

LETTERS TO THE EDITOR

**Comment on "Ice Ages and the Thermal Equilibrium
of the Earth, II," by D. P. Adam ***

The purpose of this comment is to note an inadvertent but unfortunate lack of referencing by Adam (1975) to prior ideas identical to some expressed in his interesting paper.

(1) On the subject of deglaciation Adam notes: "The final disappearance of low-latitude continental ice sheets occurs when the oceans cool to the point that they cannot supply enough snow to maintain the glaciers."

(2) After stating the fundamental proposition, Adam recognizes the need for a time lag between melting of ice and rewarming of the seas otherwise complete deglaciation would not occur: "When this occurs, there is a long time lag while the ice sheets melt away. During this time, the oceans warm, and an obvious question is why the warming oceans during the early part of an interglacial do not initiate a resurgence of ice growth before the ice sheets disappear entirely."

(3) Then, evidence of a time lag is given: "the post-glacial warming of the North Atlantic was not an instantaneous event. Ruddiman and McIntyre (1973) have demonstrated that the retreat of polar waters from the North Atlantic was time-transgressive and lasted from about 13,500 BP to at least 6500 BP."

In our "Theory of Ice Ages III," Ewing and I (Donn and Ewing, 1966) recognized that it seems theoretically

easier to explain the initiation than the termination of glaciation in view of the vast cooling effect of a large continental ice sheet. Our statements follow:

(1) We explain the cause of glacial retreat by a cooling of the North Atlantic Ocean as: "The cause of glacial retreat appears to be a more subtle combination of factors than the cause of glacial growth. The explanation may well lie in the pronounced temperature decrease of the surface waters of the North Atlantic Ocean. . . . A reasonable estimate for the resulting temperature of these waters would be 10°C below the present mean (about 15°C). This amount of cooling would have lowered the vapor pressure by about 50 percent, and this, in turn, would have resulted in a great decrease in the rate of nourishment of the ice sheet."

(2) Then, we note the need for a lag in warming of the sea surface: "For glacial retreat to be total, it is necessary for a significant lag to occur between the warming of the ocean and the beginning of retreat."

(3) Finally, we document the existence of the lag: "Such a lag appears to have occurred at the end of the Wisconsin (Wurm) stage. There seems to be general agreement among European and American geologists that maximum glacial advance occurred about 18,000 to 20,000 years ago (see for example Farrand, 1965) and that it was followed by a retreat stage with minor or local readvances. Although the evidence is far from complete, glacial retreat on land is also indicated by the rise in sea level

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which began, according to the summary and interpretation of Farrand (1965), about 19,000 years ago and reached approximately the present level 6000 years ago. . . . Paleotemperature analysis of deep-sea cores, based on the principle of the O^{18}/O^{16} ratio, as formulated by Urey (1947) and developed by others (e.g., Urey *et al.*, 1951) shows that Atlantic surface temperatures declined almost continuously until about 13,000 years ago (e.g., Emiliani, 1955). Broecker and his associates (1960) also concluded, from a study of climate chronology, that ocean surface temperature rose sharply after 15,000, and probably close to 12,000 years ago. Although the core data indicate a very rapid initial rise of temperature, the curves for temperature relative to time (e.g., Rosholt *et al.*, 1961) show that the rise to interglacial temperature levels was not completed until about 2000 to 3000 years ago."

Elsewhere in his paper, Adam stresses the very great importance of snow albedo as a most important term in the positive feedback of a glacial cooling regime, giving the impression that this too is an original idea. But every theorist on glaciation beginning at least with Brooks (1949) has given detailed attention to the subject of snow albedo.

This letter is simply to establish priority of ideas and publication and not to criticize. Understandably, many of us gain familiarity with ideas from years of personal involvement with the literature of a subject and later assume that others are equally knowledgeable of our sources.

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Reply to Comment by William L. Donn

It is difficult to come up with a new idea regarding ice ages any more, and there are only two concepts in my paper which I still believe, perhaps mistakenly, that I originated myself. One is that a surface meltwater layer (which has been discussed before by others) can act to regulate the amount of energy available for evaporation from the oceans. The other is the treatment of the entire problem of ice ages as being primarily an energy problem. Again, many authors have touched upon this before, especially Flohn (e.g., 1974), but I know of no one else who has used this approach as the foundation for work on ice ages.

The ideas cited by Donn are not new. Grunsky (1927) was wrong about nearly everything, but he clearly understood that declining sea surface temperatures would inhibit glaciation. Lewis (1946, p. 46) was even more explicit, noting that "The reason for the cessation of the whole process [glaciation] must be that eventually the great loss of energy, due to the albedo effect, causes a general lowering of temperature that ultimately reaches the surface waters of the tropics. . . . Because of the great change in rate of evaporation with temperature, presumably these surface temperatures would need to be lowered only 1° or 2°C in order to produce sufficient diminution in evaporation to bring the whole glacial epoch gradually to a close."

I did not wish to claim originality for this idea in my paper, but rather to emphasize why it is important: The supply of energy is limited, and declining ocean surface temperatures make less and less of this energy available for evaporation because of increases in the Bowen ratio.

The idea that glacial albedo affects the amount of energy absorbed from the sun has been around for at least a century and is cited by Croll (1875, p. 60).

I greatly admire the famous papers by Ewing and Donn, and they have been fundamental in stimulating my own thoughts on the subject of ice ages. In not citing them I wished to avoid disagreeing with them about their central theme, the freezing and thawing of the Arctic Ocean. Whether or not the Arctic Ocean repeatedly froze and thawed during the Pleistocene is not of particular importance to my model, so I chose to avoid introducing the subject at all. My debt to Ewing and Donn is expressed indirectly through the titles of my papers, which are numbered in direct imitation of their own series.

To Dr. Donn, Dr. Lewis, Dr. Grunsky, Dr. Croll, and to all others whom I have similarly neglected to cite, I offer my apologies. No slight was intended.

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