PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

General Discussion

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Phil. Trans. R. Soc. Lond. A 1990 **330**, 679-681
doi: 10.1098/rsta.1990.0049

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Printed in Great Britain

General discussion

S. K. Runcorn, F.R.S. (*University of Newcastle upon Tyne, U.K.*). In examining whether there is evidence in the records of the Earth's climate for small variations with periods of about 200 years, the geophysicists suppose that the large fluctuation from year to year (of which we are very conscious) due to the instabilities of the atmosphere–ocean system may average out over long periods so as to reveal shorter-period changes in solar activity. There is an interesting analogy with the Earth's magnetic field, which varies considerably on a shorter timescale, yet over longer time spans the mean field is exactly that of a dipole aligned along the axis of rotation. Can we tell, from the archaeological record, whether climatic changes, resulting for instance in the migration of peoples, are short lived, or whether they might be produced by longer-term environmental changes?

J. D. Evans, F.B.A. (*Institute of Archaeology, London, U.K.*). Archaeologists are not well placed for direct inferring of short-term fluctuations in climate or solar activity. They must depend upon archaeo-biological evidence and physical dating techniques (such as ^{14}C), most of which are not adequately sensitive to reveal 11-year periodicities, though they may sometimes pick up 200-year periodicities.

A. M. Snodgrass, F.B.A. (*Museum of Classical Archaeology, University of Cambridge, U.K.*). At one extreme it could be held that the ending of the last glaciation is the latest climatic event for which it would be reasonable to expect to find broad reflections in the archaeological record. At the other extreme, however, one might start looking for archaeological effects that covered only three or four years, like the one towards the end of the Bronze Age that P. I. Kuniholm hinted (this Symposium). My own view is much closer to the former extreme than the latter; as an archaeologist I am very unhappy about linking up such short-term phenomena with major breaks in historical continuity. As Kuniholm said, it is not merely climatic change, but human perception of it, that has even the potential for affecting historical processes.

E. M. Jope, F.B.A. (*The Queen's University, Belfast, U.K.*). While tree-rings (with their potential sensitivity to fluctuations in both climate and solar activity) are cognisant of single-year increments, there is often much uncertainty in relating the tree-ring sequence of the sample exactly to the archaeological or historical context or 'event'. The same difficulty applies to high-precision ^{14}C dating; however, in very favourable (but rather rare) circumstances it can occasionally be possible to date the building of a timber structure to less than $\pm 1\%$ (Jope 1986). But to date a structure is still not to relate to a climatic episode or solar activity.

Concerning Runcorn's point about relation of migration of peoples to climatic changes, I must stress that multiple factors are at work here: social, economic, epidemic, climatic, catastrophic, volcanic eruption (Pyle 1989). Such parameters (each in itself multivariate) might all be integrated under the concepts of chaos theory: a people approaching the threshold of instability in one parameter alone might be sufficient to disrupt life and lead to migration (a proposition that interested P. Foukal).

J. D. Evans, F.B.A. Many archaeologists have for long been ever more precisely quantifying their evidence. Much fruitful work has been done in recent years in the application of statistical techniques to interpretating archaeological data (e.g. in the study of wear on implements, or the changes down through sediment- or ice-cores), and some of this can have direct bearing on following short-term climatic or solar fluctuations.

A. M. Snodgrass, F.B.A. I strongly endorse Professor Evans's point about quantifying archaeological data. Archaeologists too have a large body of primary data that can be presented graphically in just the ways that scientific findings have been presented at this meeting; and some of us are increasingly presenting our data in such ways. This would then constitute a proper basis for correlating archaeological and scientific data, preferable to searching for one-off matches with unique climatic or historical events.

E. M. Jope, F.B.A. Much of the evidence nowadays produced from archaeologically motivated work is really archaeo-scientific data. It is the archaeological scientists' job to make the fullest possible use of such data, in harness with the more purely archaeological evidence, to intensify our understanding of the human past and the climatic and solar past. Some kinds of evidence are still not adequately used, such as soils, or sediment cores, and especially ice-cores; the latter can be very informative in relation to past human activity and climatic fluctuation, and they are particularly time sensitive (H. Oeschger & J. Beer, this Symposium), and note a recent example in Peru (Thompson *et al.* 1988): 'The ice cores from the Quelccaya ice cap contain a 1500-year record of the climatic variability that affected human activities in Southern Peru'.

G. Barker (*Leicester, U.K.*). It is difficult to fund archaeological work on the scale needed to yield meaningful archaeo-climatic data, especially in relation to Mediterranean lands.

G. Beran (*Wallingford, U.K.*). I'd like to draw attention to the potentially informative nature of hydrological studies, feeling (perhaps justifiably) that the topic had been underplayed at this Discussion Meeting.

Sir George Porter, P.R.S. What possibility is there for forecasting future climatic trends from archaeological or historical data? I ask this because there might be money in it!

E. M. Jope, F.B.A. It might be tried once, but archaeologists' futurology is not likely to be invoked for a second time.

This Panel, which is representative of archaeologists, warmly welcomed this opportunity to recognize Hans Suess's seminal influence on the subject; if he had not in earlier times stood doggedly by the actuality of his 'wiggles', we should not today be in the very favourable position over high-precision tree-ring calibration of the ^{14}C timescale, through more than 10000 years (Pearson & Stuiver 1986).

D. H. Tarling (*Geological Sciences, Polytechnic of the Southwest, Plymouth, U.K.*). It is interesting to note that, some 10 years or more ago, most explanations of the variation in production of ^{14}C in the ionosphere were attributed to variations in geomagnetic properties. For good

reasons, particularly ^{10}Be, moderate and short-term solar fluctuations are now being considered as major factors affecting the short-term discrepancies between the dendrochronological and uncorrected radiocarbon ages, while it is still assumed that long-term (not less than 10^3 year) variations are associated with changes in the intensity of the main dipolar geomagnetic field. However, the truth probably lies somewhere between these extremes. The entire catalogue of ancient geomagnetic field intensity determinations, based on either archaeological or geological fired materials, is insecure (see, for example, Walton 1988) and, in any case, have a very confined distribution and hence relate more to local geomagnetic changes, rather than necessarily global changes. At the moment, the strongest evidence for long-term global geomagnetic field changes is that of the long-term fluctuations in the production of ^{14}C and other causes cannot be excluded. Conversely, it has recently been found that there are clear cyclicities in the modal rate of change in the direction of the geomagnetic field in at least northwestern Europe (U.K. and France) during the past 2000 years or so (Tarling 1988, 1989) based on Clark *et al.* (1988). The most prominent is a periodicity of 266 ± 27 years in the modal rate of solid angular change and this is also reflected in the rate of change relative to the axial geocentric dipole field direction. The relationship between rate of directional change and field intensity is not established and such results are still highly localized. None the less, archaeomagnetic studies do provide the only method of defining such geomagnetic variations during the past few thousand years and are required to establish the relationship to many interacting, little understood processes.

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