Reports

Late Pleistocene Paleotemperatures at Tongue of the Ocean, Bahamas

Abstract. *Estimates of paleotemperatures, based upon paleoecological analysis of planktonic foraminiferal thanatocoenoses of three piston cores from Tongue of the Ocean, Bahamas, indicate a maximum mean variation between Late Pleistocene glacial and nonglacial stages of 3.6°C. The data also indicate that the Early Wisconsin glacial stage was 0.7°C warmer than the Late Wisconsin glacial stage.*

Oxygen isotope geochemistry has been used extensively to estimate Pleistocene paleotemperatures in surface ocean water (*1, 2*). Emiliani (*1*) has indicated a maximum temperature variation between glacial and nonglacial stages of 5° to 6°C in the equatorial Atlantic and Caribbean. Shackleton (*3*) and Dansgaard and Tauber (*4*) have presented evidence that the maximum temperature variation in this region was only 2°C. The difference in these paleotemperature estimates arises from the fact that Emiliani (*1*) considers that the glacial-nonglacial variation in ocean isotopic composition amounts to 0.5 per mil, whereas Shackleton (*3*) and Dansgaard and Tauber (*4*) base their estimates upon a change of 1.2 to 1.6 per mil. Our independent estimate of Pleistocene near-surface paleotemperatures, based upon paleoecological analysis of planktonic foraminiferal thanatocoenoses of three piston cores from Tongue of the Ocean, Bahamas (core 6274: 24°51.3′N, 77°44.0′W; core 6275: 24°40.0′N, 77°33.0′W; core 6278: 24°00.0′N, 77°21.0′W), indicated a maximum mean variation between glacial and nonglacial stages of 3.6°C.

A method has been presented by which a reasonably precise estimate of temperature may be obtained for the upper 150 m of the water column (*5*). First, the structure of the planktonic foraminiferal population must be calculated for each thanatocoenose. Then an estimate of the paleotemperature of each thanatocoenose may be obtained from the formula

$$T = \frac{\Sigma p_i e_i}{\Sigma p_i} \quad (1)$$

where p_i represents the percentages of individual species whose depth optima occur in the upper 150 m and e_i represents the optimum temperature of that species. The optimum depths and temperatures for the species of planktonic foraminifera living in the Bahamian region have been determined (*5*).

Cores were sampled at 10-cm intervals, and the planktonic foraminiferal thanatocoenoses were identified (*6*). These data were then used to determine the Late Pleistocene chronology and paleoclimatology by means of standard micropaleontologic techniques (*6*). The Late Pleistocene chronology of core 6275 was verified by radiocarbon dating (*6*). All three cores were divided into postglacial, late glacial, interstadial, early glacial, and interglacial intervals, probably corresponding to the Z, Y, X, W, and V stages, respectively, of Ericson and his co-workers (*7*). We calculated the paleotemperature of each thanatocoenose by using Eq. 1 and data on the planktonic foraminiferal environment (*5, 8*). In Table 1 the paleotemperature data for each core are summarized.

Table 1. Univariate statistical characterization of paleotemperatures (in degrees Celsius) of glacial and nonglacial stages recorded in cores 6274, 6275, and 6278 from Tongue of the Ocean, Bahamas.

Core	No. of samples	Mean temperature ± standard deviation	Observed temperature range
		Postglacial	
6274	8	25.7 ± 0.3	25.3–26.2
6275	10	24.8 ± 0.2	24.6–25.1
6278	17	24.8 ± 0.5	23.9–25.8
		Late glacial	
6274	5	23.6 ± 1.3	22.4–25.4
6275	6	24.0 ± 0.3	23.3–24.2
6278	7	22.4 ± 0.7	21.7–23.5
		Interstadial	
6274	9	25.1 ± 0.6	24.1–25.6
6275	4	24.8 ± 0.3	24.5–25.1
6278	12	24.7 ± 0.4	23.8–25.1
		Early glacial	
6274	2	24.3 ± 0.1	24.2–24.3
6275	3	24.3 ± 0.6	23.6–24.7
6278	2	23.4 ± 0.0	23.4
		Interglacial	
6274	42	25.5 ± 0.6	24.2–26.6
6275	43	25.1 ± 0.4	24.2–25.8
6278	58	24.8 ± 0.4	23.9–25.7

Thanatocoenoses reflect both geologic and biologic factors. The main geologic processes that might have influenced planktonic foraminiferal thanatocoenoses at Tongue of the Ocean could have been the test solution (*9*) and vertical mixing (*10*). The planktonic foraminifera were excellently preserved, with the exception of most specimens of the extremely fragile species *Hastigerina pelagica* (d'Orbigny), and we do not believe that solution has introduced any serious bias into the data for the thanatocoenoses. Tongue of the Ocean is a region of relatively high sedimentation rates (*6, 11*), and this should significantly reduce the effect of vertical mixing. We therefore believe that thanatocoenoses from Tongue of the Ocean constitute a fairly accurate record of planktonic foraminiferal biocoenoses.

Planktonic foraminiferal biocoenoses respond not only to temperature but also to other ecologic factors, both abiotic and biotic. Salinity analyses of thanatocoenoses from Tongue of the Ocean indicated a variation of less than a tenth of a part per thousand (*8*). It was difficult to ascertain the importance of the other ecologic factors. The difference in estimated temperature from one core to the other for any given correlative interval probably reflects responses to these unmeasured ecological factors (*12*).

Because the importance of these unmeasured ecological factors is not known, we believe that it is best to interpret the estimated paleotemperatures in terms of relative variation from one stage to another. Table 1 indicates a maximum variation between glacial and nonglacial stages of 4.2°, 2.5°, and 4.1°C for cores 6274, 6275, and 6278, respectively. This represents a maximum mean variation of 3.6°C between glacial and nonglacial events at Tongue of the Ocean, which is in good agreement with the 3° to 4°C variation that Imbrie and Broecker (*13*) obtained from the analysis of piston cores from the equatorial Atlantic. Emiliani [table 1 in (*14*)] reviewed the micropaleontological evidence for glacial-interglacial temperature variation in low latitudes. Temperature variations based upon planktonic foraminifera indicated amplitudes of 4° to 5°C for the equatorial Atlantic. Emiliani's estimates of temperature from planktonic foraminiferal data were based on the frequency of selected species, whereas our estimate was based upon all species having a depth preference within the upper 150 m of the water column. A selective use of a few species could be responsible for shifts in the amplitude of temperature variation between glacial and nonglacial stages. Inspection of Table 1 also indicates that the early glacial stage had a mean temperature 0.7°C warmer than the late glacial stage. This reflects the sawtooth pattern of the glacial cycle indicated by Broecker and Van Donk (*2*).

Most paleotemperature studies have been carried out on piston cores from areas with relatively low sedimentation rates in an attempt to obtain as complete a Pleistocene record as possible. Our study and that of Imbrie and Broecker (*13*) indicate that investigation of regions with relatively high rates of sedimentation gives a more detailed history of the Late Pleistocene. Our results and those presented by Imbrie and Broecker (*13*) indicate a maximum variation between glacial and nonglacial stages of 3° to 4°C for the western equatorial Atlantic Ocean during the Late Pleistocene. This value is intermediate between the 5° to 6°C value of Emiliani (*1*) and the 2°C value of Shackleton (*3*) and Dansgaard and Tauber (*4*). It would therefore appear that variation in the ocean isotopic composition between Late Pleistocene glacial and nonglacial stages was more than 0.5 but less than 1.2 to 1.6 per mil.

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References and Notes

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15. Research partially supported by NSF grants GA-1258 and GA-1664. Collection of the piston cores by Duke University's R.V. *Eastward* was supported by NSF grant GB-0869. We thank O. H. Pilkey and R. D. Perkins for reading the manuscript.

15 October 1970

Fossil Penguin from the Late Cenozoic of South Africa

Abstract. Spheniscus predemersus, *new species, from the late Pliocene of Langebaanweg, Cape Province, is the first fossil penguin to be described from Africa. It is closely related and possibly ancestral to the living species,* Spheniscus demersus, *of southern and southwestern Africa.*

Penguins now occur on all continents and many islands south of the equator. Fossils ranging from late Eocene to Pleistocene in age have been found at various localities in southern Australia, New Zealand, and Argentina, and on Seymour Island, north of the Antarctic Circle off the northeast end of the Antarctic Peninsula. Although Recent penguins are numerous along the coasts of southern and southwestern Africa, no fossil penguins have previously been reported from that continent. Several late Cenozoic specimens have now been found in excavations carried out for the South African Museum near Langebaanweg in southwestern Cape Province, and these have kindly been submitted to me for study by Q. B. Hendey. Details as to locality, horizon, and dating have been given by Hendey (*1, 2*).

The specimens, all in the South African Museum, Cape Town, are as follows:

L6510. Left humerus complete except small portion, probably less than 1 mm, of extreme distal tip. From "E" quarry (*1*), horizon uncertain but probably horizon 1.

L12887A. Left humerus lacking proximal end. From "E" quarry, horizon 1.

———. Right humerus, shaft, lacking both ends. From site 1/1968, "E" quarry, horizon 3 or 4.

L6507. Right tibiotarsus, approximately proximal half. From "E" quarry, horizon unknown but probably horizon 1.

L3656. Left femur, from "E" quarry, horizon uncertain but probably horizon 1.

L13154. Right femur. From "E" quarry, horizon 1.

———. Proximal pedal phalanx, from "E" quarry, horizon 3 or 4.

The fossils from "E" quarry were at first (*1*) considered early middle or, at oldest, perhaps early Pleistocene in age, but later study (*2*) indicates that horizons 1 and 2 are Pliocene and horizons 3 and 4 are Pleistocene. The fossils from the latter horizons may have been derived from the older levels, and the

Table 1. Measurements, in millimeters, of femora of *Spheniscus* sp. from Langebaanweg.

Specimen	Length	Width: Proximal	Width: Medial	Width: Distal
L3656	84.7	19.5	8.6	16.8
L13154	80.1	19.3	7.7	16.6

Fig. 1. *Spheniscus predemersus*, new species, holotype, South African Museum specimen L6510. This specimen is the left humerus shown in ventral view at natural size.