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

Climate and Holocene Culture Change: Some Practical Problems

A. C. Renfrew

Phil. Trans. R. Soc. Lond. A 1990 **330**, 657-663
doi: 10.1098/rsta.1990.0046

Phil. Trans. R. Soc. Lond. A **330**, 657–663 (1990)
Printed in Great Britain

Climate and Holocene culture change: some practical problems

By A. C. Renfrew, F.B.A.

Department of Archaeology, University of Cambridge, Downing Street, Cambridge CB2 3DZ, U.K.

In recent years, not least through tree-ring studies for the Holocene and studies of oxygen isotope ratios in Foramenifera in deep-sea cores for the Pleistocene, both linked with radioactive chronometry, useful and well-dated information has become available for global temperature variations. Yet we seem at present little closer to understanding the climatic influences upon human settlement, or upon such major episodes in human existence as the agricultural revolution or the emergence of pastoral economies.

In making reference to the developments in archaeological survey techniques over the past 20 years, and the increasing collaboration with geomorphologists and settlement geographers, I seek to highlight the gap in the chain of argument between data for global climatic parameters and impact on human communities. Where are the phytologists, the ecologists, the crop plant geographers? Where is the necessary focus upon the crucial themes of changing microclimates and changing agricultural productivity for specific species? An attempt is made to define more closely this deficiency.

Archaeology and chronology

Chronology has always been one of the principal preoccupations of archaeology, and it is probably fair to say that the relation between archaeology and geophysics in this area has traditionally been a symbiotic one. For instance that pioneering work by Zeuner, *Dating the past* (Zeuner 1946), naturally drew upon a wide range of geophysical phenomena, most of them climatically dependent, and also relied to some extent upon calculations of solar radiation. But at the same time, he quite frequently found it convenient, especially when dealing with the palaeolithic period (i.e. the Pleistocene) to 'date' geological deposits (in a broad, relative sense) by the precise typological features of the industries of stone tools that some of them contained, which could be assigned a quite well-defined place within the established culture sequence in terms of their shape and of details of manufacture.

Even with the increasing dependence upon radioactive clocks, there are factors (such as the atmospheric concentration on ^{14}C) that are climatically dependent. The archaeological context has on occasion been of significance not only for providing materials of approximately appropriate antiquity (for instance of old wood for tree-ring work), but in a few cases for providing material that can be fairly well dated by historical means. For instance those dating techniques that depend upon variations in the direction and intensity of the Earth's magnetic field have generally needed first to establish what these chronological variations have been before using this information to date sites of uncertain chronology. The initial documentation of that chronological variation has usually relied upon the finding of suitable samples of baked clay in secure contexts which could be dated by traditional archaeological (i.e. historical) means.

It is worth recalling also that Willard Libby's first clear clue that his assumption of secular constancy for the atmospheric concentration of radiocarbon was questionable came from what was essentially an archaeological source: from Ancient Egypt. The first test of the radiocarbon dating method (Libby 1955) had come from a plot of the 'absolute specific radioactivity' of selected 'samples of known age' against their historical age in years. All of these samples were from archaeologically secure contexts in Egypt, dated by the historical chronology for Egypt, ultimately based upon the records of the Ancient Egyptians themselves of the successive reigns (and their duration) of the pharaohs. Later, a fuller plot of radiocarbon determinations for comparable material indicated that something was wrong (Libby 1963):

> This plot of the data suggests that the Egyptian historical dates beyond 4000 years ago may be somewhat too old, perhaps five centuries too old at 5000 years ago, with decrease to 0 at 4000 years ago. In this connection it is noteworthy that the earliest astronomical fix is at 4000 years ago, that all older dates have errors, and that these errors are more or less cumulative with time before 4000 years ago.

The observation was a sound one, but Libby's assumption that the Egyptology rather than the physics was at fault was not. As is known, subsequent research has in general vindicated the Ancient Egyptian historical dates, whereas the variation in the atmospheric concentration of radiocarbon makes necessary the calibration of radiocarbon dates. One of the great triumphs in the field of chronology of recent years has been the establishment of the bristlecone pine dendrochronology by the late Charles Wesley Ferguson, and the pioneering dating programme by Hans Suess, with the production of the first calibration curve, about which we have heard in the course of this conference. It is particularly gratifying that the Irish bog oak dendrochronological sequence and the accompanying radiocarbon dating programme in the Belfast laboratory (see M. G. L. Baillie, this Symposium), has served to corroborate and confirm this work, so that for the Holocene period radiocarbon dating, appropriately calibrated, is the principal dating technique available to the archaeologist.

The impact of this technique in archaeology has of course been immense. The most striking consequence is undoubtedly the emergence of a 'world archaeology', where the culture sequence of each continent can be dated without any need for a pre-existing historical chronology. In a sense the prehistory of Australia, for instance, continued to the eighteenth century A.D., but the arrival of the first humans there, at least 40000 years ago, and subsequent activity there can be approached with the same confidence as in Europe or Western Asia.

A further major consequence of the 'second radiocarbon revolution', if we may so term the impact of the calibration of the radiocarbon timescale, has been the revision of many of our ideas about cultural relations between Europe and the Near East. To choose one example, where our French colleagues have been particularly active, the megalithic monuments of Western Europe were once thought to derive from Mediterranean ancestors in the earlier third millennium B.C., and thus themselves to begin around 2300 B.C. in such supposedly peripheral areas as Iberia, France, Britain and Denmark. Yet we now know that the earliest of these structures were built in Brittany, where the radiocarbon laboratory at Gif-sur-Yvette has yielded uncalibrated radiocarbon dates as early as 3800 B.C., leading to calibrated dates of as early as 4600 B.C. Monuments such as Barnenez or Ile Longue can now be recognized as predating the pyramids of Egypt by more than 1500 years. They are quite simply the earliest well-preserved built stone monuments that are known.

With the establishment of a globally valid dating system for the Holocene, which is of course essentially an achievement in the field of geophysics, albeit reliant also upon dendrochronology and using archaeological material in the earlier stages, it might be thought that the archaeologist would have no further contribution to make to questions of geochronology. But yet this is not quite true. For there is at least the hope that, for some time ranges, global marker events may one day be used to allow certain dates to be established within a single year.

The first such 'global event' to gain widespread attention is the paroxysmal eruption of the volcano of Santorini (Thera) in the Aegean Sea sometime around the sixteenth century B.C. The dating problem was first posed by the archaeologists. Spyridon Marinatos, the excavator of the splendid Bronze Age site of Akrotiri on Thera, put forward the suggestion that it was precisely the erupton on Santorini (which had destroyed and buried the settlement of Akrotiri) that was responsible for the destruction of the Minoan civilization of Crete in around 1450 B.C. (Marinatos 1939).

Subsequent work called this into doubt, because the pottery buried on Thera (in 'Late Minoan Ia' style) was typologically earlier than the pottery found in the destroyed palaces of Crete ('Late Minoan Ib' style). Radiocarbon dating was brought into play, but the dates showed a bewilderingly wide range, suggesting that local geochemical distorting influences were at work (Nelson *et al.* 1990).

The fascination of this dating question from the geophysical point of view, however, is that the fine tephra from the eruption may have had global climatic effects, as has been postulated both for ice-core sequences in Greenland (Hammer *et al.* 1987), and for the Californian bristlecone pine (La Marche & Hirschboeck 1984). These have been used to suggest the much earlier date of 1628 B.C. for the eruption of Thera, a proposal which finds some support also from the Irish tree-ring date (Baillie & Munro 1988). It would indeed be fascinating if these two dating methods, which follow solar-dependent annual counts, could be used to give a precise date, within a single calendar year, for this archaeologically well-dated event. It would then be applicable to other archaeological contexts, for instance in Rhodes, Melos and Crete (Renfrew 1978; Marketou 1990), where traces of Santorini tephra from the Minoan eruption have been identified. There is the prospect, therefore, of using these correlations between disciplines, to offer a chronological precision within a single year (instead of the precision restricted to several decades offered by direct radiocarbon determination), possibly applicable in several parts of the world.

Unfortunately, however, it is difficult to establish that it was precisely the Santorini eruption which was causing such severe effects in 1628 B.C. in both Greenland and California. Volcanos much nearer home may be suspected, and at present there seems no easy way of deciding. Yet this is a good example of the sort of chronological precision which may, in just a few favourable cases, be obtainable.

Climate and archaeology

When we turn to the interrelations between the fields of climatology and archaeology, matters are very much less clear. Indeed if one were to make a criticism of the programme of the present conference, it would be that, in its concentration upon the geophysical and astronomical sciences, it has almost entirely omitted the essential links between global climate upon the one hand and human history on the other. This has been a geophysicists conference, into which the life sciences (with the fleeting exception of tree-ring studies) have not been allowed to intrude.

The contributions to archaeology that we have been discussing have been, almost without exception, to chronology. The broader consequences of solar variability have only been cursorily explored, notably in the very interesting paper by H. Faure & M. Lerous (this Symposium).

Yet it cannot be denied that the significance of climate for the course of human history has been enormous: the flora and fauna upon which human populations depend for their subsistence are governed by climatic factors. Yet these climatic factors, while no doubt ultimately dependent at least in part upon solar variability, are more effectively expressed in terms of other parameters: above all in rainfall. But the relevant measure may not be an aggregate annual one. Seasonal measures of rainfall are needed, and of direct solar radiation during the growing season, and of extent of winter frosts. Moreover, these measures are needed locally. There can be no doubt that a regional approach is needed, so that the local climatic history may be reconstructed, and then the local vegetational history inferred and confirmed.

For it is not only that 'an army marches on its stomach'. Cultures and civilizations perish or flourish largely upon the basis of their subsistence productivity. Whether we are discussing hunter-gather régimes, or farming economies, it is the effects of climate upon subsistence which interest us. All other climatic effects are secondary. So if we are interested in human history and prehistory – which is, I take it, the principal reason for inviting an archaeological participation in this meeting – it is imperative to give due attention to such fields as geomorphology and crop plant geography, and above all to entertain the contribution of precise regional studies. For what we, and earlier cultures, experience on the ground is not global climate but the relevant microclimate.

The casual reader of the programme for this conference might suppose that the great advances being made in the study of global climatic variability (which in reality means mainly global variability in net annual solar radiation) have yielded some advances in our understanding of the principal changes in Holocene human history. Nothing could be further from the truth. For although, mainly from the study of oceanic temperature variation in the Pleistocene (from deep-sea cores), we know much more about the background to the palaeolithic culture sequence, the much more subtle effects of climate in the Holocene are little understood.

The best example is perhaps offered by the phenomenon of system collapse, for which three controversial examples may be cited here: the decline of the Indus Valley civilization in what is now India and Pakistan in the early second millennium B.C.; the demise of the Mycenaean civilization of Greece around the twelfth century B.C., and the collapse of the Classic Maya civilization of Mesoamerica around A.D. 900. In each case archaeologists have offered a bewildering range of conflicting explanations: plague, invasion, earthquake, revolt and of course climatic reasons. What I would like to highlight here is that in every case famine due to drought, and famine due to flooding and increased rainfall have been simultaneously offered as explanations (see, for example, Rhys Carpenter (1966) for the Mycenaean civilization). Nothing could more effectively illustrate the primitive state of the present stage in climatic studies as applied to the early past that explanations based upon (*a*) major rainfall increase, (*b*) major rainfall decrease, and (*c*) no significant change in rainfall may still be offered for each of the places and times under discussion (see Adams 1973, p. 23).

To say this is not to belittle the contributions that have been made, especially in the field of vegetational studies, mainly by palynology but also using other vegetational or climatic indicators such as land molluscs. We now know a good deal about the environment, in terms of geomorphology, flora and fauna, of many ancient sites during their *floruit*. But this often tells

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

us little about the dynamic aspects, about such issues as repeated crop failure over a number of successive years, which might have prompted radical social changes. Environmental archaeology has only rarely developed techniques that allow it to operate on a timescale of individual years. Yet it is on a timescale of months, years and at the very most decades, that climatic and subsistence changes are experienced.

The annual variations under discussion in this Symposium are thus potentially of the highest importance for archaeology. But, as I have tried to stress, they have to be understood in terms of their local climatic effects. Much more detailed modelling is needed to give us the links between fluctuation in solar radiation, seen as cause, and local subsistence effects (including climatically dependent crop failure) seen as effect.

This, perhaps essentially negative, point is the main one that I wish to stress in this Symposium. If global effects are to be applied to human affairs, they must be applied with some vision, some understanding, of the relevant scale of analysis. We have to begin to envisage crop production in a local region of just a few hundred square kilometres, on a year by year basis. We have to forecast (or retrodict) both long-term trends in production of the relevant plants (including plants used by grazing animals), and catastrophic crop failures, and above all repeated crop failures. Until the modelling techniques are available for these undertakings there is little that will allow us to link global solar variation with the archaeology on the ground.

The causes of environmental change

By way of example, to illustrate the complexity of the task facing the archaeologist who seeks to interpret the cultural data utilizing evidence for climatic change, I should like to cite the important question of local environmental change on the north Mediterranean littoral during the Holocene period. The focus of interest is upon the period following the inception of farming, i.e. on the Neolithic, Bronze Age and Iron Age periods, to use a rather outmoded terminology. The archaeologist naturally seeks to reconstruct the environment of the communities under study at the time they were flourishing. But this task is greatly complicated by several factors, not least the changes in the landform caused by erosion and deposition, which have materially changed the agricultural potential of the catchment area for many archaeological sites.

One of the most sustained and detailed examinations of this issue has been carried out by Gilman & Thornes. They aptly remark, on one aspect of the issues facing them (Gilman & Thornes 1985, p. 48):

> Our view is that fluviatile responses to climatic change are still so poorly understood, even under present regimes, that attempts to assert past climates from localised sedimentary sequences are still too primitive and conflicting to provide a...secure base....

The converse is of course also true that a precise knowledge of past global climate would not at present allow any adequate evaluation of local geomorphological effects.

To offer a specific example, some years ago I was excavating a major prehistoric site, Phylakopi, on the north coast of the Cycladic island of Melos in the Aegean. The site flourished during the Bronze Age: in the late Bronze Age, from around 1600 B.C. it was fortified, with a central administrative building or mansion from which came evidence of literacy in the form of a fragment of a tablet in the Minoan Linear A script. There were fresco fragments also showing signs of influence of the Minoan civilization of Crete. From around 1400 B.C. the

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

resemblances were rather with the Mycenaean civilization of Mainland Greece, with a sanctuary and indications of cult practice comparable with other found on the Mainland. Around 1100 B.C. the site was abandoned, never to be reoccupied, like many in the islands. This was the time of the decline and end of the Mycenaean civilization.

Whether the decline and end of such sites had something to do with climatic change is an issue that has been much debated, but it was not one which we could hope to answer from this single site. However, we could hope to determine at what date the fine natural harbour to the south of the site became silted up. Earlier geomorphological studies in Greece of Holocene soil erosion and deposition have established two major phases, the more recent of them, termed the Younger Fill by Vita-Finzi (1969) within the Holocene. This major depositional phase has been studied by Bintliff in several areas. Vita-Finzi put forward evidence to suggest that the episode responsible for the Younger Fill deposits which he studied were to be dated to the late Roman and early mediaeval periods, from *ca.* 200 B.C. He initially suggested that deposition of the Younger Fill was synchronous throughout the Mediterranean, thus emphasizing a climatic cause.

Geomorphological work on Melos by Davidson & Tasker (1982) suggested other possibilities. In the first place a well was examined in what are now the field immediately to the south of the site of Phylakopi, where the harbour had been situated in Bronze Age times. The material in the section may be described as colluvium, formed by the deposition of material washed down from the surrounding hill slopes. The pottery from the lower levels indicated that the hillslope wash had been initiated after the inception of the late Bronze Age and before classical times.

Buried organic matter in a colluvial section in the upper Phylakopi valley yielded a radiocarbon date which after calibration could be set at 1050–1150 B.C. (Davidson & Tasker 1982, p. 88).

These observations suggest that the processes leading to the deposition of what might be termed the Younger Fill began in Melos very much earlier than Vita-Finzi had suggested, indeed before the abandonment of Phylakopi in *ca.* 1100 B.C. They raise the possibility that, in Melos at least, and perhaps in other areas, the process was an anthropogenic one, arising in the first instance through over exploitation and in particular probably over-grazing leading to a phase of increased erosion in the late Bronze Age. Whether this was a process which contributed to the strong economic and agricultural recession seen at the end of the Bronze Age cannot yet be established. For it could be argued that the converse was the case, and that the abandonment of many fields as a consequence of this recession, and the failure to maintain the terrace systems that may already have made many hill slopes cultivable, may have led to increased erosion.

Now the point of offering this modest investigation to your attention on this occasion is to illustrate how far we are from integrating into the discussion a clear and reliable view of the impact of climatic change upon human occupation of Melos or indeed the Mycenaean world in general. The pollen evidence for Greece (Turner 1978), which is at least as good as for other Mediterranean lands (although no suitable deposits have been found on Melos itself), does not give clear cut evidence of a climatic episode that could be associated with a widespread episode of erosion and deposition such as might account for the Younger Fill.

Was there such a climatic episode? Or is the Younger Fill in fact to be dated differently in different areas, the complex product of a relation between anthropogenic and climatic factors?

It is of course precisely here that the investigations under discussion at this meeting should come to our aid. We are discussing major and widespread geomorphological changes that might be synchronous and that might be climatically determined. But the intervening arguments are lacking that might take us from the emerging data for variations in solar radiation, experience on a global scale, and climatic fluctuations, mainly variations in rainfall, experienced in south Greece and the Aegean islands.

My suggestion is that comparable difficulties will be found for most of the major changes in human settlement pattern or in agricultural production that archaeologists have wished to investigate in different parts of the world. The archaeological problems are there, involving changes of major significance in human history. The global climatic data are evidently improving in quality in a striking way, as the papers at this meeting have impressively documented. But where are the intervening arguments, the reliable frameworks of inference, which will take us from known global variation in radiation or temperature to specific climatic effects in individual regions? Until these are developed and adduced we cannot be said to be undertaking interdisciplinary discussions, as we should be doing. We are merely speculating, as archaeologists and geophysicists have done for more than a century.

References

Adams, R. E. W. 1973 The collapse of Maya civilisation, a review of previous theories. In *The Classic Maya collapse* (ed. T. P. Culbert), pp. 21–34. Albuquerque: University of New Mexico Press.
Baillie, M. G. L. & Munro, M. A. R. 1988 Irish tree-rings, Santorini and volcanic dust veils. *Nature, Lond.* **307**, 344–346.
Carpenter, R. 1966 *Discontinuities in Greek civilisation*. Cambridge University Press.
Davidson, D. & Tasker, C. 1982 Geomorphological evolution during the late Holocene. In *An island polity, the archaeology of exploitation in Melos* (ed. C. Renfrew & M. Wagstaff). Cambridge University Press.
Gilman, A. & Thornes, J. B. 1985 *Land-use and prehistory in south-east Spain*. London: George Allen and Unwin.
Hammer, C. U., Clausen, H. B., Friedrich, W. L. & Tauber, H. 1987 The Minoan eruption of Santorini in Greece dated to 1645 BC? *Nature, Lond.* **328**, 517–519.
La Marche, V. C. & Hirschboeck, K. K. 1984 Frost in trees as records of major volcanic eruptions. *Nature, Lond.* **307**, 121–126.
Libby, W. F. 1955 *Radiocarbon dating*. Chicago University Press.
Libby, W. F. 1963 The accuracy of radiocarbon dates. *Science, Wash.* **140**, 278–280.
Marinatos, S. 1939 The volcanic destruction of Minoan Crete. *Antiquity* **13**, 425–439.
Marketou, T. 1990 Santorini tephra from Rhodes and Kos; some chronological remarks based upon the stratigraphic evidence.
Nelson, D. E., Vogel, J. S. & Southon, J. R. 1990 More radiocarbon data for the last occupation of Akrotiri.
Renfrew, A. C. 1978 Phylakopi and the Late Bronze I period in the Cyclades. In *Thera and the Aegean World* I (ed. C. Doumas), pp. 403–422. London: Thera and the Aegean World.
Turner, J. 1978 The vegetation of Greece during prehistoric times: the palynological evidence. In *Thera and the Aegean World* I (ed. C. Doumas), pp. 765–773. London: Thera and the Aegean World.
Vita-Finzi, C. 1969 *The Mediterranean valleys: geological changes in historical times*. Cambridge University Press.
Zeuner, F. E. 1946 *Dating the past*. London: Methuen.