

THE INTRIGUING RELATIONSHIP BETWEEN COILING DIRECTION AND REPRODUCTIVE MODE IN BENTHIC FORAMINIFERA

R NIGAM AND A S. RAO

NATIONAL INSTITUTE OF OCEANOGRAPHY, DONA PAULA, GOA 403 004

ABSTRACT

Changes in coiling direction in foraminifera have been used extensively as proxy data for paleoclimates. However, most of the studies centred around planktonic foraminifera, and various causes (including reproductive mode) were suggested for coiling direction changes. We explored the relationship between mode of reproduction and coiling directions in benthic foraminifera.

Benthic foraminiferal species *Cavartalia annectens* (Parker & Jones) in 58 samples obtained from a core off Karwar, west coast of India, show sinistral and dextral coiling and also dimorphic (sexual and asexual) mode of reproduction. Proloculus size has been taken as indicator of change in reproductive behaviour. Results indicate that mean proloculus size and ratios of dextral/sinistral forms are inversely proportional ($r = -0.49$) and relationship is significant at 95 % level of confidence ($r = 0.29$). It is therefore proposed that (i) coiling direction in benthic foraminifera are related to mode of reproduction and (ii) forms with smaller proloculus have a preference to coil dextrally. This study may have significant consequences for interpretation of paleoclimatic records from shallow regions. However, these inferences need to be confirmed by additional culture and faunal studies with other species of benthic foraminifera.

INTRODUCTION

Amongst the various methods developed for paleoclimatic interpretations taking foraminifera into consideration, the one based on coiling directions is very simple and widely used. However, most climate studies are centred around coiling direction in planktonic foraminifera (See review by Kennett, 1976).

Although benthic foraminifera are quite useful in studying coastal climate, very little attention has been paid to the study of their coiling direction (Scott, 1974). Foyn (1936, 1937) and Lee *et al* (1963) suggested that coiling direction was associated with stages in life cycles. Bradshaw (1957) studied *Ammonia beccarii* in laboratory culture and showed that neither temperature nor salinity had any influence on coiling direction. Longinelli & Tongiorgi (1960) found a greater proportion of left-coiled specimens of two species in cooler waters and hence suggested a temperature control. Brooks (1967) has not found any variation in coiling direction throughout the year in Narragansett Bay. Recently, Malmgren (1984) showed that various morphotypes, including coiling direction in *Ammonia beccarii*, in samples from southern Europe, did not show any clear relationship to the environmental variables. However, it was also proposed that coiling preference may be a function of reproductive mode rather than temperature or depth (Boltovsky & Wright, 1976). Hallock & Larsen (1979), while studying coiling direction in *Amphistegina* from tropical & subtropical localities noticed that

proportions of dextral *A. lessoni* & sinistral *A. lobifera* increased in a +4°C thermal effluent. According to them, a possibility exists that coiling direction in *Amphistegina* is genetically controlled but environmentally influenced. For example, some environmental factor may be more favourable for the division of nuclei carrying information for sinistral coiling. Based on previous studies, Lipps (1979) has summarised 16 suggested 'causes' of coiling direction changes in foraminifera. He has further stated that enough evidence is not available to confirm or disprove these suggestions. However, he selected only two hypotheses for detailed discussion: one, of temperature control because it is used very commonly and the other, of differences in reproductive strategy related to productivity of water.

The objective of the present study is to evaluate the status of relationship between coiling direction and modes of reproduction (through mean proloculus size) in benthic foraminifera and its possible implications in paleoclimatic studies.

We investigated the relationship between the mean proloculus size and ratios of dextral and sinistral specimens of *Cavartalia annectens* (Parker & Jones, 1865, Billman *et al.*, 1980), in samples from a short core from the Centraj west coast of India. This species was selected because it is a common species in the west coast (Bhatia, 1956, Bhalla & Raghav, 1980, Nigam, 1984, 1986b, 1987, 1988 Nigam *et al.*, 1979, etc). Its large size (0.3 - 1.3mm) and abundance

ensures accurate and statistically reliable measurement of proloculus size as well as calculation of mean values for proloculus size and coiling ratios. The variation in mean proloculus size in the species and its implications for paleoclimatic studies has already been discussed by Nigam & Rao (1987).

MATERIALS AND METHODS

The 58 samples were obtained from a box core (length 1.16 m) collected during cruise 156 of *R. V. Gaveshani* (Figure 1). The core was subsampled at 2 cm intervals. All these samples were washed through a 63 μm sieve and oven dried. About 75 specimens of *Cavartalia annectens* from each subsample of the core, were separated. Dextral (clockwise) and sinistral (anti-clockwise) coiled specimens, and mean proloculus size were determined for each sample. Measurements for proloculus size were made with the help of a micrometer ocular.

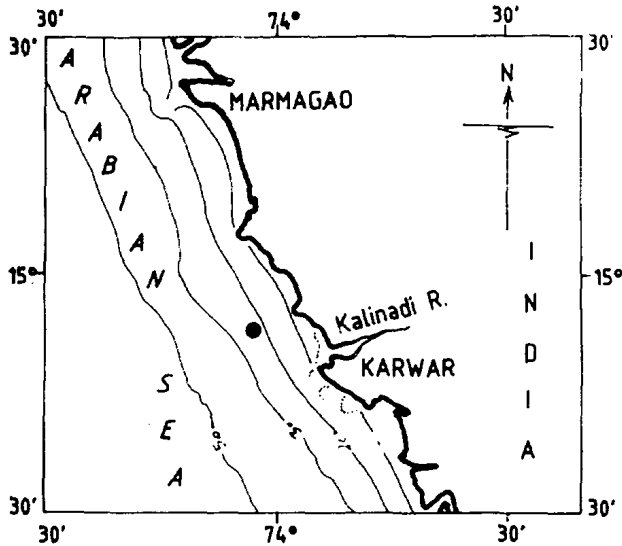


Fig. 1 Location Map showing position of core.

Observations regarding coiling direction are not at all difficult. The specimen is kept in dorsal view and the direction of progression of new chambers is noted. In a dextrally coiled specimen, new chambers are added in a clockwise manner, while anti-clockwise addition gives a sinistral coiled specimen. Coiled specimens can be counted in any assemblage.

Computations for correlation coefficients and regression equations between various parameters were carried out on ND 520 computer at the computer centre at N.I.O. The levels of significance (95%

limit) were determined from Table 7 of Fisher & Yates (1964).

A total of 4468 specimens were used from 58 samples. Of these, 89% were sinistraly coiled. The mean proloculus size (MPS) variation is between 0.0485 mm to 0.068 mm. Figure 2 exhibits the down core variations in mean proloculus size and percentage of dextral specimens. Relationship between mean proloculus sizes and ratios of dextral/sinistral has also been shown graphically (Figure 3).

DISCUSSIONS

Many workers have found that coiling direction in planktonic foraminifera may have some environmental control (Ericson, 1959; Bandy, 1960; Van Valen, 1969; Caralap, 1987 and many others). Ecological conditions affect the reproductive behaviour of foraminifera, too. As a rule, microspheric specimens are considerably less than megalospheric forms. Under

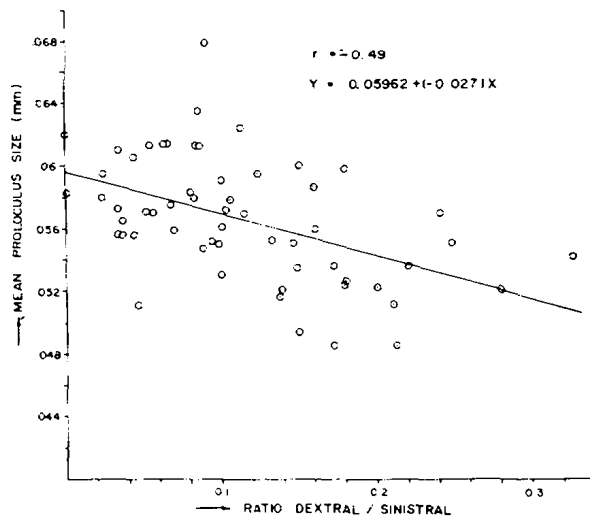


Fig. 2 Down core variations in mean proloculus size & percentage of dextral forms of *C. annectens*.

unfavourable conditions, however, microspheric forms are comparatively more than megalospheric forms (Boltovskoy & Wright, 1976). Some other observations indicate (Hofker, 1930) that temperature is a major factor in governing reproductive behaviour.

If ecologic factors, or more precisely temperature, governs both coiling direction and reproductive mode, it is natural to look for a relationship between them.

Features associated with reproduction need more attention. It is well known that the shape, size and proloculus size of tests of foraminifera belonging to the same species are different. This phenomenon is related to reproduction and known as dimorphism, and the two forms are known as megalospheric and microspheric. Size is the simplest to measure and some workers (Thiede, 1971; Steuerwald & Clark, 1972 and Vella, 1974) noted a tendency in several planktonic species for the coiling direction to be related to the size of the specimens. Where planktonic species are concerned, size is the only important factor which gives information about dimorphism, (if any) as measurement of other related but more reliable features like proloculus size is difficult. In benthic foraminifera, at least in the case of *C. annectens*, proloculus size can be easily measured. Moreover, the size of the proloculus (first chamber) and the direction of coiling (which is decided by addition of a few chambers soon after formation of the first chamber) will remain unchanged with the growth of specimens, and hence, will be independent of size. Therefore, for the present study the proloculus size and microspheric/megalospheric ratios have been taken as factors representing modes of reproduction.

Figure 2 shows the inverse relationship between percentage of dextral forms with MPS. Figure 3 gives a quantified relationship between MPS and ratios of dextral/sinistral forms. Correlation value (r) is - 0.49 which is quite above the 95 % level of significance ($r = 0.29$). Therefore, it may be concluded that (i) coiling directions in benthic foraminifers are related to mode of reproduction (ii) low MPS forms (microspheric) have a tendency to coil dextrally.

Explaining the reasons for the above detailed relationships is beyond the scope of this paper. However, it is interesting to cite the work of Alpatov (1957). He suggested (In: Boltovskoy & Wright, 1976, p. 57) that "organic molecules comprising the protoplasm are disymmetrical (dextral or sinistral), giving the protoplasm an optical activity. This optical activity may be advantageous to the organism." Does this 'advantageous' mean that foraminiferal species adjust themselves to changes in environment by adjusting molecular composition of protoplasm, thus leading to preferential reproduction (microspheric/megalospheric) and coiling direction (dextral/sinistral)? This possibility *can* be tested through detailed *culture* studies only.

An alternative hypothesis was proposed by Lipps (1976). According to him "In tropically rich or fluctuating environments, populations must have a high intrinsic *rate of growth*, which is accomplished by

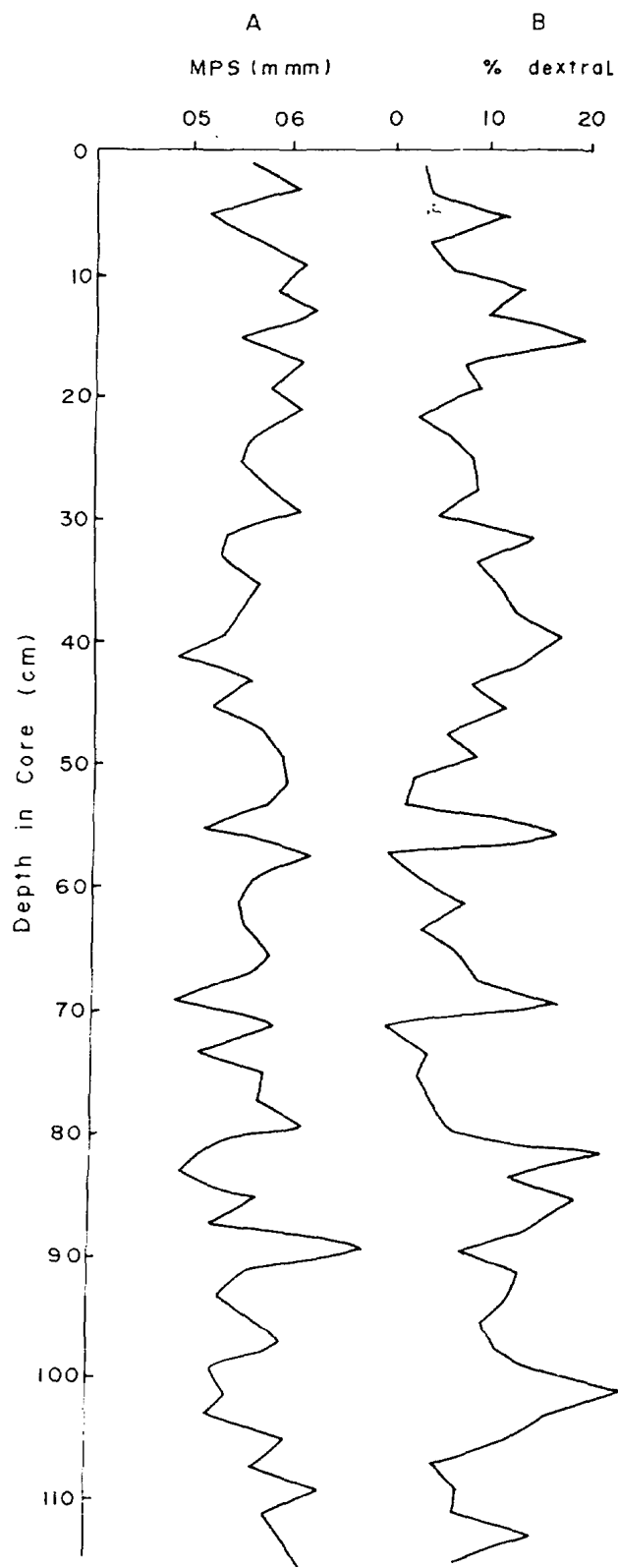


Fig. 3 Relationship between graphic ratios of dextral/sinistral forms and mean proloculus size.

a sexual reproduction, whereas in poor or stable regimes, population growth need not be fast and more elaborate reproductive strategies can be involved (sexual). Coiling ratio change in time and space may therefore indicate changes in tropical supply".

Present study is based only on one species from a limited geographic area. For more conclusive results, a number of species from different environmental conditions will have to be studied in field as well as in laboratory cultures.

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