Reports

Pleistocene Climates in the Atlantic and Pacific Oceans: A Reevaluated Comparison Based on Deep-Sea Sediments

Abstract. *Variations of the* Globorotalia menardii *complex in cores from the Indian Ocean can be interpreted as indicating climatic changes that are opposite to trends exhibited by the total planktonic fauna. The questionable value of correlations between different water masses based on a single species can be shown by* Neogloboquadrina dutertrei subcretacea *in cores obtained off the coast of California and Baja California. This information, in addition to previous correlations between Quaternary cores of the Atlantic and Pacific oceans, indicates that the Pleistocene history of the two oceans was parallel.*

Ericson and Wollin (*1*) have recently compared the variations in the abundance of the *Globorotalia menardii* (d'Orbigny) complex in Quaternary cores from the southeastern Pacific with their generalized tropical Atlantic climatic model (*2*) based on the same species group. Their data suggest that the temperature changes of surface waters of the two oceans have been more nearly opposed than synchronous during the time interval involved. Correlation by Blackman and Somayajulu (*3*) of faunal zones from cores near the coast of Peru with similar zones in Atlantic cores made it necessary for Ericson and Wollin (*1*) to conclude tentatively that, in contrast to the Atlantic, the Pleistocene record in the Pacific varies from area to area.

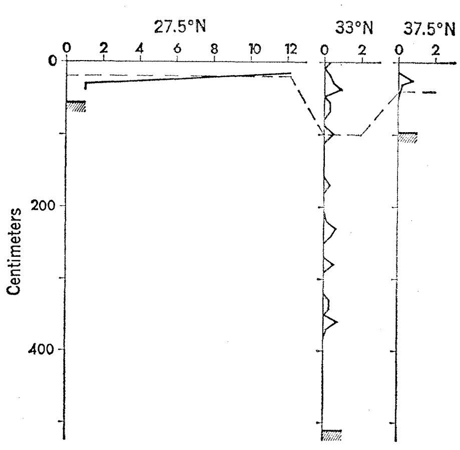

Fig. 1. Relative abundance of *Neogloboquadrina dutertrei subcretacea* (Lomnicki) in three cores obtained off the coasts of California and Baja California. The broken line indicates the Pleistocene-Holocene boundary as determined from sedimentological and paleontological data. Allan Hancock Foundation station numbers and approximate locations of the cores are (left to right): AHF 7249, off Cedros Island; AHF 10615, off Los Angeles; AHF 7436, off San Francisco.

In the Pacific, many workers (*4–7*) indicated significant correlative faunal varations at the Pleistocene-Holocene boundary. Thomas (*6*) and Morin (*7*) have identified the warm interval of the early Wisconsin in the tropical and in the temperate North Pacific, respectively. Kennett (*5*), working with Middle and Upper Pleistocene cores from the subantarctic region of the Pacific, also found comparable paleoclimatic trends. The faunal changes shown in all these studies correlate with variations reported in the Atlantic (*2*, *8*), although Ericson and Wollin (*1*) were unable to distinguish parallel trends in their Pacific cores.

Examination of the location and oceanographic setting of the cores used by Ericson and Wollin (*1*) suggests that a planktonic foraminiferal fauna of transitional to subtropical type in Bé's classification (*9*), or of midlatitudes in Blackman and Somayajulu's system (*3*), should predominate at least in the surface of the cores. The *Globorotalia menardii* complex should, accordingly, make a relatively small contribution to the total fauna. The latest distributional tables by Parker and Berger (*10*) corroborate these conclusions, which are in direct contrast to findings in the tropical Atlantic, where the *G. menardii* complex is abundant in the water column and in Holocene sediments (*11*).

By sampling across water masses of contrasting faunal characteristics in the same ocean, one can also find contrasting planktonic events, especially if correlations are based solely on one species. This may be illustrated by variations in populations of the *Neogloboquadrina dutertrei* (d'Orbigny) group. The relative abundance of *N. dutertrei dutertrei* (d'Orbigny) has been shown by Vincent (*12*) to increase from 5 percent of the planktonic foraminiferal population below the Pleistocene-Holocene boundary to about 15 to 20 percent above it in the subtropical southwestern Indian Ocean. Morin (*7*) has reported a change of similar magnitude at the end of the Pleistocene off Cedros Island, Baja California (Fig. 1), in populations of *N. dutertrei subcretacea* (Lomnicki). Beneath the temperate waters off Los Angeles and San Francisco, the increase at the end of the Pleistocene (Fig. 1) involves a change of less than 1 percent of the planktonic foraminiferal population. The discontinuous distribution of *N. dutertrei subcretacea* in the Holocene of the Los Angeles core shows the uncertainty involved in using the abundance of a single species to define paleoclimatic events in a water mass where it is rare.

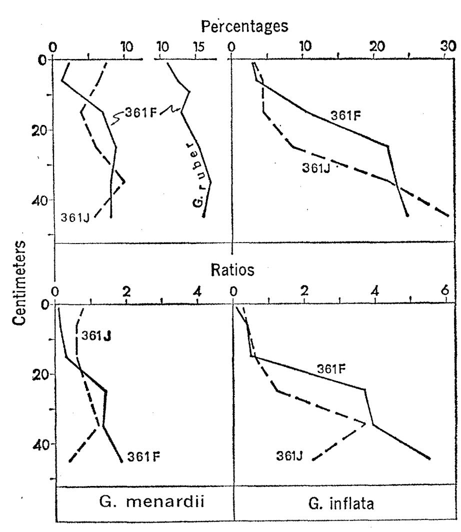

Fig. 2. Variation in relative abundance of the *Globorotalia menardii* (d'Orbigny) complex and *Globorotalia inflata* (d'Orbigny) in two cores (361 F and 361 J) from the Mozambique Channel, Indian Ocean. Percentages show relative abundance in total assemblage; ratios were calculated according to Ericson and Wollin's (*8*) technique (numbers of specimens divided by weight in milligrams of washed sample).

This uncertainty should be even more pronounced in comparing the frequency of the *G. menardii* complex in tropical Atlantic cores with temperate to subtropical South Pacific cores, since these forms have a more restricted distribution than the *N. dutertrei* group (*9, 10*).

The doubtful significance of correlations based on the *G. menardii* complex in areas outside its typical habitat can be demonstrated by examination of two cores from the Mozambique Channel, Indian Ocean. The area is in a planktonic province comparable with that of Ericson and Wollin's (*1*) cores. Vincent (*12*) has convincingly shown that the Pleistocene-Holocene boundary can be defined in the Mozambique Channel by the significant decrease in relative abundance of the temperate species *Globorotalia inflata* (d'Orbigny), from over 20 percent of the planktonic foraminiferal fauna below the boundary to less than 5 percent above it (Fig. 2). If the frequency technique of Ericson and Wollin (*8*) is used, the ratios obtained are between 3 and 6 below the boundary and under 0.5 above it (Fig. 2). Reversed trends are shown by most warm water species, such as *Globigerinoides conglobatus* (Brady), *G. sacculifer* (Brady), *N. dutertrei dutertrei*, and *Pulleniatina obliquiloculata* (Parker and Jones), supporting the evidence for a warm water influx. Analysis of the *G. menardii* complex (Fig. 2) shows, however, an increase of the complex below the boundary in core 361 F, whereas no definite trend exists in core 361 J. If this evidence is considered alone, without study of the total fauna, a cooling above the boundary would be suggested, in opposition to the actual situation. These contradictory findings are of the same kind and magnitude (Fig. 2) as those of Ericson and Wollin (*1*).

It might be assumed that selective solution of foraminiferal tests could create these opposing trends, in light of the latest information regarding carbonate solution and the lysocline position (*10, 13*). As shown in Fig. 2, however, the frequency of *Globigerinoides ruber* (d'Orbigny), a temperate to tropical species highly susceptible to solution (*10*), does not decrease below the boundary.

In conclusion, correlation attempts based solely upon the *G. menardii* complex in cores from different water masses, especially those of marginal tropical areas, are of questionable value. This fact, in addition to previous reports showing correlation between Quaternary cores of the Atlantic and the Pacific oceans, indicates that the Pleistocene climatic history of the two oceans was not opposed but parallel.

RONALD W. MORIN
FRITZ THEYER
EDITH VINCENT

Department of Geological Sciences, University of Southern California, Los Angeles 90007

References and Notes

1. D. B. Ericson and G. Wollin, *Science* **167**, 1483 (1970).
2. ———, *ibid.* **162**, 1227 (1968).
3. A. Blackman and B. L. K. Somayajulu, *ibid.* **154**, 886 (1966).
4. O. L. Bandy, *J. Paleontol.* **34**, 671 (1960); ———, *Progr. Oceanogr.* **4**, 27 (1967); A. Kheradpir, *Micropaleontology* **16**, 102 (1970); J. R. Duncan, G. A. Fowler, L. D. Kulm, *Geol. Soc. Amer. Bull.*, in press.
5. J. P. Kennett, *Antarct. J. U.S.* **4**, 178 (1969).
6. C. W. Thomas, *Pac. Sci.* **23**, 473 (1969).
7. R. W. Morin, *Amer. Ass. Petrol. Geol. Bull.* **54**, 559 (1970).
8. D. B. Ericson and G. Wollin, *Micropaleontology* **2**, 257 (1956).
9. A. W. H. Bé, *Antarctic Map Folio Series* (American Geographical Society, New York, 1969), folio 11, p. 9.
10. F. L. Parker and W. Berger, *Deep-Sea Res.*, in press.
11. E. Boltovskoy, *Secretar. Mar. Serv. Hidrol. Nav.* **H639**, 1 (1964); W. Schott, *Deut. Atlantische Exped. "Meteor"* **3**, 43 (1935).
12. E. Vincent, *Amer. Ass. Petrol. Geol. Bull.* **54**, 558 (1970).
13. W. Berger, *Deep-Sea Res.* **15**, 31 (1968).
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X-ray Survey of Centaurus A

Abstract. *An x-ray survey of Centaurus A has given marginal evidence of its x-ray flux. If taken as an upper limit on inverse Compton x-rays generated by scattering interactions between relativistic electrons and cosmological background photons, the observation implies an upper limit of close to 3°K for the background radiation temperature.*

Centaurus A, at a distance of about 4 megaparsecs, is the nearest of the powerful radio galaxies. It is also one of the most extended radio nebulas, and this feature, combined with its nearness, gives it a large extent in the sky. Radio astronomers have been able to resolve its structure in some detail, both for intensity distribution and polarization. The radio galaxy consists of two double sources: an extended pair separated by a distance of 240 kiloparsecs and covering a spread of at least 600 kiloparsecs, and a pair of components whose projections fit within the dimensions of the optical galaxy. Both halves of the extended source are nearly symmetrical, although the northern lobe has a slightly higher peak intensity. Figure 1 shows the contour pattern of radio intensity with the contribution of the central source removed. Over most of the extended source, the polarization pattern is fairly uniform and there is no significant evidence of complex irregularities in the magnetic field.

Shklovsky (*1*) has pointed out that an x-ray survey of Centaurus A could be made with sufficient resolution to permit one to identify emission from the extended source as distinct from that of the central region. The angular separation of peak emission centers in the extended double source is about 3 degrees, so that the respective contributions of the north and south lobes could, in principle, be separated from that of the central source with 1-degree collimation of the x-ray receptor. Shklovsky emphasized that any observable x-ray emission from the extended source would need to be produced by inverse Compton scattering of the 3°K background radiation. A measurement of the Compton x-ray flux could place significant limits on the microwave background radiation, the ratio of relativistic electrons to protons, and the strength of the magnetic field in the radio plasma.

In April 1968, we flew an Aerobee rocket carrying two proportional counters equipped with a 1 degree by 8 degree field of view. Each counter had a thin film Mylar window, ⅛ mil in thickness, and was sensitive to x-rays from about ¼ to 10 kev. The rocket was stabilized and programmed to scan the radio source slowly from north to south. To determine the direction of view, a series of star field photographs was made during the progress of the scan. Unfortunately, certain mechanical malfunctions of the protective door system marred the performance of the aspect camera and of one of the counters. Reliable aspect data were obtained only after 172 seconds from the time of launch. The track of the scan is indicated on Fig. 1 as determined by successive star field photographs at 5-