

## Micropalaeontological proxies for understanding palaeoclimate

Rajiv Nigam

National Institute of Oceanography, Dona Paula, Goa-403004  
nigam@nio.org

Global warming, ozone depletion, sea level rise, climate change are all consequences of increased emission of green house gases. Such environmental problems are economically taxing to every economy. Thus prediction of future climates on the decadal and centennial time-scales helps in the right management and distribution of resources. Predictive models are derived on the basis of large datasets on past climates, spanning thousands of years, i.e. well beyond the era of instrumental records which exist just for about 150 years. The study of past climates as derived from proxies is called '**palaeo-climatology**'. Many mineralogical, sedimentological, geo-morphological, geophysical and chemical proxies have been used to study past climates. However, evolution of life has always been governed by prevailing climates and thus remains of past life i.e. fossils have proved to be the best proxy for evolution of climates.

'**Palaeontology**' (Palaeo-ancient; onto-life; logy-study) is the science that deals with the study of fossils. However, '**micro-palaeontology**' has emerged as a very important discipline with applications in palaeo-climatology, the reasons being:

1. They are abundant and have a wide geographic as well as geologic distribution.
2. Being small in size they are very easy to recover in large numbers in very small amount of sample.
3. As smaller organisms, they are very sensitive to changing environments and thus evolve fast.

Plants and animals possessing hard parts (exoskeletons or endoskeletons) are capable of being preserved as fossils, unaltered for a large periods of time. Marine environments characterised by undisturbed and uninterrupted sedimentation provide the best environment for preservation of diverse microfossils, and thus serve as the longest archives of past climate.

In recent years, attempts are being made to study marine sediments to generate high-resolution proxy records for palaeoclimatic fluctuations. Sediments collected from almost all marine environments i.e. from coastal inter-tidal / beach environments to deep sea, have been exploited to obtain information about modern and past oceanographic processes. Beach sand, if examined through a microscope shows the presence of many biogenic sediments viz. skeletal remains of

organisms amongst the mineral grains. This component of the sediment may include the juveniles/fragments of larger animals like molluscs, echinoids, arthropods, etc. But the shells of microscopic organisms such as carapace of microscopic arthropods (ostracoda), the coiled chambered shells of protozoans (foraminifera), fragments of coralline algae, and many other skeletal kinds, predominate. In the deeper regions like continental shelf and slope such biogenic sediments are also accompanied by palynological fossils such as pollen and spores and land plants, transported and deposited by wind. The deepest regions of the ocean are characterised by the accumulation of grey, sticky ooze, composed almost entirely of the remains of planktonic unicellular plants and protozoans, which can be recovered to a tune of thousands of specimens preserved in per gram sediment. Such deep-water deposits comprising nearly 100% biogenic sediments are termed "ooze" (e.g. foraminiferal ooze, nanno-ooze, radiolarian ooze, Pteropod ooze etc.). All of these serve as potential microfossils.

Based on the composition of shells, microfossils can be subdivided as following:

**Calcareous microfossils:** Foraminifera, Cocolithophores or Nannoplankton, Ostracods, Pteropods, Calpionellids, Calcareous Algae and Bryozoa.

**Siliceous microfossils:** Radiolaria, Marine diatoms, Silicoflagellates and Ebridians

**Phosphatic microfossils:** Conodonts and other phosphatic microfossils

**Organic-walled microfossils:** Dinoflagellates, Acritarchs and Tasmanitids, Spores and pollen in the marine realm and Chitinozoa

Each group of organisms has a different habit and habitat and thus has its own significance. Eg. Calcareous microfossils prevail in the lower latitudes, at warmer temperatures and/or shallower depths, whereas siliceous microfossils prevail in higher latitudes and/or deeper depths. Similarly some organisms are benthic in habit and provide information of sea-bottom conditions whereas the planktonic ones provide information about the water column. Thus, depending upon the objectives and area of interest one needs to choose the right microfossil. Different groups of microfossils when used in combination could give a wholistic picture within a sedimentary regime and thus cover up for shortcomings of one another.

Microfossils can be recovered from unconsolidated sediments, and also from consolidated sediments i.e. sedimentary rocks. But the method of collection in field and sorting in the laboratory differs for both. In the field they can be collected by three different types of sampling: a) Grab sampling (surface sediments) (b) Coring (subsurface sediments) and (c) Dredging (consolidated rocks). Similarly depending upon the type of sample (consolidated/unconsolidated) and the group of microfossils to be studied, processing techniques in the lab vary. The important methods for finally separating individual specimens from the sediments include (a) preparation of smear slides (Eg. Nannofossils and spores and pollens) and (b) wet sieving and separating the microfossils by hand picking (Pteropods, Foraminifera, Radiolarians from unconsolidated sediments) and /or using floatation methods (from consolidated sediments).

Out of whole array of microfossil proxies employed to reconstruct past climatic variations, Foraminifera have been used most extensively for their following characteristics:

1. Being unicellular, they are extremely sensitive to their ambient environmental changes
2. They are almost entirely marine
3. They are omnipresent in the marine regime and thus can be recovered from every marine environment from the lowest to the highest latitude.
4. They are very abundant and diverse.
5. They are both- planktonic and benthic in habit and thus provide information of bottom and water column conditions.
6. Their diversity is a function of changing environment thus different environments are characterised by different and typical assemblages.
7. Their test i.e. exoskeleton which is capable of being preserved, is the basis of its classification. Thus, every change in environment is visible in the form of a morphological manifestation such as: change in coiling direction, change in size, deformation of the test, varied calcification of the test, etc.
8. Recent technological advancements allow geochemical studies of its test which give precise isotopic and chemical concentrations over the past.
9. It is possible to culture these foraminifera in the lab, enabling calibration/validation of field results.

The Micropalaeontology Lab at the National Institute of Oceanography is almost 30 years old and pursuing palaeoclimatic research in the country through foraminifera, radiolaria and nannoplankton. Being most abundant in marginal seas, foraminifera are being used here intensively to exhibit the application of microfossils

for paleoclimatic reconstructions. During the early days, established foraminiferal parameters like their distribution, abundance, coiling direction, mean size, oxygen isotopes, etc were evaluated as paleoclimatic proxies. During these studies, certain new techniques were also developed for determining various components of palaeoclimate like palaeomonsoons, past sea level changes, past storms/tsunamis etc.

### Palaeo-monsoons

The original idea of using dimorphic ratios or mean proloculus size (MPS) in palaeoclimatic reconstruction was based on sediments from the North Sea. Further, significance of correspondence between river (Kali in Karwar) discharge and mean proloculus size of benthic foraminifera exhibited the use of MPS in palaeomonsoonal studies (Fig. 1 & 2).

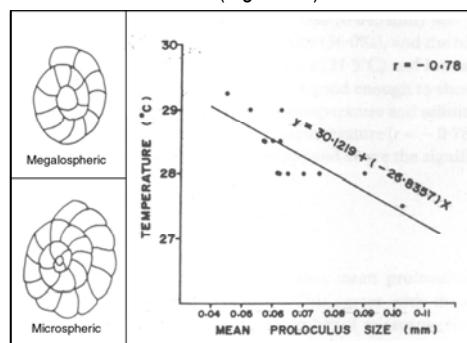


Fig.1.

Similarly, while studying surface and subsurface sediments off central west coast of India, it was noticed that morphological (coarser morphogroups) variations of benthic foraminifera's response to salinity can be used as additional tool in palaeomonsoonal studies (Fig. 3).

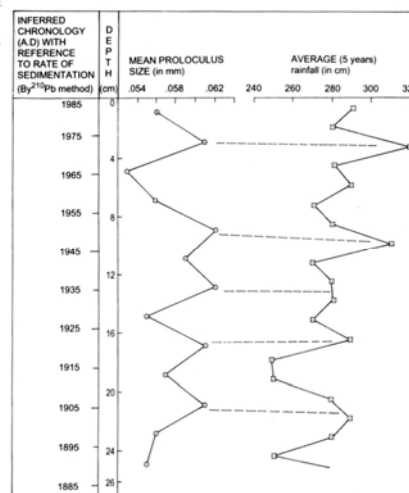


Fig. 2.

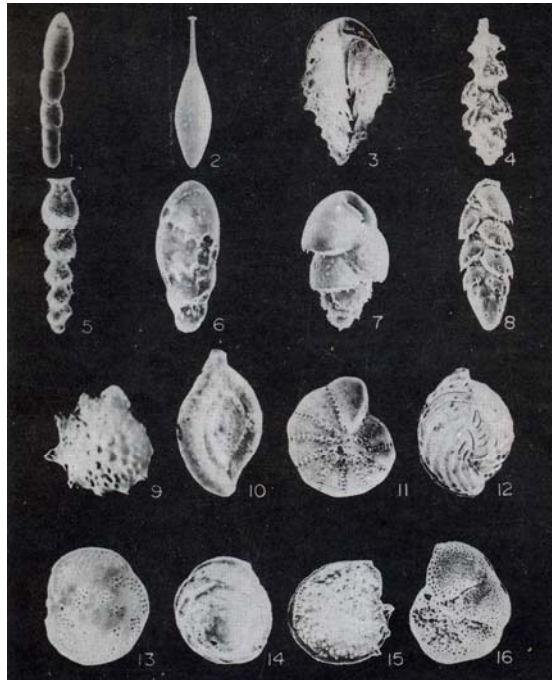


Fig. 3: Representative species of foraminiferal morphogroups, 1-8: Angular asymmetrical; 9-16: Rounded symmetrical

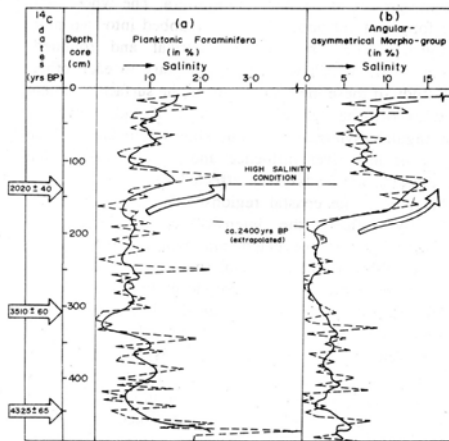


Fig. 4.

These techniques are simple, less expensive, time saving in sorting out samples and adaptable to computer image processing. Development of these techniques helped to generate high-resolution records of palaeomonsoon. In quest for high resolution records (decadal to century), core samples off Karwar, west coast of India were analysed. The results showed the clear signals of marked high rainfall around 4000 and 3500 years BP and reversals of rainfall condition since 3500 years B.P. with a marked low at 2000 years BP (Fig. 4). These findings gathered support from palynological investigations of the same core. A cyclicity of approximately 77 years in concentration of drought years was also deciphered (Fig. 5) and possibilities of

correlation between inferred cycle and Gleissberg cycle in variation of radius of the sun were pointed out (Fig. 6). Since reliability of any new technique can be best supported through culture experiments, a foraminiferal culture programme is established at the National Institute of Oceanography, Goa and detailed work in this direction is in progress (Fig. 7).

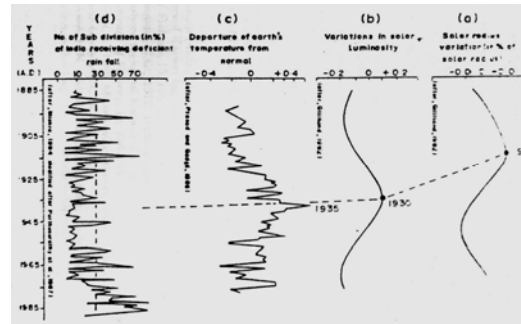


Fig. 5.

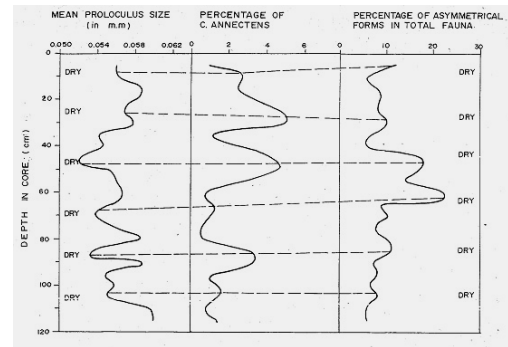


Fig.6.

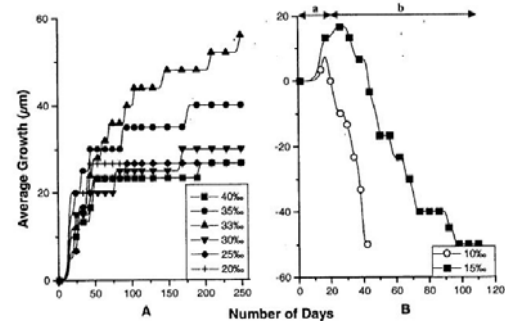


Fig.7.

### Sea Level Studies

It is important to understand sea level fluctuations in the recent past to assess accurately the magnitude of suspected future rise in sea level due to global warming. In order to understand past changes in relative sea levels, two fold strategies should be followed. To get the idea about sea level higher than today, coastal areas may be explored for erosion or depositional features above the present sea level. On the contrary to decipher



Fig. 8.

sea levels lower than present, such signatures need to be traced within the marine regime, parallel to the present coastline. During the course of investigations, it was discovered that barnacle fouling on relict tests (Fig. 8) can be used as an additional tool for identifying palaeoshore line changes. Based on planktonic percentage of foraminifera in surface sediment of the Arabian Sea, a regional model for palaeodepth determination was devised. One of the main advantages of the proposed model is that it requires no detailed taxonomic study of the fauna. It is sufficient to separate the fauna into two groups i.e. planktonic and benthic. Preliminary sea level fluctuation curves can be prepared by using palaeobathymetric information through the proposed model. As per this model  $D = e^{(0.0496p + 3.036)}$ , where  $p$  = percentage of planktonic foraminifera and  $D$  = depth in meters. Such information is of immense use to develop predictive models.

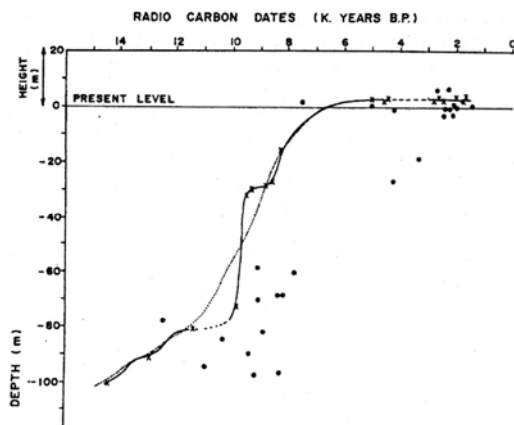


Fig. 9.

Nigam and others, produced the updated curve for late Pleistocene-Holocene sea level fluctuations (Fig. 9), in which they succeeded in demonstrating that, as compared to present, sea level was lower by 100 m about 14,500 years BP, and 60 m about 10,000 years BP. During the last 10,000 years, three major episodes of sea level fluctuations were also reported. Recently, with the help of this sea level curve, he has explained the discovery of Neolithic settlements in Gulf of Khambhat - the oldest civilization site known to man.

### Palaeostorm/ Palaeo-tsunami and Migration of fishes

Through a recently concluded study from the shallow water areas off Kachchh, it was discovered that a storm(s) had hit this region - 8000 years BP. They also exhibited how foraminifera can be used to decipher palaeostorms(s).

Attempts are also being made to decipher migration / extinction of fishes through study of **Otoliths** [fossilized fish remains] in Holocene sediments. This study will be useful for evaluating the consequences of global warming on fisheries.

### REFERENCES FOR FURTHER READING

- Jones, D.J., 1969. Introduction to microfossils. Hafner publishing Co. 406 pp.
- Boltovskoy, F. and Wright, R., 1976, Recent Foraminifera: Dr. W. JunkPubl., The Hague, 515 p.
- Haq, B.U. and Boersma, A., 1978. Introduction to marine micropalaeontology. Elsevier Publ. Co. 376 p.
- Brasier, M.D., 1980. Microfossils. George Allen and Unwin 193 p.
- Kennett, J.P., 1982. Marine Geology. Prentice- Hall Inc. 813 pp.
- Sengupta, B.K. (Ed.) Modern Foraminifera (Kluwer, Great Britan) 1999, 371p
- Nigam, R. Addressing environmental issues through foraminifera: Case studies from the Arabian Sea, Journal of the Palaeontological Society of India: 50(2); 2005; 25-36.