Reports

On Pleistocene Surface Temperatures of the North Atlantic and Arctic Oceans

Abstract. Two additional interpretations are given for the important data of D. B. Ericson on the correlation of coiling directions of *Globigerina pachyderma* in late Pleistocene North Atlantic sediments with ocean surface temperatures. One interpretation relates the distribution of this species to the distribution and circulation of ocean water masses. On the basis of our ice-age theory, our second interpretation uses the data and correlations of Ericson to establish temperature limits of a thermal node, a line on which glacial and interglacial temperatures were equal, for the North Atlantic Ocean. This line crosses the strait between Greenland and Scandinavia. Further, Ericson's interpretation of the 7.2°C isotherm implies that the glacial-stage surface waters of the Arctic Ocean were between 0° and 3.5°C.

In a recent paper, Ericson (*1*) has supplied paleontological evidence from which he draws certain quantitative conclusions about surface temperatures in the North Atlantic and Arctic oceans during late Pleistocene time. He shows that the present 7.2°C April isotherm (taken from the 45°F isotherm), which follows the northern boundary of the Gulf Stream to Iceland and then swings eastward to the Faroe Islands, separates the occurrence of sinistral and dextral *Globigerina pachyderma* found in the upper sediments of cores. The former lie to the north and the latter to the south of this boundary. Previous positions of this boundary have been traced by the study of coiling ratios from lower samples of the cores. Ericson reports that "during late Pleistocene time the boundary between the provinces of right and left coiling was never much farther north than it is now, but at other times it was a good deal farther south."

Ericson states that his conclusions (that is, that the temperature was lower in late Pleistocene time than at present in a zone "extending a good deal farther south" of the 7.2°C April isotherm, and not as warm as 7.2°C in the Arctic Basin and the Norwegian and Greenland seas) appear to be strongly supported by both the horizontal and vertical distributions of all observed species of *Globorotalia*, which have proved to be very reliable temperature indicators (*2*).

With our present state of knowledge regarding the living habits of foraminifera and the circulation of water masses and hydrography of the ocean, two additional interpretations of Ericson's data and conclusions seem possible.

1) It should be noted that Ericson's faunal boundary and the 7.2°C isotherm both follow the northern margin of the Gulf Stream and North Atlantic Drift where strong convergence and very steep temperature gradients exist. Certainly the isotherms here are so closely spaced as to be indistinguishable on the basis of sedimentary faunal content. This is probably also true between Iceland and the Shetland Islands, where the isotherm divergence shown on existing Hydrographic Office charts is no longer to be regarded as accurate. Ericson's selection of only the April isotherm positions seems open to question, despite the apparently fortuitous fit. It may well be that each variant of *Globigerina pachyderma* is associated with a particular water mass rather than with a critical range of surface temperatures.

This implies that Ericson's data show the way to map former positions of a major ocean current. Core material is available for testing this possibility on the antarctic convergence in the Scotia Sea, and perhaps a similar procedure can be used in the charting of paleopositions of many of the major ocean currents.

2) However, if Ericson's correlations are correct, then important quantitative deductions pertinent to our theory of ice ages (*3*) can be drawn from his work. It is fundamental to this theory that during a glacial stage there is an increased interchange of water between the Arctic and the North Atlantic which warms the former and cools the latter. In fact, the abruptness of the temperature rise in the Atlantic at the end of Wisconsin time, as recorded in sediments, was the starting point for this theory.

It is an obvious consequence of our theory that there must be a thermal node separating the Arctic region, which became warmer, from the North Atlantic region, which became cooler during the glacial stage. It seemed highly probable to us that this temperature node would be in the strait connecting the two major basins. If Ericson's interpretation is assumed to be correct, then the present 7.2°C April isotherm clearly establishes the southern limit of this node. The northern limit must of course lie to the south of the pack ice. It seems quite significant that this nodal region approximates the strait that we regarded to be so critical in the interchange of Atlantic with Arctic waters.

Until some organism or other method is found that will permit a narrowing of the nodal limits based on Ericson's data, it is suggested that the node be located at the central position corresponding to the 3.5°C isotherm, roughly between the pack ice and Ericson's faunal boundary, as shown in his Fig. 1. On the basis of this, it can be concluded from our theory that the Arctic surface waters during a glacial stage were between 0° and 3.5°C.

Although it is quite difficult to prove the association of the variants of *Globigerina pachyderma* with particular water masses at present, owing to the complicated structure of the Gulf Stream and the North Atlantic Drift, it seems that our second interpretation, while quite consistent with our ice-age theory, is nevertheless founded on some questionable correlations. We therefore cannot consider the problem as settled, but there seems to be no justification for Ericson's conclusion that Pleistocene refrigeration was the result of a reduction on total radiation from the sun and not a consequence of some purely terrestrial cause (*4*).

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References

1. D. B. Ericson, *Science* **130**, 219 (1959).
2. ———, G. Wollin, J. Wollin, *Deep-Sea Research* **2**, 152 (1954).
3. M. Ewing and W. L. Donn, *Science* **123**, 1061 (1956); *ibid.* **127**, 1159 (1958).
4. This paper is contribution No. 392 of the Lamont Geological Observatory.

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Type manuscripts double-spaced and submit one ribbon copy and one carbon copy.

Limit the report proper to the equivalent of 1200 words. This space includes that occupied by illustrative material as well as by the references and notes.

Limit illustrative material to *one* 2-column figure (that is, a figure whose width equals two columns of text) or to *one* 2-column table or to *two* 1-column illustrations, which may consist of two figures or two tables or one of each.

For further details see "Suggestions to Contributors" [*Science* **125**, 16 (1957)].