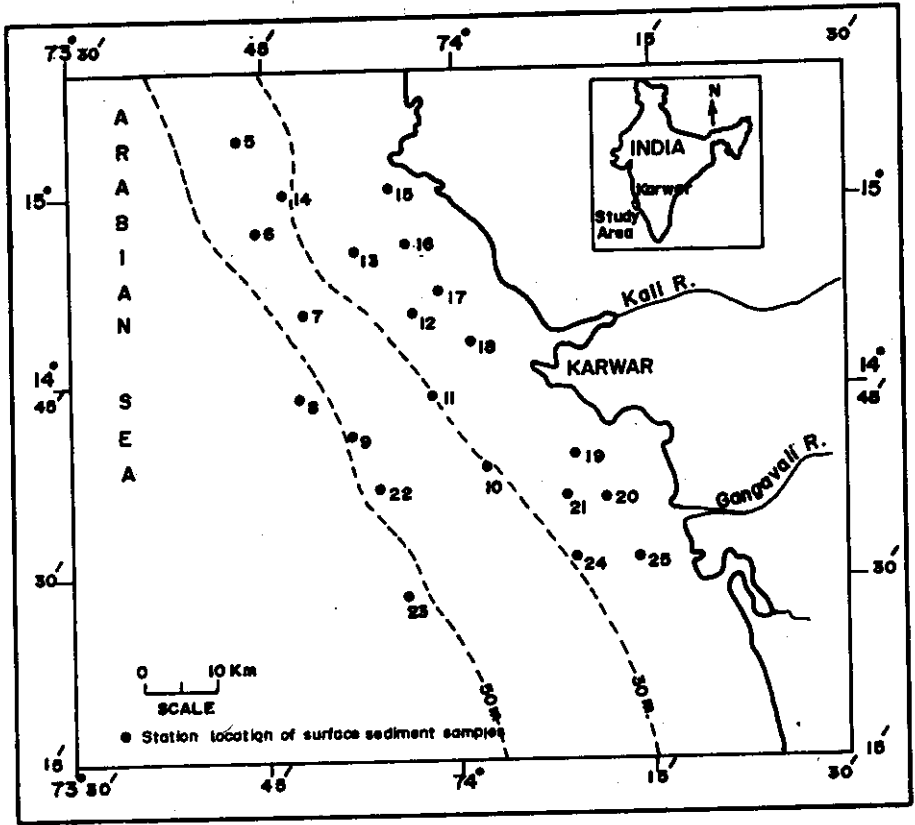


Fig.1. Location of the surface sediment samples.

placed in two morpho-groups. The distribution pattern of these morpho-groups reveals that in general angular- asymmetrical group varied from 12.72 to 65.47%, whereas rounded- symmetrical group fluctuated between 34.53 and 87.28% (Figs. 2 and 3).

DISCUSSION

As mentioned earlier, calm and quiescent ambient water conditions are prejudicial for the symmetry of the benthic foraminiferal test. It is expected that areas less affected by river discharge will yield maximum asymmetrical forms. The distribution pattern of benthic foraminiferal forms reveals similar situations (Figs. 2 and 3). It is clearly shown in Fig. 2 that near river mouths angular-asym-

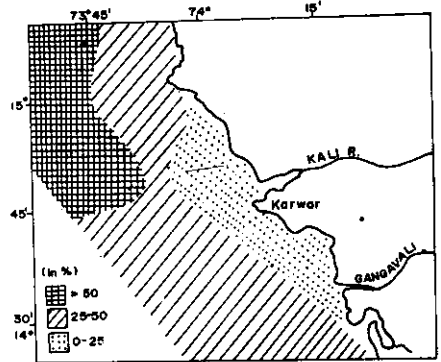


Fig.2. Distribution pattern of angular-asymmetrical morpho-group in the surface sediments off Karwar.

metrical forms are relatively less (<25%), whereas, it is increasing gradually as one

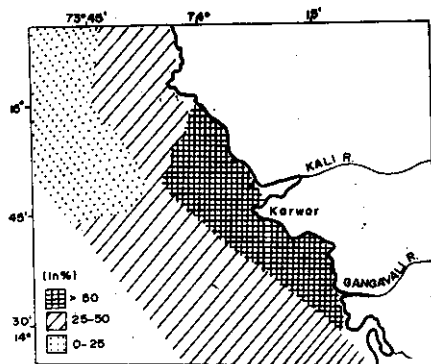


Fig.3. Distribution pattern of rounded-symmetrical morpho-group in the surface sediments off Karwar.

moves away from the river mouth. A reverse situation arises in case of rounded-symmetrical morpho-group, which is abundant near river mouths (> 50%) and decreasing while moving away from the river mouth (Fig.3). In view of this it may be inferred that river discharge has pronounced effect over external test morphologies of benthic foraminifera. It is apparent that fresh water river discharge has an adverse effect on the angular-asymmetrical forms of foraminifera.

Turbulence not only governs the symmetry but also controls the overall population of benthic foraminifera in coastal regions. A considerable reduction has been observed in areas of higher turbidity (Myers, 1942; Closs, 1962; Frerichs, 1970; Nigam, 1984). Therefore, it may also be speculated that under highly turbulent environment benthic foraminiferal population struggle to survive by developing some sort of symmetry in the test. This explanation seems to be reasonable by the fact that in undisturbed sediment an individual can easily occupy a preferred microhabitat. On the other hand, in turbulent conditions, its position and orientation would be controlled largely by the motion of the sediment. Foraminifera with symmetrical tests are able to move more easily through the sediment and hence are able to regain their

preferred microhabitat following disturbance of the sediment by turbulence (Severin, 1983).

In general fresh water run off has mostly been aimed for the study of paleoproductivity and population dynamics of coastal marine ecosystem (Drink Water, 1986). However, based on the present study it is concluded that fresh water river discharge has significant control over foraminiferal test morphology. Thus angular-asymmetrical forms could be taken as an indicator of quiescent environment whereas, rounded-symmetrical forms may be considered as indicative of turbulent environment and the relationship of morpho-groups with fresh water discharge could also be utilized for the study of monsoonal precipitation over the catchment area.

If monsoonal precipitation over the catchment area had varied in the past, such conditions can be reconstructed by studying the variations in morpho-groups fluctuations in sub-surface sediments collected through coring in the coastal areas.

Reconstruction of paleoclimates during the last 2,000 years has been taken as priority research all over the world as stream I under the International Geosphere Biosphere Programme (I.G.B.P.). In order to reconstruct the history of the past climatic changes sub surface coastal sediments can be exploited as source and morpho-groups analysis as tools. The use of morpho-groups instead of species has several advantages like, no modern counterpart of such morpho-groups is required as in the case of species, these groups are not sensitive to changes in habitat of individual species and are independent of taxonomic differences that arise among the authors regarding synonymy, species level taxonomy need not be determined and precious time can be saved in the sorting of the samples. Besides, data handling is much simpler because number of morpho-groups is smaller than number of species. Analysis using morpho-groups may be adaptable to computer image processing.

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References

- CLOSS, D. (1962). Foraminiferous e Tecame-bas da Lagoa dos Patos: Escol. Geol., Univ. Rio Grande do Sul, v.11, pp. 1-130.
- CORLISS, B.H. (1985). Microhabitats of benthic foraminifera within deep sea sediments. *Nature*, v. 314, pp. 435-438.
- CORLISS, B.H. and CHEN, C. (1988). Morphotype pattern of Norwegian sea, deep sea benthic foraminifera and ecological implications. *Geology*, v.16, No. 8, pp. 716-719.
- CORLISS, B.H. and EMERSON, S. (1990). Distribution of Rose Bengal stained deep sea benthic foraminifera from the Nova Scotian continental margin and Gulf of Maine. *Deep Sea Res.*, v.37, pp. 381-400.
- DRINK WATER, K.F. (1986). On the role of fresh water outflow on coastal marine eco system - A workshop Summary. In: S.Skreslet (Ed.) The role of fresh-water outflow in coastal marine ecosystem. Springer-Verlag, Berlin, Heidelberg. NATO ASI series G. v.7., pp. 429-438.
- FRERICHS, W.E. (1970). Distribution and ecology of benthonic foraminifera in the sediments of the Andaman Sea. *Contrib. Cushman Found. Foram. Res.*, v.21, No.4, pp. 123-147.
- KAIHO, K. (1991). Global changes of Paleogene aerobic/anaerobic benthic foraminifera and deep sea circulation. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, v.83, No. 1-3, pp. 65-85.
- KHARE, N. (1990). An aberrant *Bulimina* species from recent sediments off Karwar, west coast of India. *GeoScience Journal*, v.11, No. 1&2, pp. 81-84.
- MYERS, E.H. (1942). Ecologic relationship of some recent and fossil foraminifera. *Nat.Res.Counc. Div., Geol. Geogr. Ann. Rept. Appen.2.*
- NAIK, U.G. and NEELAKANTAN, B. (1989). Seasonal abundance of phytoplankton in the inshore waters of Karwar. *Comp. Physiol.Ecol.*, v.14, pp. 219-226.
- NAIK, U.G., REDDY, C.R., SHEITY, D.C. and NEELAKANTAN, B. (1990). Plankton of Karwar waters with remarks on the hydrographic conditions and fishery. *Fish.Tech.*, v.27, pp. 98-102.
- NAIR, R.R., ITTEKOT, V., MANGANINI, S.J., RAMASWAMY, V., HAAKE, B., DEGENS, E.T., DESAI, B.N. and HONJO, S. (1989). Increased particle flux to the deep ocean related to monsoons. *Nature*, v.338, pp. 749-751.
- NEELAKANTAN, B., NAIK, U.G., PRASAD, P.N. and KUSUMA, M.S. (1988). Hydrobiology of Kali estuary and adjoining brackish water systems, Karwar. *Environ. and Ecol.*, v.6, No. 1, pp. 139-147.
- NIGAM, R. (1984). Living benthic foraminifera in a tidal environment: Gulf of Khambhat (India). *Mar. Geol.*, v.58, No.3/4, pp. 415-425.
- NIGAM, R. (1987). Distribution, factor analysis and ecology of benthic foraminifera within innershelf regime of Vengurla - Bhatkal Sector, West Coast, India. *Jour. Geol. Soc. India*, v.23, No. 3, pp. 327-334.
- NIGAM, R. (1988a). Influence of estuaries on shelf foraminiferal species and its environmental implications. *Indian Jour. Mar. Sci.*, v.17, No.3, pp. 214-216.
- NIGAM, R. (1988 b). Fluctuating monsoonal precipitation as revealed by foraminiferal variations in shelf regime off Karwar (India). *Current Sci.*, v.57, No.9, pp. 480-491.
- NIGAM, R. (1993). Foraminifera and changing pattern of monsoon rainfall. *Curr. Sci.*, v. 64, No. 11 & 12, pp. 935-937.
- NIGAM, R. and KHARE, N. (1992a). Oceanographic evidences of the great floods at 2,000 and 1,500 B.C. documented in Archaeological records. Dr. S.R.

Rao 70th Birthday Felicitation Volume 2, pp. 517-522.

NIGAM, R. and KHARE, N. (1992b). The reciprocity between coiling direction and dimorphic reproduction in benthic foraminifera. *Jour. of Micropaleontology, Glasgow (UK)*, v. 11, No. 2, pp. 221-229.

NIGAM, R. and NAIR, R.R. (1989). Cyclicity in monsoon. *Bull. Sci.*, v.5, pp. 42-44.

PHLEGER, F.B. (1956). Significance of living foraminiferal populations along the central Texas coast. *Contrib. Cushman Found. Foram. Res.*, v.7, pp. 106-151.

RIVONKER, C.U. and REDDY, M.P.M. (1990). Hydrographic conditions in the region off Hosbettu, south Kanara coast and its influence on pelagic fisheries. *Fish. Tech.*, v.27, pp. 20-24.

SEVERIN, K.P. (1983). Test morphology of benthic foraminifera as a discriminator of biofacies. *Mar. Micropal.*, v.8, pp. 65-76.

WIDMARK, J.G.V. and MALMGREN, B. (1992). Benthic foraminiferal changes across the Cretaceous - Tertiary boundary in the deep sea, DSDP Sites 525, 527 and 465. *Jour. Foram. Res.*, v.22, No.2, pp. 81-113.

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