

## RECENT FORAMINIFERA ALONG WEST COAST OF INDIA : RETROSPECT, PERSPECT AND PROSPECT

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**Abstract :** An immense quantum of work on foraminifera is being carried out in Indian waters by various research centers and universities. However, a thorough review of the foraminiferal studies from Indian waters is yet to be made. A critical review will also help to check repetition of the work and to guide workers to decide the thrust areas and take up multi directional approaches to such studies. In view of this a review of the foraminiferal studies carried out exclusively off the west coast of India as phase I (of a three phased projected comprehensive compilation) of data from the Indian waters is presented in this paper. Besides, the publication status of the foraminiferal studies during the last 13 years (1980-1994) in few leading Indian Journals namely *Journal of Paleontological Society of India (Paleontology journal)*, *Journal of Geological Society of India (Geology journal)*, *Proceedings Indian Academy of Sciences (Earth atmospheric and oceans journal)* and *Indian Journal of Marine Science (multi disciplinary oceanography journal)* have also been evaluated. A bibliography of the foraminiferal studies and the highlights of the different studies are presented in tabular forms

### INTRODUCTION

Foraminifera are the inconspicuous protozoans, yet they are the most abundant diverse and widely distributed micro-organism in the marine realm. Refined techniques have demonstrated that the distribution of foraminifera is not random but is controlled by environmental gradient and therefore, have been exploited as environment indicator to a great extent than any other micro fossil group. These organisms when entombed in ancient sediments are frequently used as stratigraphic guides. Their mineralized shell sensitively record physico-chemical properties of the environment that can be deciphered and utilized for paleoenvironmental and paleoclimatic analyses. Such studies have been carried out with the notion "*Paleo ecologic interpretations based directly or by analyzing upon modern distribution pattern can be no better than our knowledge of living species*" (Douglas, 1979).

Hence, to utilize these micro-organisms efficiently adequate knowledge of their distri-

bution pattern in modern marine environment is of utmost importance. In spite of the large quantity of literature available on modern benthic foraminifera from world's ocean there is still much work to be done to establish the basic distribution pattern in space and time along Indian coast and continental shelf (approximately 6,000 Km long), having prolific presence of foraminifera. However, to take up research in this direction a number of problems arises such as,

1. Survey of the previous literature becomes very difficult as published papers are in scattered forms and there is a need to compile them.

2. Difficulty in proper identification of foraminiferal species as no catalogue / atlas of recent foraminifera is available from Indian region. The atlas / catalogues from other oceans are of limited importance for Indian workers. A lot of data has been generated

from Indian regions by various centers working on recent foraminifera (eg. Banaras-Hindu University, Varanasi, IIT Kharagpur, IIT Bombay, Aligarh Muslim University of Roorkee, Delhi, Waltair, Tirupati, Madras, Mysore, O.N.G.C., G.S.I. etc.) and these need to be evaluated and collated.

In view of this, a review of the foraminiferal studies carried out exclusively off the west coast of India (Figure 1) as phase I (of three phased projected comprehensive compilation) of work done in Indian waters is presented.

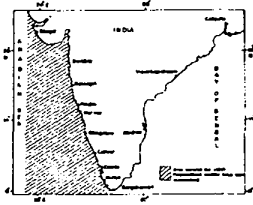


Fig.1. Area covered for which foraminiferal studies have been summarized in Tables 1 and 2

The main objectives of the present work are :

1. To review the status of the foraminiferal studies in few leading Indian Journals.
2. To prepare a bibliography of the foraminiferal studies in Arabian Sea bordering west coast of India.
3. To highlight the main essence of different studies.
4. To propose the prospects of these studies and indicate emerging areas in the field of foraminiferal research.

### SYNTHESIS OF DATA

This paper defines the status of foraminiferal studies in Earth Sciences and synthesizes the large volume of published data so that patterns may be inferred which will assist the future workers. In order to meet the requirement, four leading Indian journals are searched for foraminiferal publications since 1980 and data have been presented into

graphical or tabular forms. Tables 1 and 2 present an exhaustive list of all the publications on foraminifera from the west coast (Figure 1). A gist of the work done on these microorganisms is also given.

### TRENDS AND PATTERNS IN THE FORAMINIFERAL PUBLICATIONS IN DIFFERENT INDIAN JOURNALS SINCE 1980

In order to study the trends and patterns in the foraminiferal studies, the major journals namely *Journal of Paleontological Society of India* (Paleontology based journal), *Journal of Geological Society of India* (Geology based journal), *Proceedings Indian Academy of Sciences* (Earth atmospheric and oceans based journal) and *Indian Journal of Marine Science* (multi disciplinary oceanography journal) have been reviewed to know total number of papers, total papers on Geology (in multidisciplinary journal), total papers on paleontology and total papers on foraminifera published during the last 15 years (1980-1994).

This analysis has revealed the following facts :

1. The total research papers in a year of all four journals varied from 181 (1988) to 241 (1990), whereas, total paleontology paper published ranged from 17 (1986) to 40 (1989). Similarly total foraminiferal papers ranged

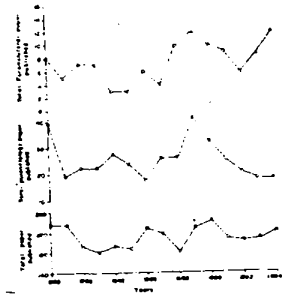


Fig.2. Profiles showing year wise total publications, total Palaeontological publications and total foraminiferal publications

**Table 1 : Publications on recent foraminifera from the western beaches of India.**

| S.N | Year   | Author                      | Area                    | Remarks  |
|-----|--------|-----------------------------|-------------------------|--|
| 1.  | 1954   | Chaudhury & Biswas          | Juhu Bombay             | 12 species of perforate foraminifera.  |
| 2.  | 1956   | Bhatia                      | Juhu Bhogat & Chaupatty | 46 species   |
| 3.  | 1960 a | Sastry & Pant               | Saurashtra              | Investigated Operculina rich sand from the sub recent deposits.  |
| 4.  | 1960 b | Sastry & Pant               | Saurashtra              | Foraminifera from millilitic limestone.  |
| 5.  | 1964 a | Rocha & Ubaldo              | Diu Gogola & Simbor     | 52 species were reported out of which 22 were already known from this area the absence of agglutinated forms suggest weak terrigenous sedimentation.             |
| 6.  | 1964 b | Rocha & Ubaldo              | Jampor and Baga (Goa)   | 24 species were reported.  |
| 7.  | 1972   | Setty & Wagle               | Goa coast               | A brief list of foraminifera with other micro-fauna is given from beach rock.  |
| 8.  | 1978   | Jain & Bhatia               | Mandvi Kutch            | 37 species including one new species <i>Pararotalia boitovskoy</i> .   |
| 9.  | 1979   | Bhalla & Nigam              | Calangute Goa           | 36 species identified. Fauna was compared with eastern beaches.  |
| 10. | 1980   | Bhalla & Nigam              | Calangute Goa           | Planktonic foraminifera and their paleo climatic significance.   |
| 11. | 1980   | Bhalla & Raghav             | Malabar coast           | 25 species and suggested that salinity is the chief governing factor.  |
| 12. | 1982   | Desai & Pandya              | Saurashtra              | Foraminifera of the coastline sediments.   |
| 13. | 1982   | Desai & Shringarpure        | Saurashtra              | Recent foraminifera are used to study the impact of sedimentation on onshore environment.  |
| 14. | 1984   | Setty et al                 | Miramar Caranzalem      | 44 benthic and one planktonic species of foraminifera from the intertidal area.  |
| 15. | 1984   | Srivastava et al.           | Veraval & Saurashtra    | 26 species of benthic and one species of planktonic foraminifera, the assemblage is typical of warm waters.  |
| 16. | 1985   | Bhalla & Lal                | Okha Gujarat            | 18 species of recent foraminifera, compared with fauna of other beaches of west coast.   |
| 17. | 1985 a | Pandya                      | Gujarat                 | Segment wise distribution is given which is controlled by various offshore and littoral processes.   |
| 18. | 1985 b | Pandya                      | Saurashtra              | 95 species including 3 planktonic ecological control on the foraminiferal diversity  |
| 19. | 1986   | Bhalla & Gaur               | Colva Goa               | 29 species.  |
| 20. | 1986   | Bhalla & Nigam              | Velsao Goa              | 27 species of recent foraminifera from the polluted environment which resulted distortion and abnormal growth in <i>Ammonia</i> species.                         |
| 21. | 1987   | Bhalla & Gaur               | Colva Goa               | Detailed systematic study of 29 species  |
| 22. | 1988   | Bhalla & Nigam              | West & East Coast       | Cluster analysis of published foraminiferal data from six beaches.   |
| 23. | 1988   | Shareef & Venkatachalapathy | Bhatkal & Devgad island | 40 species from Bhatkal and 41 species from Devgad island, check list is also provided.  |
| 24. | 1994   | Talib & Farooqui            | Dwaraka Gujarat         | 26 species of benthic foraminifera Cluster analyses of data from six beaches (east & west) suggest that entire west coast of India may be included in the mixed. |

from 3 (1985) to 12 (both in 1989 & 1994) [ Figures 2 a, b and c ].

2 In multidisciplinary oceanographic journal (I.J.M.S.) out of 1070 papers 146 papers dealt with Marine Geology, whereas only 1.68 % of the total publications were concentrated on foraminifera during the last 15 years.

The year wise details of different journals is summarized in Table 3. As far as cumulative growth of foraminiferal paper in different journals is concerned the best growth is recorded in *Journal of Geological Society of India* (Figure 3). The overall status of foraminiferal research papers in different journal is shown in Figure 4. In *Indian Journal of Marine Science* and *Proceedings of Indian Academy of Sciences* generally paleontological papers were based on foraminifera. Thus all together 3152 papers were published in these journals out of which 375 were concentrated on paleontology. Out of these 375 papers 114 papers were on foraminifera (Figure 5). Thus only 3.62 % of the total paper published since 1980 till 1994 dealt with foraminifera.

### FORAMINIFERAL PUBLICATIONS FROM THE ARABIAN SEA

The study of foraminifera in Indian waters started with the pioneer work of Chapman (1985), Hofker (1927 ; 1930) and Stubbings (1939). In 1963 Sastry prepared an annotated bibliography of the foraminiferal work. Later

on Bandy et al. (1972) presented an overview of the foraminiferal research carried out in Indian waters. Since then except Setty (1982 a) who provided a brief historical resume of foraminiferal studies in Arabian Sea, no detailed review is made on such studies. Tables 1 and 2 summarize the comprehensive work carried out on the west coast of India (Arabian Sea).

The literature review of the foraminiferal studies since 1980 have suggested the following facts :

1. With the acquisition of research vessels, there is a shift in focus from beaches to offshore areas which reflected in a total of 15 papers published on the western beaches and 80 papers published on in shore and offshore regions.
2. After the introduction of personal computers, tendencies to exploit statistical tools for synthesizing foraminiferal data have increased.
3. There has been a shift from basic research to applied research.
5. Very little efforts have been made to study the chemistry of the tests.
6. Few attempts have also been made to study the temporal variations of foraminifera in order to interpret paleo climate/environment.

### RECOMMENDATIONS FOR FUTURE FORAMINIFERAL STUDIES

#### 1. Paleoclimates

After the initiation of International

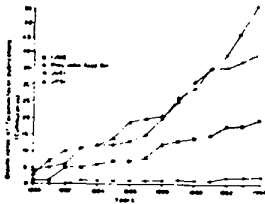


Fig.3. Cumulative growth rate of foraminiferal publications

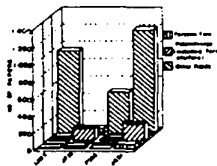


Fig.4. Overall status of total foraminiferal research papers in different journals

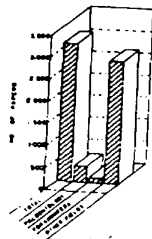


Fig. 5 Overall status of publications in different fields since 1980.

Table 2 : Publications on recent foraminifera from Western nearshore and offshore regions of India.

| Sl No. | Year       | Author                       | Area                           | Remarks   |
|--------|------------|------------------------------|--------------------------------|---|
| 1.     | 1951       | Kurián                       | Travancore Coastal Waters      | Recorded Presence of <i>Operculina granulosa</i>  |
| 2.     | 1953       | Kurián                       | Waters                         | Granulosa.  |
| 3.     | 1958       | Seihulekshimi Amma           | Trivandrum                     | Described 114 species.  |
| 4.     | 1967       | Chatterjee & Gururaja        | Mangalore                      | Foraminifera comprises 90% of the assemblage, having 12 genera including one planktonic form  |
| 5.     | 1968       | Antony                       | Kerala (Vizhngom to Cannanore) | Out of 164 species identified in the surface sediments bathymetric distribution of few common species.  |
| 6.     | 1970 a & b | Rao                          | Gulf of Cambay                 | Illustrated 84 species from 4 samples.  |
| 7.     | 1970 c     | Rao                          | N.E. Arabian Sea               | A rare species of <i>Triloculina echinata</i> d' Orbigny.   |
| 8.     | 1971 a     | Rao                          | Gulf of Cambay                 | Recent foraminifera with 16 figures.  |
| 9.     | 1971 b     | Rao                          | Saurashtra                     | Recent foraminifera from 8 core top samples yielded 92 species.   |
| 10.    | 1971       | Seibold                      | Cochin backwaters              | Sections and stereoscan micro photographs revealed that only one species <i>Rotalia braccatilar. sobrina</i> is a true <i>Ammonia</i> .                                       |
| 11.    | 1971       | Zobel                        | Arabian Sea                    | Planktonic foraminifera and role of ocean watermass in their distribution.  |
| 12.    | 1972       | Rao                          | Off Bombay                     | 22 species of plan ktonic foraminifera shows mixing of Antarctic water in this region.  |
| 13.    | 1972       | Seibold                      | Cochin backwaters              | Report on the transport of foraminifera.  |
| 14.    | 1972       | Setty                        | Shelf off Kerala               | 22 species of planktonic foraminifera including <i>globigama hexagona</i> and <i>Gilboquadrina conglomera</i> which disappeared from Atlantic are seen to be living today.    |
| 15.    | 1972       | Setty & Guptha               | Karwar & Mangalore             | 15 species of planktonic foraminifera.  |
| 16.    | 1972       | Venkata chalapathy & Shareef | Mangalore                      | Pyritization in certain foraminifera from recent sediment   |
| 17.    | 1973 a     | Guptha                       | Kavaratti                      | 20 species of benthic foraminifera  |
| 18.    | 1973 b     | Guptha                       | Shelf off Cochin               | 24 species of planktonic foraminifera   |
| 19.    | 1973       | Rao                          | S. E. Arabian Sea              | 25 Species of planktonic foraminifera. Compare to bay of Bengal, Arabian Sea has greater diversity of species which may be due to higher salinity in Arabian Sea.             |
| 20.    | 1973       | Seibold, E. & Seibold, I     | Kerala Shelf                   | New species <i>Cassidella Panikkeri</i> .   |
| 21.    | 1973       | Setty                        | Western shelf                  | Popular article on foraminifera as climatic indicators.   |
| 22.    | 1973       | Zobel                        | Arabian Sea                    | 24 sediment cores and 100 grab samples were studied to reconstruct climatic conditions during the late Quaternary.  |
| 23.    | 1974       | Banerjee                     | West Coast                     | Benthic foraminifera used as an aid to study pollution.   |
| 24.    | 1974       | Guptha                       | Continental Slope off Bombay   | 25 Species of planktonic foraminifera.  |
| 25.    | 1974       | Rao                          | Goa                            | Living population is poor in lower reach of Mandovi and Zuari estuaries, areas of high organic carbon exhibited low species diversity assemblages.                            |
| 26.    | 1974       | Setty                        | Kerala Coast                   | 32 species of recent benthic foraminifera including <i>Hyalina balthica</i> from shelf sediments with a short account of the important character of each species is recorded. |

|     |        |                               |                            |  |
|-----|--------|-------------------------------|----------------------------|--|
| 27  | 1975   | Antony                        | Kerala                     | Living <i>A. beccarii</i> in the sediment of Kayamkulam lake.  |
| 28  | 1975   | Antony & Kurian               | Vembanad estuary           | <i>A. beccarii</i> may cease to be able to live in the estuaries.  |
| 29  | 1975   | Seibold                       | Cochin                     | Lagoon and coast of Cochin for benthonic foraminifera. 69 species including one new species, more abundant forms of taxonomic/ ecological interest are discussed.                        |
| 30. | 1975   | Venkata chalalpathy & Shareef | West coast                 | Morphology, distribution and wall structure of <i>ammonia beccarii</i>   |
| 31. | 1976   | Bhatia & Kumar                | Kanvar                     | 35 benthic species including <i>Caribbeanella</i> sp. from Anjediv island, Binge bay.  |
| 32. | 1976   | Dalal                         | Goa                        | Statistical analysis of Rao's 1974 data.   |
| 33. | 1976   | Setty                         | Goa                        | Foraminiferal response to the effect of industrial effluent in Cola bay  |
| 34. | 1976   | Venkata chalalpathy & Shareef | Mangalore                  | Morphologic and microstructural characteristic features of some smaller foraminifers of considerable taxonomic significance.   |
| 35. | 1977   | Setty                         | Shelf Slope Arabian Sea    | Two new sub species namely <i>Neoglobobuadrina pachyderma dextralis typica</i> and <i>Neoglobobuadrina pachyderma sinistralis typica</i> .   |
| 36. | 1978   | Venkata chalalpathy & Shareef | Mangalore                  | Scanning electron Microscopy of rotaliid group   |
| 37. | 1979   | Nigam <i>et al.</i>           | Dabhol Vengurla Sector     | A checklist of 64 benthonic foraminiferal species.   |
| 38. | 1979   | Rao & Rao                     | Trivandrum                 | 85 Species of foraminifera. 3 faunal grouping were recognised. solution effect on the test of foraminifera was observed at out fall area.  |
| 39. | 1979   | Setty <i>et al</i>            | Central West Coast         | Graphic pattern: of 8 foraminiferal dominant groups in nearshore region.   |
| 40. | 1980 a | Antony                        | South West Coast           | 17 species of living foraminifera of in the intertidal area near Cochin.   |
| 41. | 1980 b | Antony                        | Kerala                     | Transport of inner shelf tests into lower estuary has been reported from Vembanad estuary.   |
| 42. | 1980   | Dalal                         | Goa                        | Statistical analysis of Rao's (1974) data.   |
| 43. | 1980   | Nigam & Setty                 | Daman                      | Occurrence of paleogene reworked foraminifera in recent sediments  |
| 44. | 1980 a | Setty & Nigam                 | Dabhol Vengurla            | Distribution of 72 dead and 32 living benthic foraminiferal species within neritic regime, indicates the existence of micro-environment.   |
| 45. | 1980 b | Setty & Nigam                 | Western continental margin | Observed eccentricity and twinning in <i>Virgulinitella pertusa</i> (Reuss).   |
| 46. | 1981   | Nigam & Sarupriya             | Ratnagiri                  | Cluster analysis and ecology of the living benthonic foraminifera.   |
| 47. | 1981   | Seibold, I. & Seibold E       | Cochin                     | Offshore to lagoonal benthic foraminifera, their distribution, transport and ecological aspects.   |
| 48. | 1982   | Nigam & Setty                 | West coast                 | Distribution and ecology of <i>Virgulinitella</i> sp. in the inshore sediments, first report of <i>V. pertusa</i> .  |
| 49. | 1982 b | Setty                         | Bombay thane creek.        | Pollution shows pits and thinning of the test wall of foraminifera.  |
| 50. | 1982   | Setty & Nigam                 | Western shelf              | Relationship between foraminiferal assemblages and organic carbon.   |
| 51. | 1983   | Nigam & Thiede                | Central West coast         | Q-mode factor analysis of 72 species of recent foraminifera from the inner shelf revealed 4 assemblages which can be related to fresh water runoff and organic matter.                   |
| 52. | 1983   | Setty                         | Western Continental margin | The occurrence of <i>Globigerina bulloides</i> and the absence or irregular occurrence of <i>Globorotalia menardii</i> indicate up welling in this region, supported by benthic species. |
| 53. | 1983   | Setty <i>et al.</i>           | Bombay - Daman             | An aberrant <i>Spiratoculina</i> species from recent sediments.  |
| 54. | 1984   | Cullen & Prell                | Arabian sea                | Principal component analysis suggested that 17 mic : abundant planktonic species exhibit systematic geographic distribution pattern which reflect both variations in living population   |

- and effect of differential dissolution.
- Response of living benthic foraminifera in high tidal environment, a total of 60 species including 16 living.
- Larger foraminifera from the calcareous relict sediments invariably mixed with recent fauna.
- Foraminifera as indicators of pollution in marine environment of Thana creek, cola bay, Karwar and Trivandrum
- Occurrence of *Rotalia tinopsis seminulata* from the pleistocene sediment.
- Microboring is studied on foraminiferal tests from Holocene deposits of Raigad district.
- 28 species of planktonic foraminifera in 74 cm long sediment core
- Frequency distribution of 52 species of recent foraminifera, faunal trend in relation to pollution.
- Planktonic foraminifera are used to study climate control over water masses
- 62 species of benthic foraminifera including 16 living, effects of river discharge is highlighted.
- Assemblages are dominated by hyaline forms with subsidiary porcellaneous and agglutinated taxa.
- Living planktonic foraminifera are governed by up welling seasonally and spatially than by sea temperature and latitude.
- Isotopic study indicated that during galcial lime N.E. monsoon circulation was the dominant feature
- Factor analysis of 60 species revealed 3 assemblages, a technique of comparing living and dead foraminifera for sediment movement.
- Q-mode factor analysis of 102 species of benthic foraminifera revealed six assemblages.
- Mean probolulus size to inversely related to salinity and temperature in benthic foraminiferal species and can be used in paleooclimatic studies.
- 107 species are reported.
- 12 agglutinated and 10 calcareous species of recent foraminifera
- Litho and bio stratigraphy of 25 bore holes, 90 species are grouped into 3 assemblages.
- Foraminiferal variations in a core from shelf regime is used to decipher monsoonal precession.
- Reproductive behaviour of foraminifera as a new tool for reconstruction of paleoclimates.
- Influence of estuaries on shelf foraminiferal species (*C. annexens*) along Dabhol-Bhatkal sector.
- Utilized foraminifera to prove large rectangular structure at Lothal, a Harappan settlement as dockyard
- Pollution studies were carried out utilizing foraminiferal population
- Planktonic foraminifera in deep sea core placed LGM at 165 cm and below LGM 3 warm and 2 cold episodes are noticed
- 6 biofacies are delineated from east to west.

|    |        |                             |                             |
|----|--------|-----------------------------|-----------------------------|
| 55 | 1984   | Nigam                       | Gulf of Khambhat            |
| 56 | 1984   | Setty                       | Karwar                      |
| 57 | 1984   | setty & Nigam               | West coast                  |
| 58 | 1984   | Sharma & Mishra             | Arabian Sea                 |
| 59 | 1985   | Gare <i>et al.</i>          | Coastal Maharashtra         |
| 60 | 1985   | Guptha & Hashimi            | North East Arabian Sea      |
| 61 | 1985   | Rao <i>et al.</i>           | Trivandrum                  |
| 62 | 1985   | Setty                       | West coast                  |
| 63 | 1985   | Setty & Nigam               | Bombay                      |
| 64 | 1985   | Srivastava <i>et al.</i>    | Kavaratti island            |
| 65 | 1985   | Zhang                       | Eastern Arabian             |
| 66 | 1985   | Fontugne & Duplessy         | Arabian Sea Bay of Bengal   |
| 67 | 1986   | Nigam                       | Navapur                     |
| 68 | 1987   | Nigam                       | Vengurda Bhatkal            |
| 69 | 1987   | Nigam & Rao                 | West coast                  |
| 70 | 1987   | Rao <i>et al.</i>           | Lakshadweep archipelago     |
| 71 | 1987 a | Shareef & Venkatachalapathy | Sunghiri island Karwar      |
| 72 | 1987 b | Shareef & Venkatachalapathy | Karnataka                   |
| 73 | 1988 a | Nigam                       | Karwar                      |
| 74 | 1988 b | Nigam                       | West coast                  |
| 75 | 1988 c | Nigam                       | West coast                  |
| 76 | 1988 d | Nigam                       | Lothal                      |
| 77 | 1989   | Banerjee                    | Off Bombay                  |
| 78 | 1989   | Dvakar Naidu <i>et al.</i>  | Southern Arabian Sea        |
| 79 | 1989   | Gupta & Bhattacharjee       | Trivandrum and Cape Comorin |

|      |        |                             |                                  |  |
|------|--------|-----------------------------|----------------------------------|--|
| 80.  | 1989 a | Madabhushi                  | Innershelf Cannanore Calicut     | Benthic foraminifera reflects variations in coastal geomorphic features.   |
| 81.  | 1989 b | Madabhushi                  | Outer shelf & upper slope Cochin | Based on benthic foraminifera paleo environment zones are distinguished.   |
| 82.  | 1989   | Mathur & Gupta              | Off Devgarh                      | Depth-wise distribution of benthic foraminifera.   |
| 83.  | 1989   | Nigam                       | Bombay & Ratnagiri               | Benthic foraminifera from shelf region, their distribution, ecology, and environmental significance.   |
| 84.  | 1989   | Nigam & Nair                | Karwar                           | Decadal cyclicality of 77 years in monsoons by using foraminifera as a tool.   |
| 85.  | 1989   | Nigam & Rao                 | Karwar                           | Subsurface sediments showed an inverse relation between coiling direction and reproductive mode in benthic foraminifera ( <i>C. arcticus</i> ?)  |
| 86.  | 1988   | Srinivasan                  | Triprayar- Azhikhode             | Grab samples and a vibro core (355 cm long) from inner shelf at 30m depth are studied, presence of <i>Uvigerina</i> in the bottom of the core represented higher sea level   |
| 87.  | 1982   | Banerjee                    | Bombay                           | Heavy metals such as Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn in the shells of benthic foraminifera.  |
| 88.  | 1980   | Divakar Naidu               | West coast                       | Upwelling and planktonic foraminifera from 21 surficial sediment samples.  |
| 89.  | 1980   | Guptha <i>et al.</i>        | S.E. Arabian Sea                 | 28 species of living planktonic foraminifera, higher diversity during summer.  |
| 90.  | 1980   | Khare                       | Karwar                           | An aberrant specimen of <i>Bullimina exilis</i> .  |
| 91.  | 1980   | Sarkar <i>et al.</i>        | Arabian Sea                      | Isootope analysis of planktonic foraminiferal test suggested that summer monsoon was weaker during the L.G.M. (ca. 18000 years ago).   |
| 92.  | 1981   | Divakar Naidu               | Eastern Arabian Sea              | Profiles of coarse fraction, CaCo <sub>3</sub> and <i>G. menardi</i> in two cores.   |
| 93.  | 1981   | Gupta                       | Arabian Sea                      | 20 species of foraminifera from D.S.D.P. site 219.   |
| 94.  | 1981   | Rao <i>et al.</i>           | Eastern Arabian Sea              | 30 species of living planktonic foraminifera from 97 plankton tows samples   |
| 95.  | 1981   | Shareef & Salyanarayana     | Karnataka                        | Paleoecological information on the predator-prey interaction in specific habitats.   |
| 96.  | 1982   | Borole                      | Arabian Sea                      | 19. of <i>G. ruber</i> (white var.) from deep sea sediment traps at depth of 1,000 and 2000 m showed very little variations during May to October 1987 having anomalous weak monsoonal rainfall indicating the use of 18. as a proxy of monsoonal precipitation. |
| 97.  | 1982   | Divakar Naidu <i>et al.</i> | West coast                       | 27 species of planktonic foraminifera are reported upwelling related productivity is observed by using <i>G. bullidoides</i> .   |
| 98.  | 1982 a | Nigam & Khare               | Karwar                           | High monsoonal rainfall inferred at ca. 2,000 and 1,500 years BC, supported by archaeological findings.  |
| 99.  | 1982 b | Nigam & Khare               | Karwar                           | A reciprocity between coiling direction and dimorphic reproduction in benthic foraminifera.  |
| 100. | 1982   | Nigam & Henriques           | Arabian Sea                      | Regional numerical model for paleo depth using planktonic percentage of foraminiferal fauna in surface sediments is proposed and compared from other regions.  |
| 101. | 1982 a | Nigam <i>et al.</i>         | Outer shelf off Bombay           | Fluctuation of sea prior to 10,000yrs BP was evidenced through the study of foraminifera in a core.  |
| 102. | 1982 b | Nigam <i>et al.</i>         | Karwar                           | Discovered that morpho-groups of benthic foraminifera as an additional tool for paleo monsoonal studies.   |
| 103. | 1982   | Rao <i>et al.</i>           | Laccadive Arabian Sea            | 25 planktonic foraminiferal species were recorded from 38 plankton tows. Foraminiferal fauna in general deplete closer affinity with that of equatorial waters of the world and is typical of a tropical reef region under peak winter conditions.               |
| 104. | 1982   | Srinivasan & Singh          | Laccadive Arabian Sea            | 123 species of planktonic foraminifera is recorded from D.S.D.P. site 219, twelve Neogene  |



planktonic foraminiferal zones are recognised.  
 Distribution of 27 species of planktonic foraminifera.  
 Based on foraminifera paleomonsoonal history of the last 4,500 years was reconstructed.  
 Fouling of intertidal barnacle on relic foraminifera in surface sediment as a tool for defining paleo shoreline.  
 Recognised Pleistocene - Holocene transition in a complex core.  
 31 species of planktonic foraminifera, *Globorotalia tumida flexuosa* has become extinct after Pleistocene in Arabian Sea.  
 Paleoclimatic potentials of mean protoconus size, 13 and 18, are compared in *C. arnheims*.  
 Paleontologic Time Series (PTS) analysis on 8 series of abundance data of *Globorotalia menardii* and total planktonic foraminifera obtained from the cores of DSDP 219, 220 and 241.  
 16 species of planktonic foraminifera from six vertical plankton tows. Low abundance of *G. bulloides* can be explained by the warming of the surface waters in combination with deepening of the mixed layer.  
 First report of *Pavonina flabelliformis* at shallower depths from Arabian Sea.  
 Morpho-groups of benthic foraminiferal species (148) were made namely angular-asymmetrical, which gets adversely affected by river discharge and rounded symmetrical which responded in a reverse manner.  
 Based on benthic foraminiferal morpho-group and planktonic foraminifera a significant change in the intensity of the precipitation was noticed around 2,000 years BP.  
 Significant positive correlation between rain fall and mean Protoconus size (MPS) was recorded in shallow sediment core.  
 A cyclicity of 77 years was noticed in the proxy foraminiferal tracers of paleomonsoonal precipitation and it was suggested that Gleitsberg solar cycle possibly modulates this inferred cycle in the recurrence of droughts in India.  
 A total of 8 benthic foraminiferal species were recorded for the first time from Arabian Sea. SEM photographs were provided.  
 The surficial distribution of coarser morphogroups in 45 samples was linked with the fresh water river discharge. An anomaly in the distribution pattern is noticed off New Mangalore Port which is attributed to dredging for the navigational channel.

|      |        |                |                                 |  |
|------|--------|----------------|---------------------------------|--|
| 105. | 1993   | Dvaker Naidu   | Western continental margin      |  |
| 106. | 1993   | Nigam          | Karwar                          |  |
| 107. | 1993   | Nigam, et al.  | West coast                      |  |
| 108. | 1993   | Bhat & Adiga   | Lakshadweep                     |  |
| 109. | 1993   | Lahiri         | Off Saurashtra, Bombay & Cochin |  |
| 110. | 1993   | Nigam & Sarkar | West coast                      |  |
| 111. | 1993   | Sarkar & Guha  | Arabian Sea                     |  |
| 112. | 1994   | Gupta et al.   | Arabian Sea                     |  |
| 113. | 1994   | Khare          | Karwar                          |  |
| 114. | 1994 a | Nigam & Khare  | Karwar                          |  |
| 115. | 1994 b | Nigam & Khare  | Karwar                          |  |
| 116. | 1995   | Nigam & Khare  | Karwar                          |  |
| 117. | 1995   | Nigam, et al.  | Karwar                          |  |
| 118. | 1995   | Khare          | Karwar                          |  |
| 119. | 1995   | Khare et al.   | Inner shelf off Mangalore       |  |

Geosphere Biosphere Programme ( IGBP) in 1986 paleoclimatic studies are gaining more importance day by day because the modern industrialization has resulted a global warming due to Greenhouse effect which may alter the future climates. In order to develop predictive models understanding of the past climatic conditions is important. For this purpose we have to rely on proxy indicator of climates. Foraminifera being so sensitive towards climate/ environmental changes and abundant through ages should be explored further to obtain high resolution paleo climatic signals. For this purpose a number of sediment cores from different geographical region and at different depth should be collected and analyzed for paleoclimatic reconstruction using foraminiferal parameters as climatic proxy.

## 2. Monograph and Atlas

In order to make the beginner acquainted with the different varieties of foraminifera along the Indian coasts, it is essential to prepare the monograph/atlas of the foraminiferal species in different regions (or sector wise). Some such attempts have already been made from other regions (Murray, 1971 ; Boltovskoy et al., 1980 ; Srinivasan and Sharma, 1980). Future Researchers in the field of paleoclimatology utilizing foraminifera as a tool will meet their requirement without going through enormous and patchy information in voluminous literature for identification of foraminiferal species.

## 3. Laboratory culturing of foraminifera

All paleoclimatic inferences like shape, size, coiling direction, number of chambers, porosity, chemical and isotopic composition of foraminifera etc. Most studies are field based and only fragmentary attempts involve laboratory experiments or mathematical modelling. If the response of foraminiferal parameters of different species towards different environmental conditions is further checked under controlled laboratory culture it will bring more accuracy and precision in the paleoclimatic evaluation. Therefore, laboratory culture should be initiated on different benthic as well as planktonic species of foraminifera.

Furthermore, the introduction of new techniques such as the stable isotope composition of the test, wall ultra structural and biochemical studies of soft parts is throwing new light on their physiology and mode of life. Therefore it is imperative that research must also be diverted towards these directions.

## 4. Collaborative programmes among research institution and various universities

The data incorporated in this study revealed that maximum (67.13 % of the total ) work has been done on offshore surface sediments whereas, foraminiferal studies in sub surface sediments (16.08 %) are relatively limited, with 16.78 % studies carried out on western beaches (Figure 6). Forty seven individuals from different organizations (universities, NIO, ONGC and Foreign organizations) have contributed to bring out a total of 24 papers on

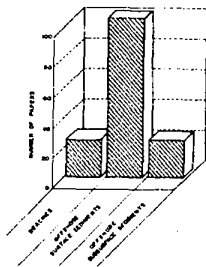


Fig.6. Showing region wise classification of the foraminiferal research along west coast of India.

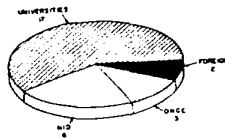


Fig.7. Relative contribution of Universities, NIO, ONGC, and Foreign Organisations in research from the Western beaches of India.

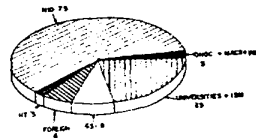


Fig.8. Relative contribution of Universities, ISM, NIO, ONGC, MACS (Pune), IIT, GSI & Foreign Organisations from the western nearshore & offshore regions.

**Table 3** : Showing year wise details of the publications in (A) Indian Journal of Marine Science, (B) Proceedings of the Indian Academy of Sciences, (Earth and Planetary Sciences) (C) Journal of Geological Society of India and (D) Journal of Palaeontological Society of India.

| Year | (A) Indian Journal of Marine Sciences |                       |                         | (B) Proceedings Indian Academy of Sciences |                       |                         | (C) Journal of Geological Society of India |                       |                         | (D) Journal of Paleontological society of India |                         |                         |
|------|---------------------------------------|-----------------------|-------------------------|--|-----------------------|-------------------------|--|-----------------------|-------------------------|---|-------------------------|-------------------------|
|      | Total paper                           | Paper on Paleontology | Paper on foraminifera X | Total paper                                | Paper on Paleontology | Paper on foraminifera X | Total paper                                | Paper on Paleontology | Paper on foraminifera X | Total paper                                     | Paper on Paleontology * | Paper on foraminifera X |
| 1980 | 79                                    | 1                     | 1                       | 39   | 0                     | 0                       | 90   | 17                    | 4                       | 28  | 21                      | 3                       |
| 1981 | 95                                    | 1                     | 0                       | 36   | 0                     | 0                       | 80   | 3                     | 1                       | 24  | 16                      | 4                       |
| 1982 | 88                                    | 4                     | 4                       | 26   | 0                     | 0                       | 67   | 10                    | 1                       | 11  | 8                       | 4                       |
| 1983 | 65                                    | 0                     | 0                       | 29   | 1                     | 1                       | 72   | 9                     | 5                       | 16  | 12                      | 1                       |
| 1984 | 60                                    | 1                     | 1                       | 38   | 0                     | 0                       | 83   | 18                    | 1                       | 12  | 8                       | 1                       |
| 1985 | 56                                    | 1                     | 1                       | 33   | 0                     | 0                       | 84   | 11                    | 0                       | 15  | 11                      | 2                       |
| 1986 | 74                                    | 0                     | 0                       | 40   | 0                     | 0                       | 102  | 8                     | 1                       | 12  | 9                       | 5                       |
| 1987 | 64                                    | 1                     | 1                       | 26   | 0                     | 0                       | 113  | 14                    | 2                       | 14  | 10                      | 1                       |
| 1988 | 75                                    | 4                     | 4                       | 17   | 0                     | 0                       | 75   | 14                    | 5                       | 10  | 7                       | 1                       |
| 1989 | 71                                    | 1                     | 1                       | 30   | 0                     | 0                       | 117  | 29                    | 6                       | 10  | 10                      | 5                       |
| 1990 | 69                                    | 1                     | 1                       | 43   | 0                     | 0                       | 108  | 16                    | 3                       | 21  | 14                      | 6                       |
| 1991 | 69                                    | 1                     | 1                       | 34   | 0                     | 0                       | 94   | 14                    | 6                       | 10  | 9                       | 2                       |
| 1992 | 71                                    | 2                     | 2                       | 29   | 1                     | 1                       | 89   | 12                    | 4                       | 6   | 6                       | 0                       |
| 1993 | 69                                    | 0                     | 0                       | 35   | 0                     | 0                       | 95   | 13                    | 7                       | 8   | 6                       | 2                       |
| 1994 | 65                                    | 1                     | 1                       | 26   | 0                     | 0                       | 112  | 10                    | 8                       | 9   | 9                       | 3                       |

X includes both recent and fossil forms.

\* Excluding Paleobotany, Sedimentology and Stratigraphy, including foraminifera.

western beaches. The relative contribution of each organization is exhibited in Figure 7. It can further be noticed that maximum contribution is made by different universities compare to other research organizations. Similarly the relative contribution of universities, ISM, ONGC, MACS (Pune), PRL, GSI, IIT and foreign organizations in offshore regions is exhibited in Figure 8, where 205 individuals attempted to bring out 119 research papers. It is interesting to note that in foraminiferal research carried out in offshore regions, participation of different universities is relatively less compare to other research organizations. In all, 143 papers have been contributed by 252 researchers belonging to eight research organizations and different universities. Out of these, 28.00 % contribution goes to various universities whereas, 66.67 % contribution is made by different research organizations. However, only 5.33 % research is contributed by foreign organizations.

It is apparent that contribution from universities is limited perhaps due to non-availability of samples from ocean beds. Therefore to procure such samples and initiate foraminiferal research programmes in respective universities, collaborative programmes have to be taken up in which both universities, collaborative programmes have to be taken up in which both universities and oceanographic organizations come together. Besides, some research oriented training programmes for procedures (onboard/laboratory) should also be introduced at post graduation levels to make the students aware of the research potentials in foraminifera.

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#### REFERENCES

- Antony, A. 1968. Studies on the shelf water foraminifera of the Kerala coast. *Bull. Dept. Mar. Bio. Oceanogr.* V.4, pp.11-154.
- Antony, A. 1975. Foraminifera from the Kayamkulam lake. *Bull. of the Dept. of Mar. Sci. Uni. of Cochin.* V.7, pp. 257-262.
- Antony, A. 1980 a. Interstitial foraminifera of the sandy beaches of the south west coast of India. *Bull. of the Dept. of Mar. Sci. Uni. of Cochin.* V.11, pp.103-132.
- Antony, A. 1980 b. Foraminifera of the vembnad estuary. *Bull. of the Dept. of Mar. Sci. Uni. of Cochin.* V.11, pp.25-63.
- Antony, A. and Kurian, C.V. 1975. Seasonal occurrence of *Rotalia beccarii* (Linne') (Foraminifera) in the Vembanad estuary. *Bull. of the Dept. of Mar. Sci. Uni. of Cochin.* V.7, pp.235-241.
- Bandy, O.L., Hans, G., Linderberg and Edith Vincent. 1971. History of research, Indian Ocean foraminifera. *Jour. Mar. Biol. Assoc.*, V.13 (1), pp.86-104.
- Banerjee, R.K. 1974. Benthic foraminifera as an aid to recognise the polluted environments. *Proc. IV Indian Colloq. Micropal. Stratigr.* pp.1-6.
- Banerjee, R.K. 1989. Foraminifera and discrimination of polluted environments along Bombay coast. *Proc. XII Indian Colloq. Micropal. Stratigr.* pp.1-18.
- Banerjee, R.K. 1992. Heavy metals and benthic foraminiferal distribution along Bombay coast, India. *Studies in Benthic Foraminifera* (BENTHOS' 90 Sendai, Japan, 1990), Tokyo University Press pp.151-157.
- Bhalla, S.N. and Gaur, K.N. 1986. A note on recent foraminifera from Colva beach sands, Goa. *Curr. Sci.* V.55 (6), pp.314-315.
- Bhalla, S.N. and Gaur, K.N. 1987. Recent foraminifera from Colva beach sands, Goa. *Jour. Pal. Soc. India.* V.32, pp.122-130.
- Bhalla, S.N. and Lal, M. 1985. Recent foraminifera from Okha beach sands, Gujarat state, a preliminary note. *Curr. Sci.* V.54 (9), pp.429-430.
- Bhalla, S.N. and Nigam, R. 1979. A note on recent foraminifera from Calangute beach sands, Goa. *Bull. Indian. Geol. Assoc.* V.12 (2), pp 239-240.
- Bhalla, S.N. and Nigam, R. 1980. Planktonic foraminifera from Calangute beach sands, Goa, and their environmental significance. *Bull. Indian Geol. Assoc.* V.13 (2), pp.147-148.
- Bhalla, S.N. and Nigam, R. 1986. Recent foraminifera from polluted marine environment of velsao
- Antony, A. 1968. Studies on the shelf water foraminifera of the Kerala coast. *Bull. Dept. Mar. Bio. Oceanogr.* V.4, pp.11-154.

- beach, South Goa, India. *Rev. De. Paleobiol.* V.5 (1), pp.43-46
- Bhalla, S.N. and Nigam, R. 1988. Cluster analysis of the foraminiferal fauna from the beaches of the east and west coast of India with reference to foramogeographical provinces of the Indian Ocean. *Jour. Geol. Soc. India.* V. 32 (6), pp.516-521
- Bhalla, S.N. and Raghav, K.S. 1980. Recent foraminifera from beach sands of Malabar coast. *Indian Jour. Mar. Sci.* V. 9 (4), pp.288-290
- Bhat, K.K. and Adiga, K.S. 1993. Late Pleistocene-Holocene transition study of a core from Lakshadweep Sea. News Letter, *Geological Survey of India (Marine Wing)*, V.9 (1), pp.5-7
- Bhatia, S.B. 1956. Recent foraminifera from shore sands of western India. *Contrib. Cushman Found Foram Res* V.7, pp.15-24
- Bhatia, S.B and Kumar, S. 1976. Recent benthonic foraminifera from the inner shelf area around Anjediv island, off Binge, west coast of India. In: *1st Symp on Benth Foram of Continental Margin. Part A Ecol. and Biol. Maritime Sediment. Spec. Pub.* V.1, pp.239-249.
- Boltovskoy, E., Giussani, G., Watanabe, S. and Wright, R. 1980. Atlas of benthic shelf foraminifera of the south west Atlantic. W. Junk (Publisher), The Hague, 147 pp
- Borole, D.V. 1992. Stable isotopic variations in foraminiferal test from Arabian Sea and its relation to the annual south-west monsoonal rainfall over the Indian sub continent. *Curr. Sci.* V.63, pp.567-569.
- Chapman, F. 1895. On some foraminifera obtained by the Royal Indian Marine Surveys 'Investigator' from the Arabian Sea, near Laccadive islands. *Proc. Zool. Soc.*, London. V.1, pp.1-55
- Chatterjee, B.P. and Gururaja, M.N. 1967. Foraminifera off Mangalore coast, south India. *Bull. Nat. Inst. Sci. India.* V.38, pp.393-397.
- Chaudhury, A. and Biswas, B. 1954. Recent perforate foraminifera from Juhu beach, Bombay. *Micropal.* V.8 (4), pp.30-32.
- Cullen, J.L. and Prell, W.L. 1964. Planktonic foraminifera of the northern Indian ocean: Distribution and preservation in surface sediments. *Mar Micropal.* V.9, pp.1-52.
- Dalal, S.G. 1976. Interrelationship between environmental parameters and foraminiferal species in Mandovi and Zuari estuaries Mahasagar. *Bull. Natn. Inst. and Oceanogr.* V.9, pp.91-93
- Dalal, S.G. 1980. Relationship between benthic foraminifera and sediment in the estuarine complex of Goa. Mahasagar - *Bull. Natn. Inst. Oceanogr.* V.13, pp. 77-79
- Desai, G.K. and Pandya, K. 1982. Microfauna of the Saurashtra coastline sediments. In the report of work based on the sponsored research programme on *Quat. Geol.* pp.191-206.
- Desai, G.K. and Shringarpure, D.M. 1982. Recent foraminifera of the saurashtra and south Gujarat coast. Impact of sedimentation on their nearshore distribution. *Sem. Vol. on Quat. Geol. Rec. Res. in Geol.*, Series 9, pp.372-377.
- Divakar Naidu, P. 1990. Distribution of upwelling index foraminifera from the sediments of western continental margins of India. *Oceanologica Acta.* V.13, pp. 327-333.
- Divakar Naidu, P. 1991. Glacial to interglacial contrast in the calcium carbonate content and influence of Indus discharge in two eastern Arabian Sea cores. *Paleogeogr. Paleoclimatol. Paleoecol.* V.86, pp.255-263.
- Divakar Naidu, P. 1993. Distribution patterns of recent planktonic foraminifera in surface sediments of the western continental margin of India. *Mar. Geol.* V.110, pp. 403-418.
- Divakar Naidu, P., Prakash Babu, C. and Rao, Ch.M. 1992. The upwelling record in the sediments of the western continental margin of India. *Deep Sea Res.* V.39 (3/4), pp.715-723.
- Divakar Naidu, P., Rao, P.S. and Pattan, J.N. 1989. Planktonic foraminifera from a Quaternary deep sea core from the southern Arabian Sea. *Jour. Geol. Soc. India.* V.34 (4), pp. 393-397.
- Douglas, R.G. 1979. In John Murray (Ed.) *Ecology and Palaeo ecology of benthic foraminifera* John Wiley & Sons Inc. New York, 397 pp
- Fortugne, M.R. and Duplessy, J.C. 1986. Variations of the monsoon regime during the upper Quaternary: Evidences from carbon isotopic records of organic matter in North Indian Ocean sediment cores. *Paleogeogr. Paleoclimatol. paleoecol.* V. 56, pp. 69-88.
- Gare, M.A., Mathur, D.R. and Vartak, A.V. 1985. On micro boring on foraminifers tests from the Holocene deposits of Raigad district, Maharashtra. *Proc. X Ind Colloq. Micropal. & Stratigr.* pp. 469-482.
- Gupta, A.K. 1991. Pleistocene benthic foraminifera and deep sea environments at northern Indian Ocean D.S.D.P. site 219. *Jour. Geol. Soc. India.* V.37, pp. 388-406.
- Gupta, S. and Bhattacharjee, D. 1989. Areal distribution of foraminifera off Trivandrum and Cape Comorin with comments on depth diagnostic

- taxa in the Arabian Sea. Recent Geo scientific studies in the Arabian Sea off India. *Spec. Publ. Geol. Sur. India*. V. 24, pp. 127-131.
- Guptha, M.V.S. 1973 a. A preliminary report on the foraminiferal assemblages from the lagoon sediments of Kavaratti Atoll (Laccadives). *Curr. Sci. V. 42 (22)*, pp.781-782.
- Guptha, M.V.S. 1973 b. Planktonic foraminifera from the sediments off Cochin, *Indian Jour. Mar. Sci. V. 2 (2)*, pp. 147-148.
- Guptha, M.V.S. 1974. Distribution of planktonic foraminifera in the continental slope sediments off Bombay. *Proc. IVth Indian Colloq. Micropal. Stratigr.* pp. 7-11.
- Guptha, M.V.S., Divakar Naidu, P. and Muralinatha, A.S. 1990. Pre monsoons living planktonic foraminifera from the Southern Arabian Sea. *Jour. Geol. Soc. India*. V. 36 (6), pp. 654-660.
- Guptha, M.V.S. and Hashimi, N.H. 1985. Fluctuations in glacial and interglacial sediments discharge of the river Indus as seen in a core from the Arabian Sea. *Indian Jour. Mar. Sci. V. 14 (2)*, pp.66-70.
- Guptha, M.V.S., Mohan, R. and Muralinath, A.S. 1994. Living planktonic foraminifera during the late summer monsoon period in the Arabian Sea. *Mar. Geol. V. 120 (3/4)*, pp.365-371.
- Hofker, J. 1927. foraminifera of the Siboga Expedition. Part 1, Siboga Exped., *Monogr. V. 4 (1)*, pp. 1-78.
- Hofker, J. 1930. Foraminifera of the Siboga Expedition. Part 2, *Siboga Exped. V. 4A*, pp. 79-170.
- Jain, S.P. and Bhatia, S.B. 1978. Recent benthonic foraminifera from Mandvi, Kutch. *Proc. VIth Indian Colloq. Micropal. Stratigr.* pp. 153-174.
- Khare, N. 1990. An aberrant *Bulimina* species from recent sediments off Karwar, west coast of India. *Geoscience Jour. V. 11 (1 & 2)*, pp. 81-84.
- Khare, N. 1994. A note on the *Pavonina flabelliformis* d'Orbigny (benthic foraminifera) from the Arabian Sea. *Geo Science Jour. V. 15 (1)*, pp. 37-39.
- Khare, N. 1995. Record of few unknown species of recent benthic foraminifera from the Arabian Sea. *Jour. Indian Acad. Geosci., V. 37(2)*, pp. 19-25.
- Khare, N., Sinha, R., Rai, A.K. and Nigam, R. (1995). Distributional pattern of benthic foraminiferal morphogroups in the shelf region off Mangalore : Environmental implications. *Indian Jour. Mar. Sci.*. (In Press).
- Kurian, C.V. 1951. The presence of *Operculina granulosa* (Leymerie), foraminifera in the coastal waters of Travancore. *Curr. Sci. V. 29 (12)*, pp. 335-338.
- Kurian, C.V. 1953. A preliminary survey of the bottom fauna and bottom deposits of the Travancore coast with in the 15 fathoms line. *Proc. Nat. Inst. Sci. India*. V. 19 (6), pp. 747-775.
- Lahiri, A. 1993. A note on diversity of two species of Globorotalia during Pleistocene - Holocene transition. *News Letter, Geological Survey of India (Marine Wing) V. 9 (1)*, pp. 7-8.
- Madabhushi, S. 1989 a. Distribution of benthonic foraminifera in the inner shelf off Cannanore - Calicut coast, Arabian Sea and its relation to marine pollution. Recent Geoscientific studies in the Arabian Sea off India. *Spec. Publ. Geol. Sur. India*. V. 24, pp. 97-106.
- Madabhushi, S. 1989 b. Distribution of benthonic foraminifera in the outer shelf upper slope area off Cochin, Arabian Sea. Recent Geoscientific studies in the Arabian Sea off India. *Spec. Publ. Geol. Sur. India*. V. 24, pp. 97-106.
- Mathur, A.K. and Gupta, S. 1989. A study of foraminiferal distribution in sea bed samples from Arabian Sea off Devgarh. Recent Geoscientific studies in the Arabian Sea off India. *Spec. Publ. Geol. Sur. India*. V. 24, pp. 111-126.
- Murray, J.W. 1971. An atlas of British recent foraminiferids. Heinman Educational Books Ltd. London, pp. 1-244.
- Nigam, R. 1984. Living benthic foraminifera in a tidal environment : Gulf of Khambhat (India). *Mar. Geol. V. 58 (3/4)*, pp.415-425.
- Nigam, R. 1986. Foraminiferal assemblages and their use as indicator of sediments movement - A study in shelf region off Navapur, west coast, India. *Cont. Shelf Res. V. 5 (4)*, pp. 421-430.
- Nigam, R. 1987. Distribution, factor analysis and ecology of benthic foraminifera within inner shelf regime Vengurla-Bhatkal sector, west coast of India. *Jour. Geol. Soc. India*. V. 29, pp. 327-334.
- Nigam, R. 1988 a. Fluctuating monsoonal precipitation as revealed by foraminiferal variations in a core from shelf regime off Karwar (India). *Curr. Sci. V. 57*, pp. 490-491.
- Nigam, R. 1988 b. Reproductive behaviour of benthic foraminifera : A key to paleoclimate. *Proc. Indian Nat. Sci. Acad. V. 54 (3)*, pp. 574-583.
- Nigam, R. 1988 c. Influence of estuaries on shelf

- foraminiferal species and its environmental implications. *Indian Jour. Mar. Sci.* V. 17 (3), pp. 214-216.
- Nigam, R. 1988 d. Was the large rectangular structure at Lothal (Harappan settlement) a "Dockyard" or an "Irrigation Tank"? *Proc. 1st Ind. Confer. on Marine Archaeology of Indian Ocean Countries Jamnagar.* pp.20-22.
- Nigam, R. 1989. Benthic foraminifera from shelf region between Bombay and Ratnagiri : Distribution, ecology and environmental significance. *Proc. Seminar on Tertiary and Quaternary sedimentation between Bombay and Ratnagiri, Poona,* pp. 1-5.
- Nigam, R. 1993. Foraminifera and changing pattern of monsoon rainfall. *Curr. Sci.* V. 64, pp. 935-939.
- Nigam, R., Hashimi, N.H., Menezes, E.T. and Wagh, A.B. 1992 a. Fluctuating sea level off Bombay (India) between 14,500 to 10,000 years, before present. *Curr. Sci.* V. 62 (3), pp. 309-311.
- Nigam, R. and Henriques, P.J. 1992. Planktonic percentage of foraminiferal fauna in surface sediments of the Arabian sea (Indian Ocean) and a regional model for paleo depth determination. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* V. 91, pp. 89-98.
- Nigam, R., Henriques, P.J. and Wagh, A.B. 1993. Barnacle fouling on relict foraminiferal specimens from the western continental margin of India : An indicator to Palaeo-sea level. *Cont. Shelf Res.* V. 13 (2/3), pp. 279-286.
- Nigam, R. and Khare, N. 1992 a. Oceanographic evidences of the great floods at 2,000 and 1,500 years BP documented in Archaeological records. *Dr. S.R. Rao 70th Birth day Fekctation volume.* V.2, pp.517-522.
- Nigam, R. and Khare, N. 1992 b. The reciprocity between coiling direction and dimorphic reproduction in benthic foraminifera. *Jour. Micropal.* V. 11 (2), pp. 221-228.
- Nigam, R. and Khare, N. 1994 a. Effect of river discharge on morphology of benthic foraminiferal test. *Jour. Geol. Soc. Ind.* V. 43 (3), pp. 457-463.
- Nigam, R. and Khare, N. 1994 b. Signals of the change in monsoonal precipitation at around 2000 years BP in a core off Central west coast of India. *Curr. Sci.* V.66 (3), pp.226-228.
- Nigam, R. and Khare, N. 1995. Significance of the correspondence between river discharge and MPS in paleomonsoonal studies. *Geomarine Lett.* V. 15, pp.45-50.
- Nigam, R., Khare, N. and Borole, D.V. 1992 b. Can benthic foraminiferal morpho-groups be used as indicator of paleo monsoonal precipitation ? *Est. Coast. Shelf Sci.* V. 34 (6), pp.533-542.
- Nigam, R., Khare, N. and Nair, R.R. 1995. Foraminiferal evidence of 77 years cyclicity of drought in India and its possible modulation by the Gleissberg solar cycle. *Jour. Coastal. Res.* (In Press).
- Nigam, R. and Nair, R.R. 1989. Cyclicity in monsoon. *Bull. Sci.* V.5, pp.42-44.
- Nigam, R. and Rao, A.S. 1987. Proloculus size variation in recent benthic foraminifera - Implications for paleoclimatic studies. *Est. Coast. Shelf Sci.* V.24, pp.649-655.
- Nigam, R. and Rao, A.S. 1989. The intriguing relationship between coiling direction and reproductive mode in benthonic foraminifera. *Jour. Pal. Soc. India.* V.34, pp.79-82.
- Nigam, R. and Sarkar, A. 1993. Mean Proloculus size, 0 13c and 0 180 variations in recent benthic foraminifera from the west coast of India and their climatic implications. *Indian Jour. Earth Sci.* V.20 (1), pp.1-6.
- Nigam, R. and Sarupriya, J.S. 1981. Cluster analysis and ecology of living benthonic foraminiferids from inner shelf off Ratnagiri, west coast. *India Jour. Geol. Soc. India.* V.22 (4), pp.175-180.
- Nigam, R. and Setty, M.G.A.P. 1980. Paleogene reworked foraminifera in Recent sediments off Daman, western India. *Proc. 3rd Ind. Geol. Cong.* Poona. pp.273-260.
- Nigam, R. and Setty, M.G.A.P. 1982. Ecological regime and distribution of *Virgulina* sp. in the inshore sediments of western India. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* V.38, pp.57-61.
- Nigam, R., Setty, M.G.A.P. and Ambre, N.V. 1979. A check list of benthic foraminiferids from the inner shelf of Dabhol-Vengurla region. Arabian Sea. *Jour. Geol. Soc. India* V. 20, pp.244-247.
- Nigam, R. and Thiede, J. 1983. Recent foraminifera from the inner shelf of the central west coast of India : A reappraisal using factor analysis. *Proc. Indian Acad. Sci. Earth and Planet. Sci.* V.92 (2), pp.121-128.
- Pandya, K. 1985 a. Holocene foraminifera from Gujarat coast. In B. Bhaskara Rao (Ed.) *Proceeding V session of Indian Geological Con-*

- grass.. pp.37-48.
- Pandya, K. 1985 b. Ecological control of the micro faunal diversity of Saurashtra and Gujarat coasts. In S.S. Merh and N.M. Vashi (Eds.) *Proceedings of Symposium on Quaternary Episodes In India*, Dept. of Geology, M.S. University Baroda (Feb. 6-8, 1983). pp.169-179.
- Rao, K.K. 1970 a. Foraminifera of the Gulf of Cambay. *Jour. Bombay Natural Hist. Soc.* V.66 (3), pp.584-596.
- Rao, K.K. 1970 b. Foraminifera of the Gulf of Cambay. *Jour. Bombay Natural Hist. Soc.* v.67 (2), pp.259-273. Rao, K.K. 1970 c. On a little known miliolid foraminifera from north eastern part of the Arabian Sea. *Curr. Sci.* V.39 (4), pp.87-88.
- Rao, K.K. 1971 a. Foraminifera of the Gulf of Cambay. *Jour. Bombay Natural Hist. Soc.* V.68 (1), pp.9-19.
- Rao, K.K. 1971 b. On some foraminifera from the north eastern part of the Arabian Sea. *Proc. Indian Acad. Sci.* V.73 (4), Sec.B. pp.155-178.
- Rao, K.K. 1972. Planktonic foraminifera in sediment samples from the eastern Arabian Sea. *Indian Jour. Mar. Sci.* V.1, pp.1-7.
- Rao, K.K. 1973. Quantitative distribution of planktonic foraminifera in the south west coast of India. *Indian Jour. Mar. Sci.* V.2, pp.54-61.
- Rao, K.K. 1974. Ecology of Mandovi and Zuari estuaries, Goa. Distribution of foraminiferal assemblages. *Indian Jour. Mar. Sci.* V. 3, pp.61-66.
- Rao, K.K., Jayalakshmy, K.V. and Krishnan Kutty, M. 1991. Ecology and distribution of recent planktonic foraminifera in eastern part of Arabian Sea. *Indian Jour. Mar. Sci.* V.20 (1), pp.25-35.
- Rao, K.K., Jayalakshmy, K.V. and Balasubrahmanian, T. 1992. Distribution of planktonic foraminifera in waters of the sub marine coral banks in south east Arabian Sea during winter. *Indian Jour. Mar. Sci.* V.2 (4), pp.233-245.
- Rao, K.K., Krishnan Kutty, M. and Panikkar, B.M. 1985. Frequency distribution of foraminifera off Trivendrum, west coast of India. *Indian Jour. Mar. Sci.* V.14, pp.74-78.
- Rao, K.K. and Rao, T.S.S. 1979. Studies on pollution ecology of foraminifera of the Trivandrum coast. *Indian Jour. Mar. Sci.* V.8, pp.31-35.
- Rao, K.K., Sivasdas, P., Narayanan, B., Jayalakshmy, K.V. and Krishnan Kutty, M. 1987. Distribution of foraminifera in the lagoons of certain islands of the Lakshadweep Archipelago, Arabian Sea. *Indian Jour. Mar. Sci.* V.16 (3), pp.161-178.
- Rocha, A.T. and Ubaldino, M.L. 1964 a. Contribution for the study of foraminifera from sands of Diu, Gogola and Simbor. Garcia de Orta (Lisboa). V.12 (3), pp.407-420.
- Rocha, A.T. and Ubaldino, M.L. 1964 b. Nota sobre los foraminiferos recientes das areia das praias de Jampore (Damao) e de Baga (Goa), Garcia de Orta (Lisboa). V.12 (4), pp.645-650.
- Sarkar, A., Ramesh, R., Bhattacharya, S.K. and Rajagopalan, G. 1990. Oxygen isotope evidence for stronger winter monsoon current during the last glaciation. *Nature.* V.343 (6258), pp.549-551.
- Sarkar, A. and Guha, A.K. 1993. Paleocceanographic implications of planktonic foraminiferal abundance at DSDP sites 219, 220 and 241 - An approach based on Paleontologic Time Series. *Jour. Geol. Soc. India.* V.41 (5), pp.397-416.
- Sastry, V.V. 1963. Bibliography of papers published ince 1939 on foraminifera from the Indian region. *Micropal.* V.9 (1), pp.107-110.
- Sastry, V.V. and Pant, S.C. 1960 a. Operculina rich sands from the sub recent deposits of Saurashtra and Madras coasts (abstract), *Ibid.* v.3, pp.275.
- Sastry, V.V. and Pant, S.C. 1960 b. Foraminifera from the miliolites of Saurashtra (abstract). *Indian Sci. Cong. Proc.*, pt. 3, pp.275.
- Seibold, E. and Seibold, I. 1973. *Cassidella panikkarini* sub sp. (Foram) from the Kerala shelf. *Mar. Bio. Assoc. India*, Publ. V.58, pp.87-90.
- Seibold, I. 1971. *Ammonia brunnichii* (Foram) and Verwandte Arten aus dem Indischen Ozean (Malabar Kuste, S.W. Indien). *Palaont. z.* V.45 (1/2), pp.41-52.
- Seibold, I. 1972. Preliminary report on the transport of foraminifera into Cochin back water. *Jour. Mar. Bio. Assoc. India.* V.14 (2), pp.452-455.
- Seibold, I. 1975. Benthonic foraminifera from the coast and lagoon of Cochin (South India). *Revista Espanola De Micropaleontologia.* V.7 (2), pp.175-213.
- Seibold, I. and Seibold, E. 1981. Offshore and lagoonal benthic foraminifera near Cochin (South West India) - distribution, transport, ecological aspects. *N. Jb. Geol. Palaont. Abh.* V. 162 (1), pp.1-56.
- Sethulekshmi Amma, J. 1958. Foraminifera of Travancore coast. *Bull. Cent. Res. Inst. Univ. Kerala.* V.6 (1), ser. c.pp.1-88.



- Setty, M.G.A.P. 1972. Holocene planktonic foraminifera from the shelf sediments off Kerala coast. *Jour. Geol. Soc. India*. V.13 (2), pp.131-138.
- Setty, M.G.A.P. 1973. Foraminifera as climatic indicator in the sediments of western Indian continental shelf. *Mahasagar - Bull. Natn. Inst. Oceanogr.* V.6 (2), pp.70-74.
- Setty, M.G.A.P. 1974. Holocene benthonic foraminifera from the shelf sediments of Kerala coast. *Bull. Earth Sci.* 3, pp.21-28.
- Setty, M.G.A.P. 1976. Relative sensitivity of benthonic foraminifera in the polluted marine environment of Cola Bay, Goa. *Proc. Vith Indian Colloq. Micropal. Stratigr.* pp.225-234.
- Setty, M.G.A.P. 1977. Occurrence of *Neogloboquadrina pachyderma* new sub species in the shelf slope sediments of northern Indian Ocean. *Indian Jour. Mar. Sci.* V.6, pp. 72-75.
- Setty, M.G.A.P. 1982 a. Recent marine microfauna from the continental margin, west coast of India. *Jour. Sci. Ind. Res.*V.41 (11), pp 674-679.
- Setty, M.G.A.P. 1982. b. Pollution effects monitoring with foraminifera as indices in Thane creek, Bombay area. *Intern. Jour. Environ. Studies.* V.18, pp.205-209.
- Setty, M.G.A.P. 1983. Upwelling along the western Indian continental margin and its geological record, A summary. In *Coastal Upwelling NATO advanced Res., Inst. Plenum Press, New York*, pp.201-216.
- Setty, M.G.A.P. 1984. Larger foraminifera from a relict structure off Karwar, western Indian continental margin. *Proc. Indian Nat. Sci. Acad.* V.50 (1), pp.127-138.
- Setty, M.G.A.P. 1985. Foraminiferal evidence to climate change with special reference to west coast of India. *Proc. Symp. Quat. Episodes in India (Neotectonism, Eustasy and Palaeoclimates)*, Dept of Geol., M.S. Univ. baroda. pp.129-134.
- Setty, M.G.A.P., Birajdar, S.M. and Nigam, R. 1984. Inter tidal foraminifera from Miramar-Caranzalem shore line, Goa. *Indian Jour. Mar. Sci.* V.13 (1), pp.49-51.
- Setty, M.G.A.P. and Gupta, M.V.S. 1972. Recent planktonic foraminifera from the sediments off Karwar and Mangalore. *Proc. Indian Nat. Sci. Acad.* V.38 (5 & 6), pp.148-160
- Setty, M.G.A.P. and Nigam, R. 1980 a. Microenvironments and anomalous benthic foraminiferal distribution within the neritic regime of the Dabhol - Vengurla sector (Arabian Sea). *Rev. Ital. Paleont.* V.86 (2), pp.417-428.
- Setty, M.G.A.P. and Nigam, R. 1980 b. Excentricity and twinning in *Virgulina pertusa* (Reuss). *Revista Espanola de Micropal.* V.12 (3), pp.431-433.
- Setty, M.G.A.P. and Nigam, R. 1982. Foraminiferal assemblages and organic carbon relationship in benthic marine ecosystem of western Indian continental shelf. *Indian. Jour. Mar. Sci.* V.11, pp.225-232.
- Setty, M.G.A.P. and Nigam, R. 1984. Foraminifera as indicator of pollution in the marine environment on the west coast of India. *Revista Italiana de Paleontologia, Milano.* V.89 (3), pp.421-436.
- Setty, M.G.A.P. and Nigam, R. 1985. Benthic foraminifera as indices of diversity and hyposalinity in a modern clastic shelf regime off Bombay. *Proc. Intern. Confer. Biol. Benthic Mar. Organisms*, Ahmedabad. pp.283-288.
- Setty, M.G.A.P., Nigam, R. and Ambre, V. 1979. Graphic pattern of foraminiferal dominance in nearshore region of central west coast of India. *Mahasagar - Bull. Natn. Inst. Oceanogr.* V.12 (3), pp.195-199.
- Setty, M.G.A.P., Nigam, R. and Faterpenkar, A. 1983. An aberrant *Spiroloculina* sp. from Recent sediments off Bombay - Daman, West Coast of India. *Mahasagar - Bull. Nat. Inst. Oceanogr.* V.16 (1), pp.77-79.
- Setty, M.G.A.P. and Wagle, B.G. 1972. Beach rock from Goa coast. *Proc. Indian Nat. Sci. Acad.* V.38 (1&2), pp.9-20.
- Shareef, N.A. and Sathyarayan, S. 1991. Predation in certain foraminifera from Quaternary sediments, Mangalore Harbour, Karnataka, S. India. *Proc. Quat. Landscape of Indian sub continent*, Geology Dept., M.S. Univ. Baroda. pp.159-164.
- Shareef, N.A. and Venkatachalapathy, V. 1987 a. Some recent agglutinated foraminifera from Sunghiri (Shimiguda) Island, west coast of India. *Proc. Vith Indian Geol. Congress. Roorkee* (21-24 Feb, 1987). pp.193-198.
- Shareef, N.A. and Venkatachalapathy, V. 1987 b. Litho and biostratigraphy of the bore hole cores, Mangalore harbour area, Karnataka coast, South India. *Proc. Vith Indian Geol. Congress. Roorkee* (21-24 Feb, 1987) pp.187-192.
- Shareef, N.A. and Venkatachalapathy, V. 1988. Foraminifera from shore sands of Bhatkal and Devgad Islands, west coast of India. *Jour. Geol. Soc. India.* V.31, pp.432-441.
- Sharma, D.C. and Mishra, D.C. 1984. Occurrence

- of *Rotalia tinopsis seminulata* from the Pleistocene sediments of the Arabian Sea. *Xth Indian Colloq. Micropal. Stratigr.* pp.547-552.
- Srinivasan, M.S. and Sharma, V. 1980. Schwager's Car Nicobar Foraminifera in the Reports of the Novara Expedition - A Revision. Published by Today and Tomorrow's Printers and Publishers, New Delhi, pp.1-83.
- Srinivasan, M.S. and Singh, A.D. 1992. Neogene planktonic foraminiferal biochronology of D.S.D.P. site 219 (Chagos-Laccadive ridge), Arabian Sea. *Proc. Indian Natn. Sci. Acad.* V.58 (4), pp.335-354.
- Srinivasan, R. 1989. Foraminiferal distribution in the continental shelf off Tripriyer Azhikode Kerala. In *Recent Geoscientific studies in the Arabian Sea off India. Spec. Publ. Geol. Sur. India.* V.24, pp.107-110.
- Srivastava, S.S., Geol. R.K. and Srivastava, S. 1987. Recent foraminifera from the beach sands near Veraval, Saurashtra coast, western India. *Geo science Jour.* V.5 (1), pp.35-42.
- Srivastava, S.S., Geol. K.K. and Nath, S.S. 1985. Recent foraminifera from Kavaratti Island (Lakshadweep) Arabian Sea, India. *Bull. Geol. Min. Metal. Soc. India.* V.52, pp.335-352.
- Stubbings, H.G. 1939. Stratification of biological remains of marine deposits of the Arabian Sea. *British Mus. (Nat. Hist.), John Murray Exped.*, 1933 - 34. V.3 (3), pp.159-192.
- Talib, A and Farooqui, M.Y. 1994. Recent foraminifera from Dwarika beach, Gujarat and foramgeographic provinces of Indian Ocean. *Indian Jour. Earth Sci.* V.20, pp.91-96.
- Venkatachalapathy, V. and Shareef, N.A. 1972. Pyritization in certain foraminifera from recent sediments of Mangalore area, west coast of India. *Proc. II Indian Colloq. Micropal. Stratigr.* pp.125-128.
- Venkatachalapathy, V. and Shareef, N.A. 1975. Morphology, distribution pattern and wall structure of *Ammonia beccarii* (Linne') from west coast of India. *Rev. Esp. Micropal. Spain* V.7 (1), pp.51-62.
- Venkatachalapathy, V. and Shareef, N.A. 1976. Certain morphologic and microstructural characteristic features of some smaller foraminifera from Mangalore area, west coast of India. *Proc. VIth Indian Colloq. Micropal. Stratigr.* pp.367-383.
- Venkatachalapathy, V. and Shareef, N.A. 1978. Scanning Electron Microscopy of some rotalid foraminifera of Mangalore coasts, Karnataka, south India. *Proc. VII Indian Colloq. Micropal. & Stratigr.* pp.446-453.
- Zhang, J. 1985. Living planktonic foraminifera from the eastern Arabian Sea. *Deep Sea Res.* V.32 (A), pp.789-798.
- Zobel, B. 1971. Foraminifera from plankton tows, Arabian Sea. Areal distribution as influenced by ocean water mass. *Proc. IInd Planktonic Conference. Rome*, pp.1323-1335.
- Zobel, B. 1973. Biostratigraphische untersuchungen an sedimentem des indisch-pakistanischen Kontinental rand's Arabisches Meer). *'Meteor' Forsch-Ergebnisse. Reihe C.*, no.12, seite 9-73.