

Proloculus Size Variation in Recent Benthic Foraminifera: Implications for Paleoclimatic Studies

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Ratios of dimorphic (microspheric/megalosperic) forms of Foraminifera are affected by temperature and hence are useful in paleoclimatic studies. In some cases, however, it is not possible to distinguish between the dimorphic forms and, therefore, mean proloculus size is useful: a higher ratio means more microspheric forms and thus a lower mean size of the proloculus. To test this possibility, the mean proloculus size of *Cavarotalia annectens* (Parker & Jones) was measured in 14 surface sediment samples from the near-shore region along the west coast of India (Bombay to Kanyakumari), covering a stretch of 10° latitude. In this region, temperature varies from 27.5 to 29.25 °C and salinity from 33.7 to 36.0‰. The results show that mean proloculus size varies from 0.045 to 0.103 mm, and is inversely proportional to temperature ($r = -0.78$) and salinity ($r = -0.71$) variations. It is proposed, therefore, that this parameter (mean proloculus size of Foraminifera) can be used as an additional tool in paleoclimatic studies.

Introduction

The forecast of long-term climatic changes is a delicate task and depends on how well the past climate is known. As meteorological and weather data are generally unavailable for periods of more than 100–150 years, their usefulness in paleoclimatic studies is limited.

To overcome this, several methods based on Foraminifera have been developed for paleoclimatic studies. These methods include: (i) estimation of CaCO_3 which is mainly foraminiferal ooze (Arrhenius, 1952; Nilson, *et al.*, 1985); (ii) calculating the percentage of benthic organisms (Revelle, 1944; Broecker, 1971); (iii) counting different species of Foraminifera in any core which are known to grow in cooler or warmer zones (Blackman & Somayajulu, 1966); (iv) observing the coiling direction in some of the species (Ericson, 1959; Kennett, 1976); and (v) examining oxygen isotopes ratio in foraminiferal tests (Emiliani, 1955; Berger, 1981). A summary of these methods is presented in Table 1.

Changes in the reproductive cycles of some organisms like diatoms have been used to study climatic changes during Quaternary (Arrhenius, 1952). However, no real attempt has been made to utilize morphological features associated with the reproductive cycle of Foraminifera for paleoclimatic studies. It is well known that the shape, size and proloculus diameter of foraminiferal tests belonging to the same species are different. This

TABLE 1. Methods for palaeoclimatic studies using Foraminifera

Method	Author	Conclusion	
		Cold	Warm
(1) Amount of CaCO ₃ (mostly foraminiferal ooze)	Arrhenius, (1952)	high	low
(2) Percentage of benthic organisms	Broecker, (1971)	low	high
(3) Number of different species (tropical/high latitude)	Blackman & Somayajulu, (1966)	low	high
(4) Coiling direction of Foraminifera (dextral/sinistral)	Erikson & Wollin (1964)	low	high
(5) Oxygen isotope ratios (¹⁸ O/ ¹⁶ O)	Emiliani, (1955)	high	low
(6) Dimorphic forms ratios (microspheric/megalospheric)	Nigam (1986a)	low	high
(7) Mean proloculus size	Present study	high	low

phenomenon is related to reproductive dimorphism and the two forms are called microspheric and megalospheric. Microspheric forms have larger tests but smaller proloculi and megalospheric forms have smaller tests but large proloculi. Recently, Nigam (1986a) has proposed a technique in which dimorphic ratios of Foraminifera were utilized to infer the nature of paleoclimates. This study was based on the changes in dimorphic ratios of *Bolivina skagerrakensis* (Qvale & Nigam, 1985) in core samples from the Skagerrak, North Sea, and it was concluded that a higher ratio of microspheric/megalospheric forms indicates a warmer climate. However, it is observed that megalospheric forms are not always smaller than microspheric forms and the same is true with proloculus size (Boltovskoy & Wright, 1976). 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 because higher ratios will normally be reflected in a lower mean size of the proloculus.

The objectives of this paper are: (i) to introduce the use of mean proloculus size, rather than dimorphic ratios, into paleoclimatic studies, (ii) to test this concept on some benthic Foraminifera from the Indian region as a case study, and (iii) to show the implications of the results in the study of paleoclimates.

We investigated variations in mean proloculus size in *Cavarotalia annectens* (Parker & Jones) from the nearshore sediments along the west coast of India. This area was selected for study because the temperature varies by 1.75°C (27.5–29.25°C) from south to north (Patil *et al.*, 1964; Ramamirtham & Patil, 1965).

Cavarotaloa annectens was selected because it is a common species in beach (Bhatia, 1956; Bhalla & Raghav, 1980; Nigam, 1982) and nearshore (Nigam, 1984; 1986b; Nigam *et al.*, 1979) sediments along the west coast of India. Its large size (0.3–1.2 mm) and abundance ensures the accurate and statistically reliable measurement of proloculus size.

Materials and methods

The 14 samples used in this study were collected on board *R. V. Gaveshani* as a part of Cruise Nos 17, 30 and 72 (Figure 1) organized in pre-monsoon periods. Samples were

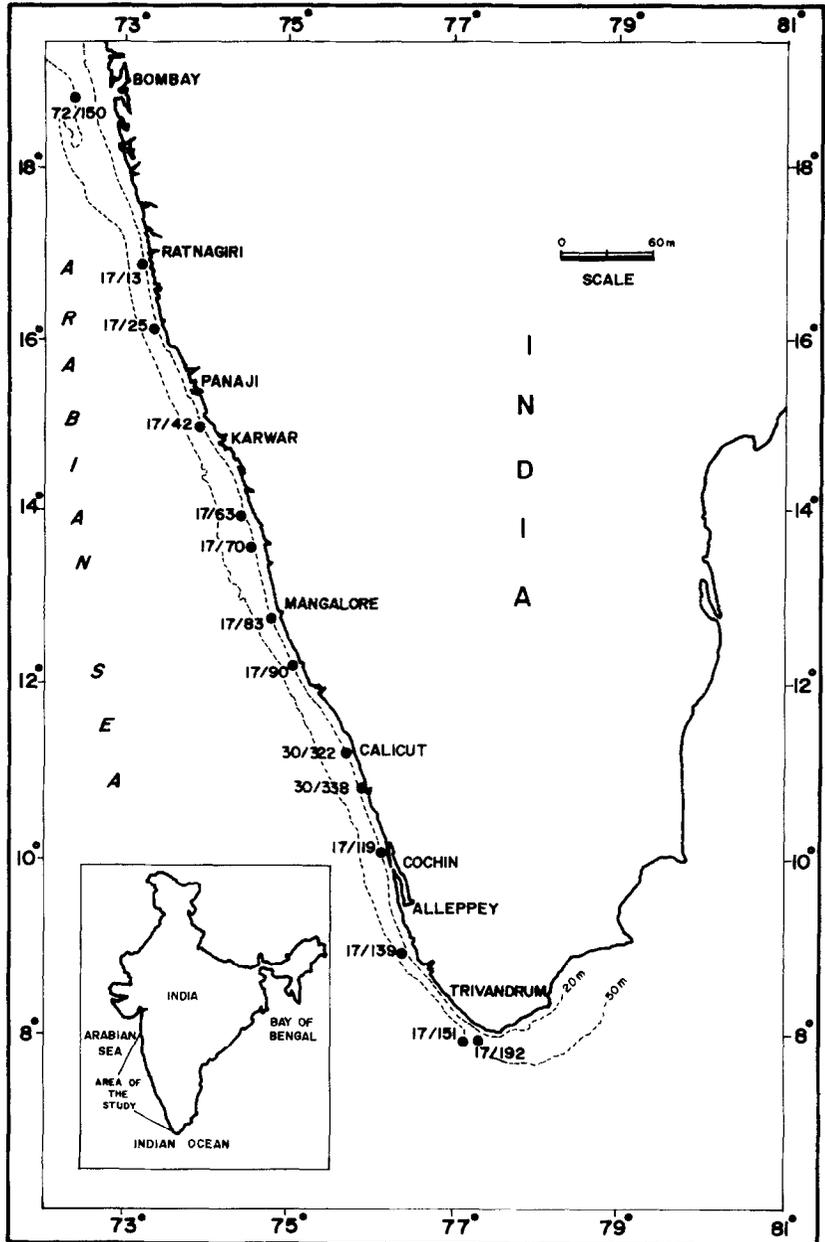


Figure 1. Station location map.

collected with the help of a La Fond Ditzé snapper and modified Peterson grab. The top 1-cm layer was separated from each sample, washed through a 63- μ m sieve and oven dried. About 75 specimens of species *Cavartalia annectens* from each station were selected and proloculus sizes were measured using a micrometer ocular.

Computations for correlation coefficients and regression equations between mean proloculus size and temperature, and mean proloculus size with salinity were calculated

TABLE 2. Co-ordinates, depth, mean proloculus size, temperature and salinity for each station

Station No.	Depth (m)	Latitude	Longitude	Proloculus size (mm)	Temperature* (°C)	Salinity* (‰)
72/1508	50.00	18°48.5'	72°21.4'	0.045	29.25	36.00
17/13	24.00	16°50'	73°14'	0.0625	29.00	35.80
17/25	26.00	16°04'	73°23.2'	0.075	28.00	35.50
17/42	23.00	14°54'	73°57.8'	0.0525	29.00	35.50
17/63	23.50	13°57'	74°26.3'	0.0575	28.50	36.00
17/70	33.00	13°34'	74°35'	0.0575	28.50	35.50
17/83	21.00	12°47'	74°41.6'	0.0625	28.50	35.00
17/90	20.00	12°14'	74°57.8'	0.06	28.50	34.50
30/322	45.00	11°28.1'	75°15'	0.062	28.00	34.50
30/338	35.00	10°51.1'	75°40.2'	0.0625	28.00	35.00
17/119	17.00	10°05'	76°07.5'	0.065	28.00	34.25
17/139	25.00	8°58'	76°22'	0.07	28.00	34.50
17/151	43.50	8°00'	77°23'	0.09	28.00	33.70
17/152	38.00	8°00'	77°29.5'	0.1025	27.50	33.70

*Data from Patil *et al.* (1964), and Ramamirtham and Patil (1965).

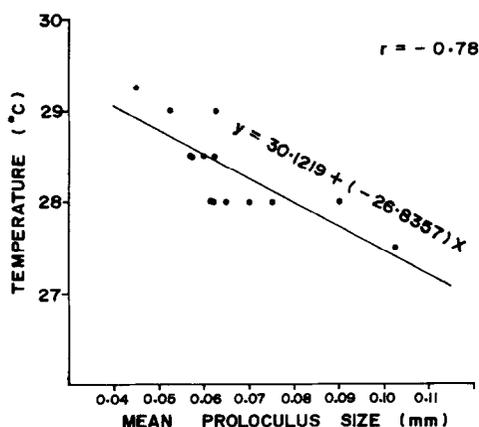


Figure 2. Relationship between mean proloculus size and salinity.

on TDC 316 computer at the computer centre of N.I.O. The level of significance was determined from table 7 of Fisher and Yates (1964).

Results

Table 2 shows locations, depths, latitudes and longitudes of the stations. The proloculus size of 1044 specimens varied from 0.013 to 0.15 mm. Mean values (each based on about 75 measurements) range from 0.045 mto 0.103 mm (Table 2).

Temperature and salinity varied in different seasons but the overall pattern is expected to remain the same from North to South in the study area. As all the samples for the present study were collected during pre-monsoon periods, temperature and salinity

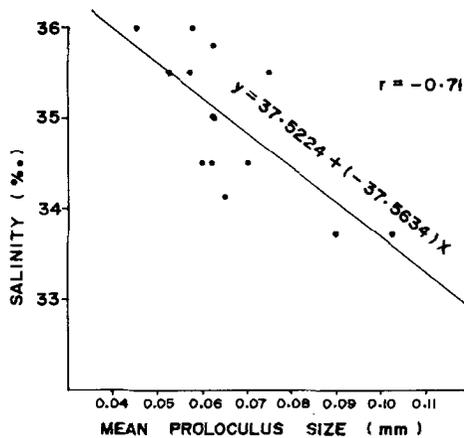


Figure 3. Relationship between mean proloculus size and temperature.

data for pre-monsoon months of corresponding locations were taken from two published reports (Ramamirtham & Patil, 1965; Patil *et al.*, 1964) and are given in Table 2.

Figures 2 and 3 show the relationship of mean proloculus size with temperature and salinity. The lowest value of mean proloculus size (0.045 mm) was recorded with the highest temperature (29.25°C) and highest salinity (36.0‰), and the highest mean proloculus size (0.103 mm) with the lowest temperature (27.5°C) and lowest salinity (33.7‰). Although the data base is small (14 samples), it is good enough to show the trends of the relationship between mean proloculus size and temperature and salinity. The correlation coefficient values for mean proloculus size with temperature ($r = -0.78$) and with salinity ($r = -0.71$) are negative (i.e. inverse relationship) and above the significance value (0.66) at the 99% confidence level.

Discussion

From Figures 2 and 3 it may be concluded that mean proloculus size is inversely proportional to the temperature and salinity. This agrees with the earlier findings of Nigam (1986a) which indicated that a larger number of microspheric forms (and hence lower mean proloculus size) indicated warmer climates.

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 paleomonsoons becomes very important. The present study can be used as a tool. Variation in the intensity of paleomonsoons must have affected the salinity and temperature of nearshore regions, particularly near river mouths. Such conditions can be detected by studying variations in mean proloculus size of a common species in a core sample at close intervals. Foraminifera, being extremely sensitive to environmental changes, can respond to and amplify even slight climatic fluctuations.

Sudden changes in the climate around 11 000 years B.P. happened on a global scale (Broecker *et al.*, 1960). Earlier studies indicate that, over the last 11 000 years the climate of the Indian region has changed from warm and arid to warm and humid (Nair & Hashimi, 1980) with a subsequent intensification of the monsoons about 10 000 B.P. (Singh *et al.*, 1972). Similar conclusions were drawn by Street and Grove (1976) after

studying lake level fluctuations in Africa. In order to investigate in more detail the climatic changes which followed the last deglaciation, a detailed study of proloculus size variations in different species from a number of locations along the Indian coast is being undertaken.

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