

## DIMORPHIC FORMS OF RECENT FORAMINIFERA: AN ADDITIONAL TOOL IN PALEOCLIMATIC STUDIES

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### ABSTRACT

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Limited culture studies of foraminiferal species show that the ratios of dimorphic forms are not constant and are affected by extremes of temperature. This feature might be utilized for paleoclimatic studies. To test this possibility ratios of microspheric/megalospheric forms were obtained for *Bolivina skagerrakensis* Qvale and Nigam, at different levels in a core (15530-4) from the Skagerrak, eastern North Sea. The values show considerable fluctuations and can be correlated with two other paleotemperature scales: the total number of benthic foraminifera and the oxygen isotope ratio. It is concluded that the microspheric/megalospheric ratios of foraminifera can be used as index of paleoclimate and that the higher ratios indicate relatively warm climates. However, this inference needs to be confirmed by additional culture studies under controlled temperature conditions, and faunal studies of cores where paleotemperatures are already established with the help of oxygen isotopes.

### INTRODUCTION

The study of paleoclimate is very important for understanding past environments and evolution as it may help to forecast future climatic patterns. Previous studies based on foraminifera have proved to be very valuable in deriving paleoclimate inferences. The methods previously used have been (1) estimation of total  $\text{CaCO}_3$  which comprises mainly foraminiferal ooze, (2) percentage of benthic organisms, (3) number of different foraminiferal species, (4) coiling direction of some of the foraminiferal species and (5) oxygen isotope ratio in foraminiferal tests in cores. The objective of the present paper is to explain a new approach based on the dimorphic ratio of foraminifera which may complement the information deduced by the other established techniques.

It is well known that the shape, size and proloculus diameter 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. As a rule the number of micro-

spheric specimens is considerably less than the number of megalospheric forms. But, under unfavourable conditions microspheric forms are comparatively more numerous than megalospheric. These unfavourable conditions seem to have been confined to the winter (Boltovskoy and Wright, 1976). However, Hofker (1930) noted that only the microspheric specimen of *Rotalia beccarii flevensis* in the Zuyderzee were able to survive 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 temperature dependent. The nature of the dependence, however, is not very clear due to lack of an adequate number of culture studies (for review see, Arnold, 1974).

Nevertheless, from the limited number of culture studies it is apparent that if the overall pattern of climate does not change, the resultant net ratios 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. In case ratios are not constant but vary, this may indicate cold or warm climatic conditions over some duration in the past. This possibility can be tested by calculating ratios of dimorphic forms of any particular species at different levels in core and by comparing the results with those of established techniques of paleoclimatic indices like the total number of benthic foraminifera and/or the oxygen isotope record.

The author made an attempt to test this hypothesis by studying *Bolivina skagerrakensis* in a core from the Skagerrak, eastern North Sea, Norway. The selection of the species *B. skagerrakensis* was based on the fact that this species immigrated into the Skagerrak very recently and became abundant (up to 45%) (Nigam, in preparation) in the upper 50 cm of the core and in the surface sediments (Van Weering and Qvale, 1983). It provides enough specimens for the calculation of microspheric/megalospheric ratios and also for oxygen isotope studies.

Other aspects of foraminifera, e.g. total foraminiferal number, number of foraminiferal species, distribution of various species at different levels in the core (Nigam et al., 1984), taxonomy of *Bolivina* cf. *B. robusta* (Qvale and Nigam, 1985) and morphometric variations in *Bolivina skagerrakensis* etc. (Nigam, in preparation) have already been discussed.

#### MATERIAL AND METHODS

A 10.5 m core (No. 15530-4) was collected on board *F/S Poseidon* on November 8th, 1980 with a 9 cm diameter gravity corer at 57°40.0'N, 7°05.5'E from a clayey sea bed at a water depth of 325 m from the Skagerrak, eastern North Sea. Based on previous studies (Nagy and Qvale, 1983), the samples were taken at 5-cm intervals from the upper 50 cm of the core. All specimens of *Bolivina skagerrakensis* from the 125 µm fraction were picked in a standard size (300–500 specimens) sample and ratios of the dimorphic forms of this species were determined. About 25 specimens were used to obtain oxygen isotope ratios.

## RESULTS

As mentioned above, the detailed distribution of various foraminiferal species in this core at different levels has already been published elsewhere. Table I represents (X) the total number of foraminiferal tests of benthic foraminifera in 1 g of sediment and inferred climate, (Y) the oxygen isotope ratios ( $^{18}\text{O}/^{16}\text{O}$ ) obtained for *Bolivina skagerrakensis* and inferred climate and (Z) the dimorphic ratios (microspheric/megaspheric) of *Bolivina skagerrakensis* and inferred climate, at different levels in the core.

## DISCUSSION

From Table I (Z) it is observed that the low values (9.10 and 9.80%) are present at the bottom of the core (40–45 cm and 45–50 cm) and at the 10–15 cm level from the top. The higher values of dimorphic ratios are present at the 25–30 cm level (16.0%) and at the 5–10 cm level (14.6%). Based on the work of various researchers (see Boltovskoy and Wright, 1976) it may be concluded that these two sets (low and high values of ratios) show extreme climatic conditions which are opposite to each other, i.e. if one set indicates cold, the other should indicate warm conditions. As there is difference of opinion regarding the relationship between dimorphic form ratios and temperature, it is difficult to reach a positive conclusion based on these observations alone.

Therefore, paleotemperature determinations on the same set of samples were carried out for comparison with two other methods, namely total

TABLE I

Variation in total benthic foraminifera,  $\delta^{18}\text{O}$  and ratios ( $\times 100$ ) of microspheric/megaspheric forms of *Bolivina skagerrakensis* in the core

Approx. ages in A.D.	Sample depth in core (cm)	First Method (X)		Second Method (Y)		Third Method (Z)	
		Inference based on total benthic foraminifera		Inference based on oxygen isotope ratio		Inference based on dimorphic ratio	
		Total no. in 1 g	Inference	$\delta^{18}\text{O}$	Inference	Ratio $\times 100$	Inference
	5–10	224	Warm	3.06	Cold	14.60	Warm
1800	10–15	86	Cold	3.03		8.99	Cold
1700	15–20	102		2.86		12.70	
1600	20–25	111		2.90		11.70	
1500	25–30	135		1.42	Warm	16.00	Warm
1400	30–35	166	Warm	2.96		10.70	
1300	35–40	155		3.03		11.10	
1200	40–45	141		3.04	Cold	9.80	
1100	45–50	94	Cold	2.97		9.10	Cold
1000							

benthic foraminifera in the samples and oxygen isotope studies. Broecker (1971, vide Somayajulu, 1977) observed a decrease in percentage of benthic (deep sea) organisms in sediments deposited in cooler periods. The latter observation was applied to the present data (Fig.1: X) and the climatic inference for extreme climatic conditions was noted against some of the samples. These results indicate cold conditions at the bottom (at the 45–50 cm level) and at the 10–15 cm level of the core with warm conditions at the 30–35 cm level and at the top (5–10 cm level) of the core.

From the oxygen isotopic distribution it is known that  $^{18}\text{O}$  is depleted in warm water and this effect is maintained in foraminiferal tests assuming that they grew in isotopic equilibrium with sea-water. This technique was applied to the tests of *Bolivina skagerrakensis* and the deduced climatic conditions were noted (Fig.1: Y). Oxygen isotope data indicate warm conditions at the bottom (45–50 cm level) and middle of the core (25–30 cm level) and cold conditions at the 45–40 cm and 40–35 cm intervals and at the top (10–15 cm and 5–10 cm level) of the core.

Although each of these independent techniques have their own limitations, in this case they all suggest similar climatic conditions at various levels in the core (Fig.1: Z). Based on this comparison it appears that the higher ratios of microspheric/megalospheric forms represent warmer climatic conditions.

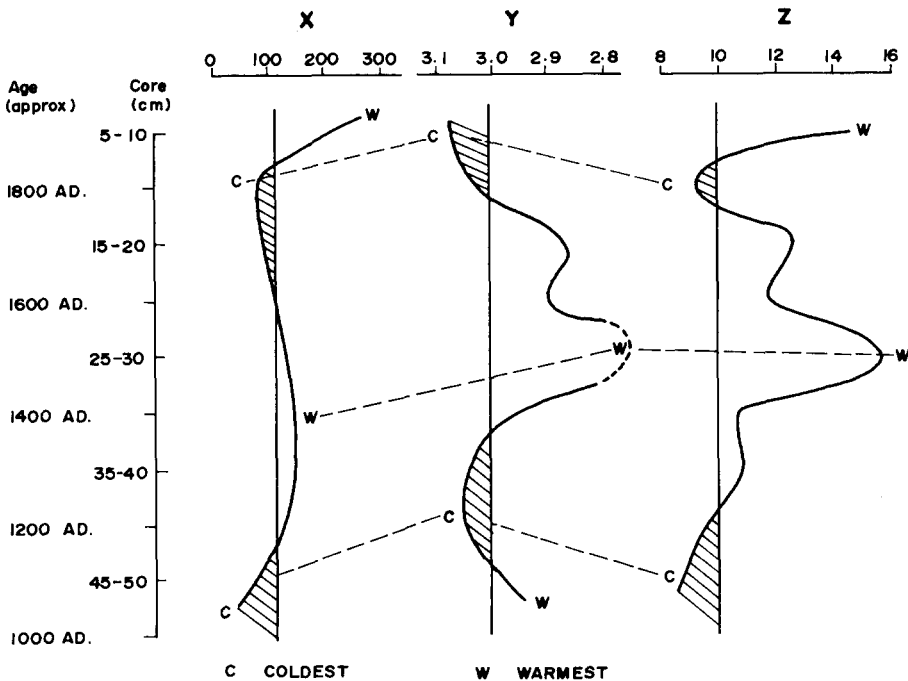


Fig.1. Comparison of results obtained from three methods: X-variation of total number of benthic foraminifera in core; Y-variation in  $\delta^{18}\text{O}$  in core; Z-variation in ratios ( $\times 100$ ) of microspheric/megalospheric forms of *Bolivina skagerrakensis* in core.

Based on  $^{14}\text{C}$ ,  $^{210}\text{Pb}$  dating and palynological studies Nigam et al. (1984) concluded that the bottom of the core (time of immigration of *Bolivina skagerrakensis*) is approximately 1000 years old and that the topmost sample (5–10 cm level) is about 50 years old. With these dates, the chronology of the climatic change can be summarised as follows: cold, about 1000 yr B.P. (900 A.D.); subsequent warming which peaked during 1400–1500 A.D. followed by cooling up to 1800–1900 A.D. and again trending towards warming. Similar climatic events were observed by others and summarised by Crowley (1983): “The climate of the past 1000 years (fig.47) has been marked by Medieval warming, followed by a cool interval (the Little Ice Age) from about 1430 to 1850 (Gribbin and Lamb, 1978; Bernabo, 1981). The subsequent warming that peaked in the 1940’s (Mitchel, 1961) completes the picture.” There are some differences in the exact timing of these events but these may be ascribed to differences in geographical locations, and some lag between events and faunal responses.

In view of the above it would appear that dimorphic ratios of foraminiferal species are useful indices in paleoclimatic studies. However, a drawback/limitation of the present study is that we have dealt with one particular species from a limited geographic area. Therefore, the finding reported in the present work has to be confirmed by culture studies of various foraminiferal species under controlled temperature and also by studies of different species in cores from different geographical areas with supporting temperature data.

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