Meetings

When Will the Present Interglacial End?

A group of scientists interested in Quaternary research gathered recently to review the possibility that their data concerning climates of the past might be valuable for long-term global climatic forecasting. They met at a working conference entitled "The Present Interglacial, How and When Will it End?" held at Brown University, Providence, Rhode Island, on 26 and 27 January 1972 (*1*). The discussion was divided into five sections: (i) environmental changes in the historical period (independent of man), (ii) the pattern of change within the last 10,000 years, (iii) the last interglacial and its end, (iv) comparison of the last interglacial with the present warm interval and projection of future change, and (v) consideration of the causes of global climatic change.

The present global cooling, which reversed the warm trend of the 1940's, is still under way. Even though man-made pollution may have contributed to the observed fluctuations, the bulk of the change is probably of natural origin (Mitchell). The present cooling is especially demonstrable in certain key regions in arctic and subarctic latitudes. Thus, snowbanks today cover areas of Baffin Island that were seasonally free of snow for the 30 or 40 years preceding the present summer cooling (Andrews, Barry, Bradley, Miller, and Williams); pack ice around Iceland is once again becoming a serious hindrance to navigation (*2*); and warmth-loving animals, such as armadillos, which expanded northward into the American Midwest in the first half of the century, are now retreating southward (Schultz).

Periods of cooling more severe than the present one are known to have occurred in the past 5000 years. They are recognized not only in deep-sea sediments (Burckle and others) but also in advances of mountain glaciers (Denton and Karlen). The climatic shifts recorded in pollen-rich lake beds in northern mid-latitudes or in the sequences of stream alluviation and downcutting are closely related in time to the social disorders that ended or severely castigated flourishing civilizations in Egypt, Mesopotamia, and the Indus Valley about 4000 years ago and the lowland Mayas in A.D. 770. This suggests that former human civilizations may have been severely affected by (*3*) "failure in the rain supply, without which neither man, nor beast, nor growing vegetation can survive" (*4*). It is hard to envision how our modern economy and social structure would react to widespread droughts several decades long, should they occur in the near future.

On the geologic time scale, the general warmth and basic bipartite pattern of the last 10,000 years of the earth's history (the elapsed part of the Holocene), which are characteristic of interglacials, were underlined by several workers (Fairbridge, Wright, and others). It has long been recognized that the climatic optimum passed 6000 to 7000 years ago and was succeeded by slow, oscillatory cooling, interrupted by milder episodes like the one in the 10th and 11th centuries (Burckle, Fairbridge). In some places, the present fauna and flora can be compared to those of the early portion of the Holocene (Absolon, Wright). The warmth-loving species of the climatic optimum have migrated south (Lozek).

One conclusion reached at the session was that there is no qualitative difference between the climatic fluctuations in the 20th century and the climatic oscillations that occurred before the industrial era. The present climatic trends appear to have entirely natural causes, and no firm evidence supports the opposite view.

The next group of contributions dealt with the structure of the last interglacial and its end. Participants considered the periodic occurrence of interglacials within the stratigraphic record to be sufficiently well established to warrant comparison with the present interglacial. There are discrepancies concerning the time-stratigraphic boundaries of interglacials (McIntyre, Mörner, Ruddiman, Terasmae), but at least for the purpose of the meeting the interglacial was tacitly defined as one uninterrupted warm interval in which the environment on a global scale reached present or even warmer climatic conditions (*5*).

These discussions focused on two points: the length of interglacials and the environmental change that marked their end. Out of more than 800 determinations of ^{18}O in fossil planktonic foraminifera (the ^{18}O content is a function of the temperature and salinity of the surface waters) covering about the last 0.5 million years, only about 10 percent indicate conditions similar to or warmer than those of today (Emiliani). In lake beds of Germany and England the length of an interglacial was found to be about 10,000 years (Shackleton, Wright). Pollen diagrams of interglacial lake beds so closely parallel the Holocene records in composition and thickness that basically the same duration must be expected for both intervals. However, recent soils in the American West are weaker than those believed to be of the last interglacial age (Morrison, Richmond), an occurrence consistent with views that the last interglacial was somewhat warmer and wetter than the Holocene (Fairbridge, Lozek).

Sea level is related inversely to the volume of continental glaciers. Thus, information concerning the duration of an interglacial high stand of the sea can be directly correlated with the ice volume of continental glaciers. On Barbados, sedimentological considerations suggest that the high stand associated with the last interglacial (terrace III, 124,000 years ago) lasted no longer than about 5,000 years. Further, preliminary evidence suggests that the interglacial high stand was immediately followed by a drop in sea level of more tens of meters within 10,000 to 15,000 years (Matthews). For this same time interval, data from deep-sea cores show that the cold subarctic waters of the North Atlantic extended to latitudes about 15 degrees south of where they are today, or roughly two-thirds of their maximum full glacial southward displacement in the late Wisconsin (McIntyre, Ruddiman). Summer temperatures at the sea surface dropped by 7°C at 50°N latitude in the Atlantic (Imbrie). During this same time interval, fine sand and dust were blown from Africa into the central Atlantic, which indicates a time of considerable disruption of the vegetation cover on the continent (Hays).

Some data indicate how rapid the cooling could have been near the end of an interglacial. In the Greenland ice core (Camp Century) a spectacular drop in ^{18}O values appears to have occurred within a time interval only about 100 years long. The event is considered to have happened around 90,000 years ago. A similar event could have happened 20,000 years earlier, but a critical segment of ice core is missing (Clausen, Dansgaard, Johnsen, Langway). A rapid cooling event is also indicated at about 90,000 years ago by the temporary complete disappearance of the warmth-loving *Globorotalia menardii* group from the southern Gulf of Mexico, an event completed within less than 500 years (Kennett). In the vicinity of Prague and Brno in Czechoslovakia, where mixed broadleaf forests flourished in past interglacials as they do today, the end of an interglacial is marked by the replacement of forests with grassland. Eolian dust of distant origin then buried the vegetation, and torrential rains turned the countryside into badlands. Woolly rhinoceros and the land snail *Puppilla loessica*, cold-resistant species of Pleistocene fauna, lived there at this time, about 110,000 years ago. The date is supported by a magnetic event interpreted as Blake (Kukla, Koci). At Tenaghi Phillipon in Greece, the interglacial forest was succeeded by grassland within a few centuries (*6*), and in the Netherlands and Denmark subarctic tundra with heath and birch replaced the temperate forests (*7*).

When comparing the present with previous interglacials, several investigators showed that the present interglacial is in its final phase (Emiliani, Imbrie, Lozek, Mörner, Wright) and that if nature were allowed to run its course unaltered by man, events similar to those which ended the last interglacial should be expected to occur perhaps as soon as the next few centuries.

The possible causes of past climatic changes were discussed in the last section. The ice-age preconditioning of the present globe (Fairbridge), the instability of atmospheric and oceanic circulation (Broecker, Flohn, Hendy, MacCracken, Mitchell, Shaw, Van Donk, Weyl), and the possibility of rapid antarctic ice "surges" (Hollin) were stressed. Theoretical considerations and some empirical data suggest that climatic change is closely related to the earth's precessional torques and thereby to the earth's magnetic field, episodic volcanism, and so forth, and to elements of the earth's orbit (Emiliani, Kukla, Stuiver). It was speculated that the astronomical motions of the earth may have led to stresses within the lithosphere with a maximum every 40,000 years. Enhanced volcanism, tectonic activity, and changes in magnetic parameters would be expected to follow this periodicity, contributing to glaciations and speeding evolution (Emiliani). Artificial heating, and production of dust and CO_2 by man's activities were shown to have diverging effects on global temperatures (Mitchell, Schneider), at present subordinate to natural processes. However, with continuing human input these effects might eventually trigger or speed climatic change. The general conclusion of this section of the conference was that knowledge necessary for understanding the mechanism of climatic change is lamentably inadequate, and that the ultimate causes remain unknown.

At the end of the working conference, the majority of the participants agreed to the following points:

The global environments of the last several millennia is in sharp contrast with climates that existed during most of the past million years. Warm intervals like the present one have been short-lived and the natural end of our warm epoch is undoubtedly near when considered on a geological time scale. Global cooling and related rapid changes of environment, substantially exceeding the fluctuations experienced by man in historical times, must be expected within the next few millennia or even centuries. In man's quest to utilize global resources, and to produce an adequate supply of food, global climatic change constitutes a first order environmental hazard which must be thoroughly understood well in advance of the first global indications of deteriorating climate. Interdisciplinary attacks on these problems must be internationally organized and encouraged to develop at a rate substantially exceeding the present pace.

In the view of the majority of participants, further investigation is especially needed in the following fields: (i) detailed reconstruction of the history of intervals of rapid environmental change, especially of the termination of the last interglacial, as well as those periods of cold or dry "events," or both, in historical times; (ii) periodicity in climatic change on all time scales; (iii) records of past climatic change contained in stratigraphic sequences of the deep-sea sediments, of continental basins in loess areas, in ice sheets, and in mountain glaciers; (iv) computer modeling of past climatic systems based on boundary conditions prescribed by the stratigraphic data; and (v) the possible interrelationships between solar radiation, solar magnetics, earth magnetics, episodic volcanism, and global climatic change.

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References and Notes

1. Participants present at the working conference were R. G. Barry (Institute of Alpine and Arctic Research, University of Colorado, Boulder); L. H. Burckle, J. D. Hays, C. Hendy, and A. McIntyre (Lamont-Doherty Geological Observatory, Palisades, New York); G. Denton and J. Hollin (University of Maine, Orono); C. Emiliani (Institute of Marine Sciences, Miami, Florida); R. W. Fairbridge (Columbia University, New York); J. Imbrie and R. K. Matthews (Brown University, Providence, Rhode Island); W. Karlen (University of Stockholm, Stockholm, Sweden); J. P. Kennett and D. W. Shaw (University of Rhode Island, Kingston); G. J. Kukla (Czechoslovakian Academy of Sciences, Prague); J. M. Mitchell, Jr. (Environmental Data Service, National Oceanic and Atmospheric Administration, Silver Spring, Maryland); G. M. Richmond (U.S. Geological Survey, Denver, Colorado); W. Ruddiman (Office of Naval Research, Washington, D.C.); C. B. Schultz (University of Nebraska, Lincoln); N. J. Shackleton (University of Cambridge, Cambridge, England); T. W. Webb III (University of Michigan, Ann Arbor); and P. W. Weyl (State University of New York, Stony Brook).
Participants who sent contributions were A. Absolon, A. Koci, and V. Lozek (Czechoslovakian Academy of Sciences); J. T. Andrews, R. S. Bradley, and G. H. Miller (Institute of Alpine and Arctic Research); W. S. Broecker and J. Van Donk (Lamont-Doherty Geological Observatory); H. B. Clausen, W. Dansgaard, and S. J. Johnsen (University of Copenhagen, Copenhagen, Denmark); H. Flohn (Meteorologisches Institut, Bonn, West Germany); C. C. Langway (U.S. Cold Regions Research Laboratory, Hanover, New Hampshire); M. C. MacCracken (University of California, Livermore); N. A. Mörner (University of Stockholm); R. Morrison (U.S. Geological Survey, Denver); S. H. Schneider (Institute for Space Sciences, National Aeronautics and Space Administration, New York); M. Stuiver (University of Washington, Seattle); J. Terasmae (Brock University, Quebec, Canada); L. D. Williams (University of Colorado, Boulder); H. E. Wright, Jr. (University of Minnesota, Minneapolis).
Papers resulting from this working conference have been accepted for publication in *Quaternary Research*.
2. N. A. Eimarsson, *Hafisinn* (Almenna Bokafelagia, Reykjavik, Iceland, 1969).
3. R. Carpenter, *Discontinuity in Greek Civilization* (Cambridge Univ. Press, Cambridge, England, 1966).
4. See also B. Bell, *Amer. J. Archeol.* **75**, 1 (1971).
5. The cold fluctuations of the historical period are considered to be within the range of present general climates and environments.
6. T. A. Wijmstra, *Acta Botan. Neer.* **18**, 511 (1969).
7. T. Van der Hammen, G. C. Maarleveld, J. C. Vogel, W. H. Zagwijn, *Geol. Mijnb.* **45**, 79 (1967).

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