CHAPTER XII

PALEOCLIMATOLOGY

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1. *Introduction*

The ultimate goal of paleoclimatology is the complete determination of the variations of climate for all parts of the world and for all portions of the history of our planet, beginning with the time of its formation. Viewed in terms of this goal, present progress in the development of paleoclimatology is most rudimentary. Indeed, paleoclimatology is one of the least developed of all of the sciences of the past, lagging noticeably behind its sister fields of historical geology, paleontology, and paleobotany.

The present discussion will be of the nature of a very short summary of the present position of paleoclimatology as regards its potentialities for useful application in geochronologic problems. It may be emphasized at the start that because of its still poorly developed state, paleoclimatology cannot yet contribute as much to the other historical sciences as they are now contributing to paleoclimatology.

It should be possible, in principle, to determine the climate of a given region at a given time by either of two approaches which may be described as the inductive and the deductive approaches. Each of these will be considered briefly, attention being given to the achievements and to present limitations of each.

2. *The inductive approach*

By assembling scattered facts from such diverse fields as geology, paleontology, paleobotany, and (for more recent times) archaeology, it may be possible to build up so internally consistent a picture of the climate of a given area at some time in the past that very high probability of correctness may be attributed to the results. This *inductive* approach is yielding an extremely interesting description of climatic variations during the past ten or twenty millenia and has indicated, very roughly, the nature of climatic trends characteristic of periods all the way back to Precambrian time. In this approach, the meteorologist and climatologist parasitize the other historical scientists; hence in a collection of papers on geochronologic methodology the meteorologist cannot cite the inductive approach to paleoclimatology as one which offers basic assistance to workers in other fields. However, it is still true that the student of paleoclimatology can serve others by employing no more than this inductive approach, for his correlations of diverse facts indicative of past climatic variations and his separation of the physically

plausible evidence from the quite improbable suggestions as to past climates provides others with a helpful picture of the vicissitudes of the climatic factor in their respective fields of specialization. When the results of an inductive study of past climates are so returned to the workers in the other historical sciences in the form of a reasonably unified and consistent description of the past temperature and precipitation variations of a region, it becomes possible to speak of paleoclimatology as a *tool* in geochronology; parasitism gives way to partial symbiosis.

Only in a few instances is the paleoclimatic record now sufficiently well-established to serve as an approximate dating tool. The several glacial periods of the Pleistocene have long since passed into this category by virtue of abundant confirmation of Agassiz's nineteenth century inductive arguments for the existence of past periods of continental glaciation. Almost equally well established at the present time is the occurrence in post-Wisconsin time of a period of interglacial warmth during which polar sea ice largely disappeared, mountain glaciers either disappeared or shrank to fractions of their present form, and lakes in lower latitudes dried up completely. This warm period extending from about 5000 B.C. to 2500 B.C., known by a confusing variety of names (Climatic Optimum, Altithermal period, Hochwarmzeit, Atlantic period, Long Drought), now serves as a fairly useful time marker which can be used with some confidence by historical scientists to bring order into some parts of their respective records. In both the Pleistocene glaciations and the post-Pleistocene warm period, fine details are lacking, however, so even these constitute only imperfect examples of the potential applications of inductive paleoclimatology to other fields. For most of the paleoclimatic record, the present is still a time in which the climatologist must depend on others to help him reconstruct crude representations of the climatic past.

3. *The deductive approach*

As an alternative to the inductive approach just described, one might hope to *deduce* the record of past climatic changes by drawing upon the conclusions and principles of those of the physical sciences which are involved in meteorological studies. If any such deductive approach were feasible today, the resultant record would indeed be an important tool for the other historical scientists, for its application would not involve the circularity that clearly weakens the inductive approach.

Unfortunately, only the most primitive steps in this direction can be taken in 1955. There does not exist today any body of knowledge upon which to draw deductively for this elegant

type of approach. It is well to examine this point in somewhat more detail.

The climate of each portion of the earth is controlled by numerous factors. The temporal and spatial distribution of solar energy is definitely the most important climatic control. Geographic factors such as land-sea distribution, altitude, and mountain barriers are also of great significance. Finally, as a still little-understood consequence of the interplay of the previously enumerated factors, the "general circulation" of the atmosphere constitutes a feature which may be regarded as the immediate controller of the gross features of climate. By the general circulation of the atmosphere the meteorologist means the large-scale airflow patterns as they are disposed over the entire globe. Whether a given region enjoys moist or dry, warm or cool climate is largely dictated by the prevailing flow of moisture and heat in the general circulation.

Since the geologist is now able to provide a reasonably exact description of past geographies, it follows that the missing links in the deductive approach to paleoclimatology are first, lack of any astrophysical basis for deducing past variations of solar energy output and, second, lack of a satisfactory theory of the general circulation of the atmosphere for relating paleogeography to past climates. Both of these shortcomings deserve further comment.

The very question of whether the sun's energy output varies in a manner that may lead to significant terrestrial climatic fluctuations is not answered satisfactorily. That weak, but real correlations between sunspot activity and certain pressure and temperature variations in the earth's atmosphere do exist is now generally regarded as established. That the total rate of energy output of the sun varies significantly is still debatable. The Smithsonian Institution has reported variations of a few per cent about the mean value of the solar constant, but the reality of these small fluctuations is not universally accepted. No observational evidence exists to indicate unambiguously that solar variations occur with periods of the order of the geologic time scale. For all of these reasons, it may seem premature to look for physical explanations for solar energy variations. However, meteorologists have sought so long for solely terrestrial explanations of climatic fluctuations that many do now feel that there remains no other reasonable hypothesis than solar variation to account for climatic change. Perhaps the leading exponent of this view is Willett who suggests that solar variations in the ultraviolet or even in corpuscular emissions, may be responsible for climatic variation.

With respect to the other major deficiency in a deductive approach to paleoclimatology — lack of anything like a complete theory of the general circulation of the terrestrial atmosphere — it seems safe to suggest that the near future will bring real improvements. When it is considered that only in the past two decades have the principal features of the general circulation been studied systematically on a global, or at least hemispheric, basis, it does not seem unduly optimistic to infer that the next one or two decades should witness substantial progress in understanding the large-scale workings of the atmosphere. It cannot be overemphasized that any real progress in this area is certain to contribute in an important fashion to paleoclimatology, but it must also be admitted that past findings in paleoclimatology may themselves be of very great aid in effecting those improvements in general circulation theory.

The present state of knowledge concerning the dynamics of the general circulation is such as to permit only very general statements to be made concerning the way in which the geography of the geologic past must have controlled the concurrent climate. One such general statement, which deserves to be made because it has not always been recognized by persons who have tried to reconstruct past climatic patterns, is that it is dangerous to attempt to extrapolate longitudinally the climatic characteristics that may be established for one given region. Although the warning against longitudinal extrapolation can be made on the basis of many studies of general circulation anomalies, it is unfortunate that no quantitative statements may be made thereon. Questions of simultaneity of excessively hot or cold periods or of excessively wet or dry periods at two points at the same latitude but at different longitudes are basic to many geochronologic problems, but the meterologist is not yet ready to give straightforward answers to these questions. Indeed, he is looking into paleoclimatology just in the hope that he may discern some illuminating principles concerning synchronism of anomalies. Clearly, the present position of paleoclimatology is best summarized by merely stating that the science is still struggling with the inductive approach.

4. *Future outlook*

There seems reason to believe that the rate of development of paleoclimatology may be increasing. On the one hand, important new dating tools are being developed to provide the paleoclimatologist with increasingly more accurate estimates of the *synchronism* of climatic events taking place in regions geographically remote from each other. Knowledge of the synchronism, or non-synchronism of climatic vagaries is critically important to intelligent selection of physically plausible patterns, and improved dating is certain to be reflected in improved

analysis of all paleoclimatic problems. On the other hand, accelerated progress in paleoclimatic research may reasonably be expected to follow from an intensified interest in the whole subject of climatic fluctuations now that it has become quite definitely established that the past four or five decades have witnessed a climatically phenomenal warming trend in the higher latitudes of the Northern Hemisphere. If for no other reason, the economic and sociological implications of "the present climatic fluctuation," as Ahlmann has termed it, are certain to stimulate new effort to find a rational explanation for climatic change. Also, growing interest in solar physics may lead to fundamental progress in the problem of solar variability which is coming to occupy a key position in current thought in paleoclimatology. For these, and perhaps other reasons, then, it may be expected that paleoclimatology may in the near future assume a more important position as a *tool* (rather than by-product) of geochronology.

BIBLIOGRAPHY

A detailed bibliography of references on paleoclimatology will not be given here. Instead a small number of general references will be cited for the benefit of readers not previously familiar with the subject.

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