CHANGES OF CLIMATE DURING THE LATE GEOLOGICAL RECORD

Introductory Remarks

by

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During the some 250 million years that elapsed subsequent to the Permocarboniferous glaciations, planetary climates were surprisingly uniform and pronouncedly non-glacial in character. Lower Tertiary floras have been interpreted as evidence of mesothermal climates polewards of latitude 60°, while tropical and subtropical forests dominated middle latitudes. Although the Eocene isoflors are noticeably zonal in their arrangement, concentric with the modern North Pole, meridional temperature gradients must have been remarkably weak. This situation of complete deglaciation and reduced latitudinal differentiation is the essence of what the late C. E. P. Brooks described as the "normal climate of geological time".

A downward trend of mean temperatures is evidenced during the course of the Tertiary, European averages being lowered by 10° C. during a 20-million-year span since the later Oligocene. Some 2 million years ago according to recent potassium-argon dates, the planet entered the violent pulsations of climate characteristic for the Pleistocene. With higher latitudes sufficiently cool, a very delicate balance of heat exchange permitted frequent thermal aberrations that may have been due to primary lowering of planetary temperature or to the cumulative momentum of changes in latitudinal heat exchange, large-scale circulation patterns, albedo, reduction of ocean water surface in high latitudes, etc. Whatever the cause the resulting physical phenomena were momentous.

Geomorphologists and geologists have spent over a century analysing the full impact of successive glaciations on the world's surface. Biologists of different backgrounds have sought answers to numerous problems in evolution by studying the evidence of migrations and mutations within the spectrum of glacials and interglacials. And the study of early man has likewise turned back into the Villafranchian dark ages of African prehistory to consider gene flow and genetic drift of early populations in a complex of changing ecological niches on that continent.

Palaeoecological and palaeoclimatological research is no longer a matter of speculation and grandiose hypotheses. Each field of investigation has aimed at and partially succeeded in obtaining quantitative rather than qualitative estimates of fossil processes. Bodies of reliable information are slowly building up in the most varied institutions of learning. Techniques undreamt of two decades ago have revolutionized our thinking. One need only recall radio-carbon dating, whereby our notions of time scales in a 70,000-year span have become tangible even if not absolute. Or the recent advances in Pleistocene comprehension thanks to potassium-argon dating, tentative yet amazing. Palaeotemperature measurements of ocean surface waters are now known for a time span of several hundred thousand years. And the biological sciences have taken great strides in elucidating total ecology.

If I may take the liberty I shall outline some of the less spectacular but equally significant directions of specialized study in the field of geomorphology. Field students have realized that cataloguing phenomena or identifying materials without process analysis is unsatisfactory. The study does not merely consist of Pleistocene glaciers and normal fluviatile cycles. A great variety of cold-climate phenomena span most latitudes awaiting careful interpretation against actualistic observations in specific ecological environments. Fluviatile features are dismembered into sedimentary entities, susceptible to laboratory analysis or comparable with carefully observed actual data such as are outlined by Miller and Leopold in a later section. Wind deposits have been employed to reconstruct storm-wind circulation means and former *grosswetter* situations. Fossil pedogenetic processes have been more widely recognized in chronological context and at least qualitatively interpreted. With the revitalization of geomorphology in its climatic aspects, dynamical earth science aspects of the Pleistocene have hope to escape the dead burden of "classical" geological investigation in which the briefest units are measured as a factor of 1.10^6 years.

Perhaps the acceleration of innovation, perfection and application of methods, with resulting accumulation of data, has never been as great as now in the field of palaeoclimatology. An example may suffice, namely the revolutionary progress of solid scientific work in the east, central and south African Quaternary during the past few years.[1] The frustrating discussions of pluvial stratigraphy in equatorial latitudes have been terminated by radio-carbon-dated pollen-analytical studies locating the last major pluvial in the time span corresponding to the Early Würm period. Geomorphological studies have likewise shown the associations of pluvial river deposits with the advance of the central-east African glaciers. Soils work on the other hand has shown the humid-type red soils of the Sudan margins to extend in analogous form from the Equator to the Alps, and to be fossil or relict. The hue-and-cry of some authors for wholesale latitudinal migrations of climatic belts seems unwarranted in the face of ever-new empirical observations.

And here there is much room for climatological and meteorological application. At the moment it seems justified to suspect that first-order climatic changes of the later Pleistocene were changes in degree and not in kind. Intensification or slackening of existing phenomena, moderate frequency shifts of alternative dynamic patterns, these all appear to call for specific consideration and thought. The fundamental question, since probably first suggested by Sir George C. Simpson, is one of planetary radiation balance and thermal exchange. Meteorologists must tackle these problems with the "palaeo" view in mind. Without thought or willingness to communicate on the part of meteorologists, the earth scientist is condemned to interpretative stagnation or heretical deviation. I am confident that it is everyone's wish at this conference that a better and more balanced future lies in wait for interdisciplinary research on changes of climate.

1. See the publications (in press) of the Wenner-Gren symposium "African ecology and primate evolution", Burg Wartenstein, Austria, July 9-22 1961.