

SHORT PAPER

Late Quaternary Faunal Change in Coastal Arabian
Sea Sediments

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Received May 11, 1982

Carbonate content and faunal composition of two gravity cores from the coastal Arabian sea provide evidence of a major environmental change in surface ocean waters about 13,000 yr B.P. Radiocarbon dating indicates that deposition rates ranged from 1.8 to 9.8 cm/10³ yr, with a major change in rate occurring in one core at about 7500 yr B.P.

Established techniques such as the analysis of (a) variations in calcium carbonate (Arrhenius, 1952; Damuth, 1975), (b) variations in the abundance of cold-, temperature-, and warm-water planktonic foraminifera, as well as their coiling directions (Ericson *et al.*, 1954; Phleger *et al.*, 1953; Blackman and Somayajulu, 1966), and (c) oxygen-isotope composition (Shackleton and Opdyke, 1973) of foraminiferal tests have increased our understanding of Quaternary climatic events on a global scale. Such studies, however, have mostly been confined to the Atlantic and Pacific Oceans. Although the International Indian Ocean Expedition resulted in micropaleontological investigations of Indian Ocean sediments (Freirichs, 1968; Oba, 1969; Bandy *et al.*, 1972; Vincent, 1976), paleoclimatic data from that region are still limited.

In this paper we report evidence of a faunal change that occurred about 13,000 yr. B.P., based on our paleontological and geochronological studies of two gravity

cores from the coastal Arabian Sea. Calcareous cores ARB52 and ARB54 were raised from an area about 100 to 200 km west of the Bombay coast (Table 1) during the fifth cruise of INS *Darshak*. Two 1-cm-thick samples at 5-cm intervals were used for CaCO₃ determination (Barnes, 1959) and faunal analysis.

Detailed procedures for the separation of the foraminifera, their frequency distribution, and the lithology of the cores and of some other coastal samples will be reported elsewhere (Kameswara Rao, unpublished manuscript). The grouping of fauna into cold-, temperature-, and warm-water faunal associations was made following the methods of Belyaeva (1964). The various species encountered in the present investigation are listed in Table 2.

The ¹⁴C method was used for geochronology. Samples of about 20 g (dry weight) were processed, and derived CO₂ was converted into methane for radiocarbon assay (Agarwal *et al.*, 1965). Three sections of

TABLE 1. LOCATIONS, LENGTHS, AND AGES OF ARABIAN SEA CORES

Core	Location		Water depth (m)	Core length (cm)	Sample depth (cm)	¹⁴ C age ^a (10 ³ yr B.P.)
	Latitude	Longitude				
ARB52	19°03' N	69°30.4' E	2240	133	10–20	8200 ± 200
					30–40	12,310 ± 250
					50–60	17,470 ± 490
ARB54	18°47' N	70°08.5' E	800	91	10–20	4260 ± 220
					40–50	7330 ± 230
					80–90	29,850 ± 420

^a Errors quoted are due to 1 σ counting statistics only.

each core were used for radiocarbon dating (Table 1). Using the ¹⁴C age versus depth plots (Fig. 1), the average sediment accumulation rate of core ARB52 was 4.6 cm/10³ yr. In core ARB54, a change in the accumulation rate from 1.8 to 9.8 cm/10³ yr occurred about 7500 yr B.P. (Fig. 1).

The percent variations of CaCO₃ and of cold-, temperate-, and warm-water planktonic foraminiferal faunas are all indicative of climatic changes, and have been plotted as a function of time (Fig. 2). Attempts have also been made to study the coiling

directions of *Globorotalia truncatulinoides* and *G. crassaformis*, as done earlier by Ericson *et al.* (1954) in the Atlantic and by Blackman and Somayajulu (1966) in the Pacific. But these attempts were not successful, for only a few specimens (2–6 per sample) were encountered and these were all dextral. The cold-water *Globoquadrina pachyderma* is also present in small concentrations (<3%) at most levels in the cores and is relatively dextral in surface samples compared to deeper levels.

Because the cores are from a tropical region (Table 1) and the Arabian Sea extends only to 25°N, it is not reasonable to expect cold-water fauna to be present in high

TABLE 2. COLD-, TEMPERATE-, AND WARM-WATER PLANKTONIC FORAMINIFERA IDENTIFIED IN CORES ARB52 AND ARB54^a

Cold-water species	
<i>Globoquadrina pachyderma</i> (Ehrenberg)	
Temperature-water species	
<i>Globigerina bulloides</i> (d'Orbigny)	
<i>Globorotalia crassaformis</i> (Galloway and Wissler)	
<i>Globorotalia hirsuta</i> (d'Orbigny)	
<i>Globorotalia inflata</i> (d'Orbigny)	
<i>Globorotalia scitula</i> (Brady)	
<i>Globorotalia truncatulinoides</i> (d'Orbigny)	
Warm-water species	
<i>Globigerinella aequilateralis</i> (d'Orbigny)	
<i>Globigerinoides conglobatus</i> (Brady)	
<i>Globigerinoides sacculifer</i> (Brady)	
<i>Pulleniatina obliquiloculata</i> (Parker and Jones)	
<i>Globorotalia menardii</i> (d'Orbigny)	
<i>Globorotalia menardii flexuosa</i> (Koch)	
<i>Globorotalis tumida</i> (Brady)	
<i>Globoquadrina conglomerata</i> (Schwager)	
<i>Candeina nitida</i> (d'Orbigny)	

^a Grouping after Belyaeva (1964).

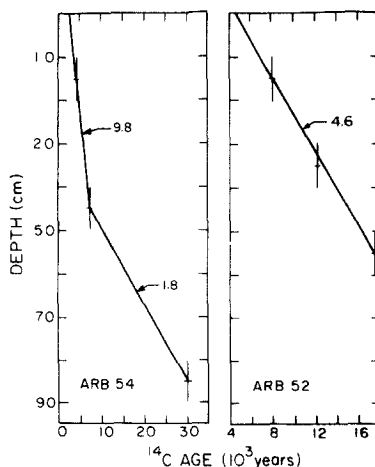


FIG. 1. Plots of ¹⁴C age versus depth in ARB52 and ARB54 (see Table 1 for details). Numbers next to arrows represent accumulation rates (cm/10³ yr).

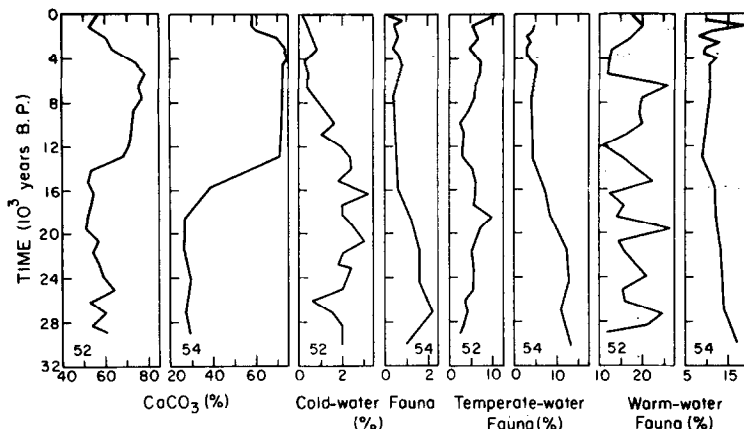


FIG. 2. CaCO_3 and faunal variations in cores ARB52 and ARB54 during the past 30,000 yr.

abundance. In fact, both cold-water and temperate-water faunas (Table 1) are present in rather small concentrations (Fig. 2). The location is optimal for warm-water fauna, and this is by far the most abundant component found.

From Figure 2 it is evident that CaCO_3 and the abundance of cold-water fauna (also, to some extent, the abundance of temperate-water fauna) show a pattern attributable to climatic change. The CaCO_3 contents of deep-sea sediments have long been known to fluctuate in response to Quaternary climatic changes (Arrhenius, 1952; Damuth, 1975). The high rate of CaCO_3 deposition during the past 13,000 yr is perhaps due to high productivity in the region, which in turn could be a result of increased upwelling. Based on their studies of coastal marine sediments of western India, Nair and Hashimi (1980) have noted high productivity during the Holocene. Both cores ARB52 and ARB54 yield essentially identical patterns of CaCO_3 variations. The abundances of cold-water and temperate-water faunas were low during the Holocene but were higher between 28,000 and 13,000 yr B.P. (Fig. 2).

In the Atlantic and Pacific Oceans and in certain parts of the Indian Ocean, the Pleistocene–Holocene boundary has been placed at about 10,000 yr B.P. based on (a)

CaCO_3 variations in sediments (Damuth, 1975), (b) changes in the deposition rate (Krishnamurthy *et al.*, 1979), (c) faunal analysis (Ericson *et al.*, 1956; Blackman and Somayajulu, 1966; Oba, 1969; Vincent, 1972, 1976), and (d) isotope measurements (Emiliani, 1955). Mercer (1972) suggests that the start of global warming about 14,500–14,000 ^{14}C yr B.P. should constitute the Pleistocene–Holocene boundary. At the present stage of our investigation it can be said that there is indeed evidence for a faunal change at about 13,000 yr B.P. or shortly after Mercer's proposed boundary.

Vincent (1972, 1976) has estimated a warming of surface water in the southern Mozambique Channel by as much as 5°C during the climatic change that occurred at the Pleistocene–Holocene boundary, based on faunal analysis of sediments. Because the deposition rates of cores ARB52 and ARB54 are high, it would be possible to make $\delta^{18}\text{O}$ measurements at close intervals to see if the faunal change is accompanied by a change in isotopic values.

ACKNOWLEDGMENTS

We thank ex-directors of NIO, the late Dr. N. K. Panikkar and Dr. S. Z. Qasim, as well as the present directors of NIO and PRL, and the scientist-in-charge of the NIO Regional Centre for encouragement. We also thank Captain F. L. Fraser and the staff of INS *Darshak* for help in core collections. Work done at

PRL was in part supported by a PL-480 grant. We thank Dr. Y. Herman and Dr. S. C. Porter for their critical reviews of this work.

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