

REPRODUCTIVE BEHAVIOUR OF BENTHIC FORAMINIFERA : A KEY TO PALAEOCLIMATE

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Many benthic foraminiferal species exhibit dimorphism associated with reproduction. The two resultant forms are known as microspheric and megalospheric forms. Culture studies, though limited in number, show that ratios of these forms are affected by extremes of temperature. This property can be utilized to study palaeoclimates. To test this hypothesis, variation in dimorphic ratios (microspheric/megalospheric) of *Bolivina skagerrakensis* at different levels in a core spanning 1000 years B.P. from the Skagerrak, E. North Sea was compared with a few other independent scales. It is concluded that higher ratios indicate a warmer climate.

However, distinction between dimorphic forms is not always possible in many species. In such cases, mean proloculus size would be useful. Higher ratios of dimorphic forms mean more number of microspheric forms and thus lower mean proloculus size. Therefore mean proloculus size can also be used for palaeoclimatic studies. This concept is again tested by studying variation in mean proloculus size in *Cavarotalia annectens* in a number of modern surface sediment samples from the inner shelf of the west coast of India. It is observed that mean proloculus size is inversely proportional to temperature and salinity.

In view of the above, it is proposed that the reproductive behaviour of benthic foraminifera can be utilized as a palaeoclimatic index.

Key Words : Palaeoclimate; Reproduction; Benthic; Foraminifera

INTRODUCTION

In recent years there has been an increased awareness about climate and its variations, the prediction of future trends and their consequences. Variability of climate from region to region and from year to year is well known. Records of climatic changes available with meteorologists go back to only the last few hundred years which help them in climate modelling and in understanding the factors influencing climate. However, when we attempt to interpret long term changes in climate to develop the scenario of future climatic trends, we need a record of climatic changes that goes back far beyond a few hundred years. Such an ancient history of climatic changes is contained in marine sediments. From the studies of surface sediments, it is by now well established that climate affects marine sediments and the fauna contained in them. Analyses of the deep sea sediments allow us to unravel the mystery of Prehistoric climatic fluctuations.

Being very sensitive to climatic changes, foraminifera have been used extensively to study palaeoclimates. However, much of the recent studies of foraminifera

in relation to reconstruction of former climates, especially palaeotemperatures, are centred around oxygen isotopic studies of benthic and planktonic foraminifera. The objective of the present paper is to put forward a very simple, less expensive and quite useful new technique arising out of recent studies carried out by author. This technique is based on reproductive behaviour of benthic foraminifera.

THE CONCEPTUAL FRAMEWORK

Changes in reproductive cycle in some of the organisms like diatoms have been used to study climatic changes during Quaternary¹. However, no significant attempt has been made to utilize morphological features associated with the reproductive cycles of foraminifera for palaeoclimatic studies. It is well known that the shape, size and proloculus diameter of foraminiferal tests belonging to the same species are different and can be broadly separated into two types. This dimorphism is related to reproduction and the two forms are called microspheric and megalospheric.

As a rule, the number of microspheric specimens is considerably less than the number of megalospheric forms. But under extreme conditions, microspheric forms are comparatively more numerous than megalospheric. These unfavourable conditions seem to have been confined to winter.² However, Hofker³ noted that only the microspheric specimens of *Rotalia beccarii flevensis* in the Zuyderzee were able to survive in the harsh winter conditions and the hot summer conditions when the temperature exceeded 20°C. These observations indicate that the ratios of dimorphic forms are only partly temperature dependent. The exact nature of the dependence, however, is not very clear due to lack of an adequate number of culture studies.⁴

Nevertheless, from the limited number of culture studies, it is apparent that if the overall pattern of climate does not change, the resultant net ratio of the two forms will remain constant and should be reflected in foraminiferal tests in the sediments deposited on the sea floor over a definite period. Variation in these ratios will then indicate changing climatic conditions during the past. This possibility can be tested by calculating ratios of dimorphic forms of any particular species at different levels in a core and by comparing the results with those of established techniques of palaeoclimatic indices like the total number of benthic foraminifera and/or the oxygen isotope record.

TESTING OF THE CONCEPT

The author made two attempts to test this hypothesis by studying dimorphism in two different species of benthic foraminifera from two different geographical localities, i.e., sub-polar region of the North Sea (Atlantic Ocean) and sub-tropical region of the Arabian Sea (Indian Ocean).

Example from the North Sea

The possibility of utilizing reproductive behaviour of benthic foraminifera was first tested on one foraminifera species *Bolivina skagerrakensis*, Quale and

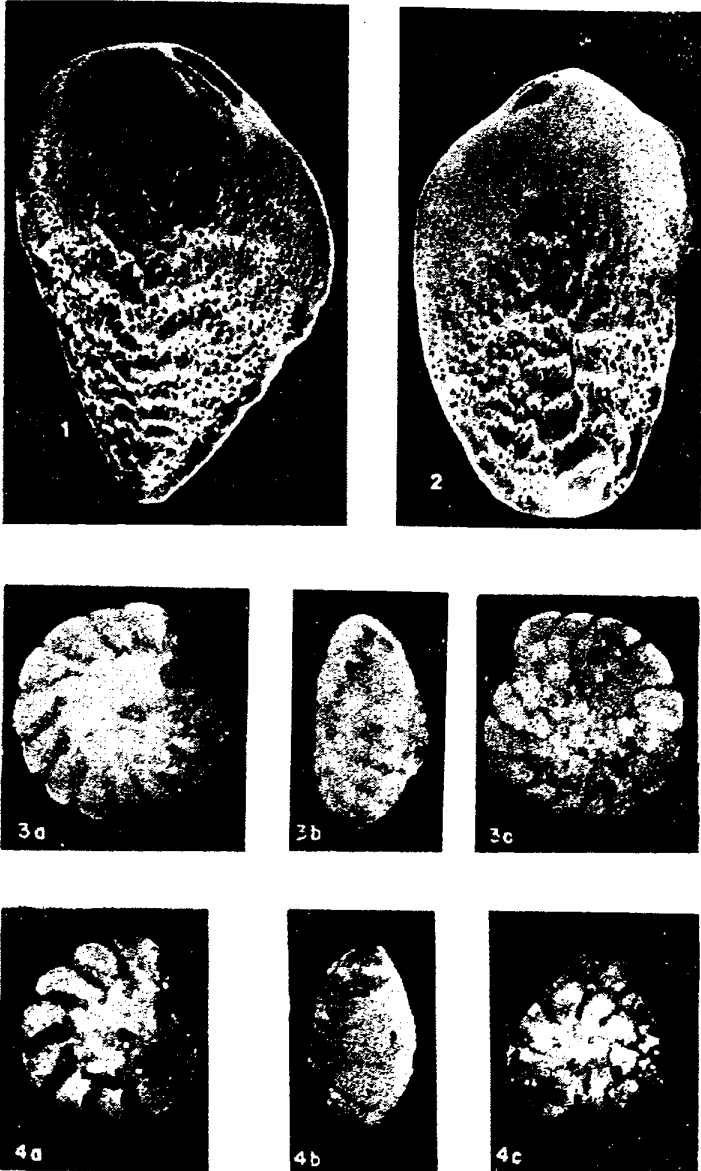


PLATE I

1. Microspheric form of *Bolivina skagerrakensis* ($\times 120$)
2. Megalospheric form of *Bolivina skagerrakensis* ($\times 155$)
3. Microspheric form of *Cavarotalia annectens* ($\times 37.5$)
4. Megalospheric form of *Cavarotalia annectens* ($\times 37.5$)

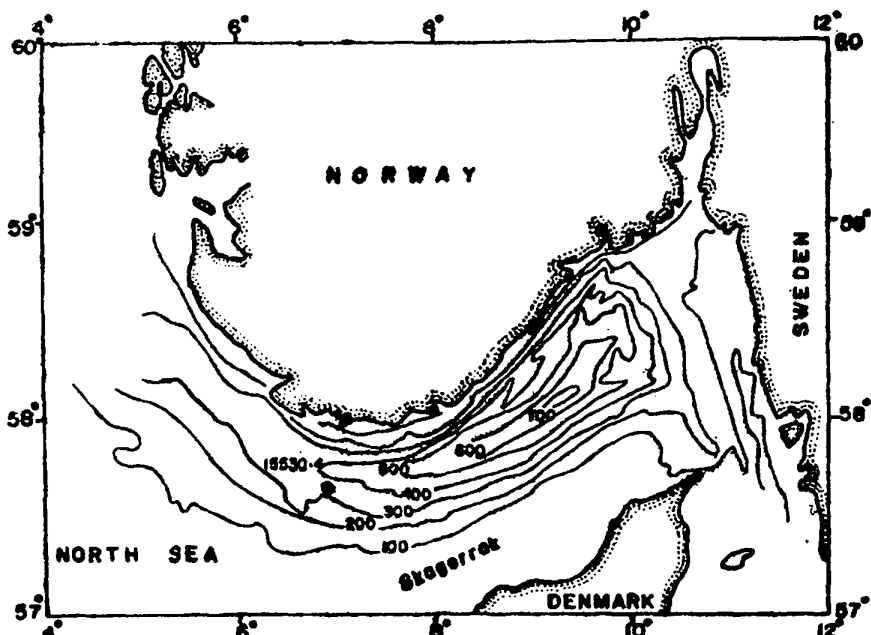


FIG 1 Map of the study area (North Sea) with location of core studied for *Bolivina Skagerrakensis*.

Nigam⁵ (Plate I, Figs. 1 & 2) from the Skagerrak region of the Eastern North Sea⁶. Ratios of microspheric to megalospheric forms were obtained for this species at 5cm intervals in the upper 60cm of a 10.5m core collected on board *F/S Poseidon* with a 9 cm diameter gravity corer at 57°40' N.; 7° 05.5' E; Fig. 1). The ratios show considerable fluctuations and they can be corrected with historical data and also with some other scales for the palaeoclimates (Fig. 2). Based on the comparison, it appears that the higher ratios of microspheric/megalospheric represent warmer climatic conditions.

Examples from the Arabian Sea

It is observed that sometimes megalospheric forms are not much smaller than microspheric forms and the same is true with proloculus size.² In such cases, identification of microspheric and megalospheric forms is difficult. Therefore, instead of ratios of dimorphic forms, mean proloculus size would be more useful. This parameter should have a direct relationship with the ratios of microspheric/megalospheric forms since higher ratios will normally reflected a lower mean size of the proloculus. This modification in the technique was tested by Nigam and Rao.⁷

The mean proloculus size of *Cavarotalia annectens*⁸ (Plate I, Figs. 3 & 4) was measured in surface sediment samples from the near shore region along the

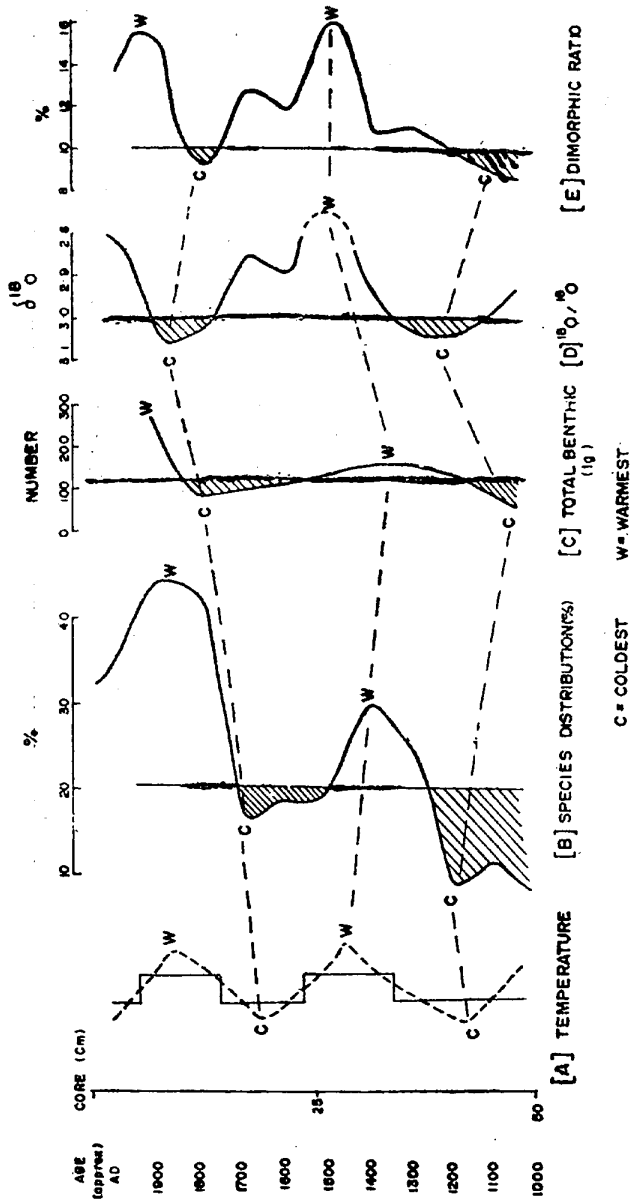


FIG 2 Comparison of results from different methods — (A) historical data, (B) distribution of *Bolivina skagerrakensis*, (C) total number of benthic foraminifera, (D) variation of $\delta^{18}O$, (E) ratios (x 100) of microspheric/megaspheric forms of *B. skagerrakensis*.

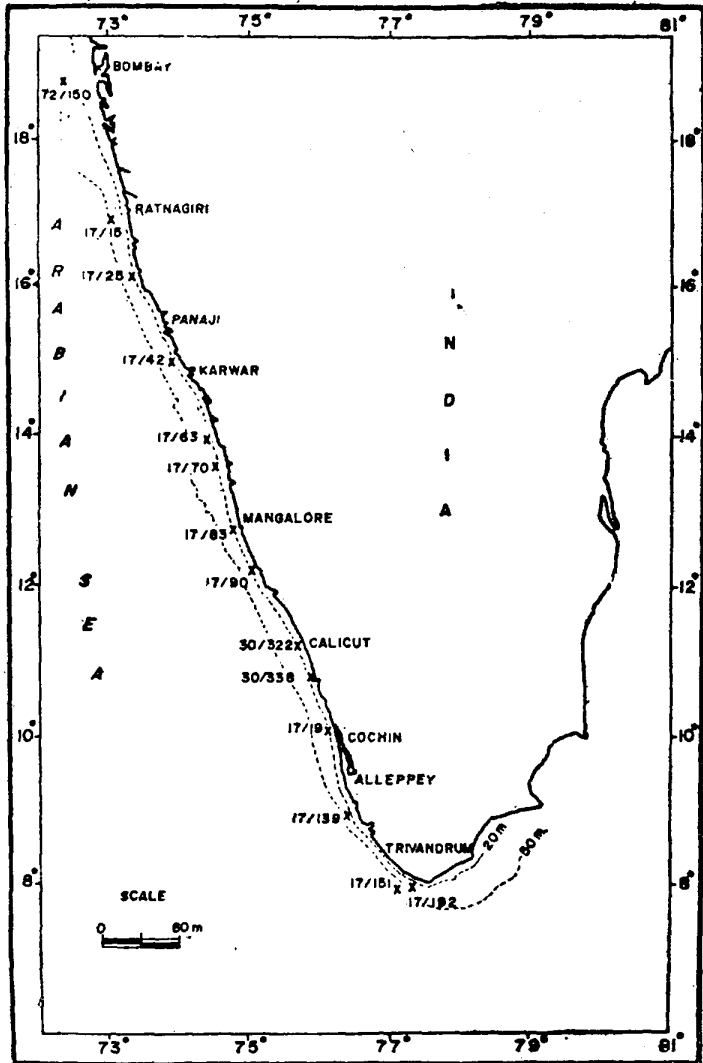


FIG 3 Map of the study area (Arabian Sea) with locations of surface sediment samples used to study mean proloculus size of *Cavartulia annectens*.

west coast of India (Bombay to Kanyakumari), covering a stretch of 10° of latitude (Fig. 3). In this region, temperature varies from 27.5 to 29.25 °C and salinity from 33.7 to 36.0 per part thousand. The results show that mean proloculus size varies from 0.045 to 0.103mm and is inversely proportional to temperature ($r = -0.78$) and salinity ($r = -0.71$) variations (Fig. 4). Therefore, it was proposed

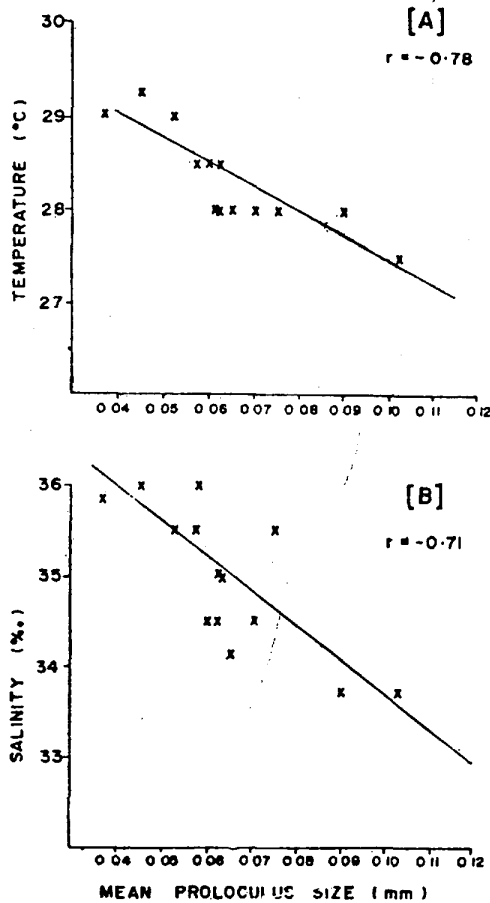


FIG 4 Relationship between mean proloculus size of *C. annectens* and temperature (A) and salinity (B).

that this parameter (mean proloculus size of foraminifera) can be used as an additional tool in palaeoclimatic studies.

In view of the above examples it would appear that features associated with reproductive behaviour of foraminifera viz. dimorphic ratios or mean proloculus size of foraminiferal species are useful indices in palaeoclimatic studies. However, a drawback/limitation of the present study is that we have dealt with only two particular species from two limited geographic areas. Therefore, the findings reported in the present work have to be confirmed by culture studies of various foraminiferal species under controlled temperature and salinity conditions and also by studies of different species in cores from different geographical areas with supporting temperature data.

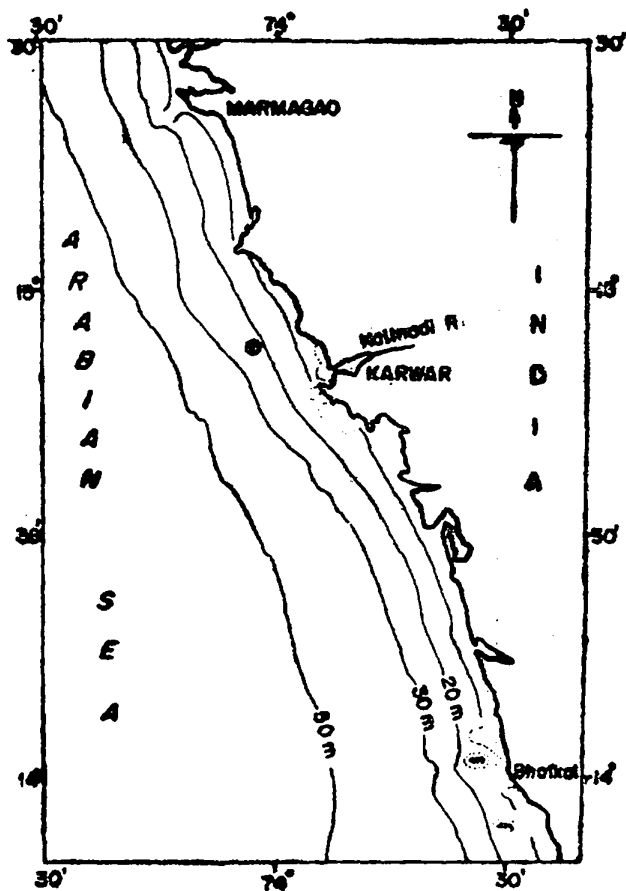


FIG 5 Map of the study area (for palaeomonsoonal studies) with location of core.

SCOPE FOR STUDYING PALAEMONSOON

The monsoon plays a vital role in the economy of tropical countries like India. To predict the future behaviour of the monsoons, the study of palaeomonsoons becomes very important. Earlier studies indicate that the climate over the Indian region has changed from warm and arid to warm and humid in the last 11Kyr⁹ with a subsequent intensification of the monsoon about 10Kyr.¹⁰ Similar conclusions were drawn by Street and Grove¹¹ after studying lake level fluctuations in Africa. In order to investigate in more detail the climatic changes and cyclicity in them, if any, which followed last deglaciation, present study can be used as a tool.

Variation in the intensity of palaeomonsoon must have affected the salinity and temperature of near-shore regions, particularly near river estuaries. Such

conditions can be detected by studying variations in ratios of dimorphic forms and/or in mean proloculus size of common species in a core sample at close intervals. Foraminifera, being extremely sensitive to environmental changes, can reflect even slight climatic fluctuations.

Such a study has already been undertaken at National Institute of Oceanography, Goa. Four box cores have been collected from the inner shelf region of the Central West Coast of India. Of these one box core collected on board RV GAVESHANI near the estuary of Kalinadi (Fig. 5) has been sub-sampled initially at 2cm interval (at 20cm from the top) and then at 5cm interval (from 20cm to 115cm). Based on the previous studies the species *Cavarotalia annectens* was selected. The preliminary results show considerable variation in mean proloculus size at different levels in the core, which in turn indicates the possible fluctuations in freshwater discharge through Kalinadi due to variation in monsoonal precipitations. The details of this study will be published in due course.

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