Climatic change, archaeology and Quaternary science in the eastern Mediterranean region

There has been a very significant shift in recent decades within the discipline of climatology away from the highly detailed, particularising approach to regional climates, with its emphasis on unique combinations of topography and surface pressure systems, and on to a far more powerful analysis in which the fundamental source of dominant surface weather systems is to be sought in large-scale airmass and circulation dynamics in the upper atmosphere. This approach rests on the fundamental link between the development and steering of surface weather and wind systems, and the general atmospheric circulation and the flow of the circumpolar vortex (the broadly latitudinal flow of dominant winds concentric around the poles) (Lamb 1978a, p.121; Lamb 1978b, p.183).

The major wind systems under analysis in this approach are such as the upper westerly system, affecting both Europe and the Mediterranean latitudes, and therefore of sufficient amplitude that the possibility exists of interpolating from indications in widely separate localities the overall climatic pattern for regions of subcontinental size. Moreover, the pattern of the dominant upper circulation features is then also inferable from discrete but consistent indications of surface weather and pressure systems on the strength of their significant distributional characteristics. Such an overall approach has been most notably applied by Professor Hubert Lamb in his extensive publications on climatic history.

These considerations encourage the modelling of climate for past eras in the east Mediterranean, even when it apparently relies excessively on data from selected areas within that wider region, or is visibly propped up by reference to data available for adjacent regions (such as temperate Europe or north Africa). Underlying this attempt therefore, and those incorporated into it from published work by previous scholars, is that concept fundamental to Lamb's *oeuvre*, that major climatic fluctuations (secular changes of climate), in one region of the globe are believed to be correlated with predictable fluctuations in contiguous regions, because of the strong interdependence of the major features of the Earth's climate and the large scale on which the underlying circulation features operate. A second major concept in Lamb's approach that is invaluable for palaeoclimatic reconstructions is the building of models for changing secular climatic patterns on the basis of analogous recent short-term fluctuations, with allowance being made for degree and duration.

The foregoing points are especially relevant to the study of climatic change in the east Mediterranean. For almost all of this region, the availability of wild

1. Latitudinal displacement of present-day circulation (westerlies, equatorial rains)
2. Changes in strength of 'zonal flow' – frequency of 'blocking' of circulation
3. Out-of-phase north vs south hemisphere circulation (shift in average position of intertropical convergence zone = ITCZ)
4. Unusual exchanges between normally remote weather systems (e.g. westerly and equatorial precipitation)

Figure 1.

game and plants, the successful maturing of cultivated cereals and tree fruits, and of pasture for domestic animals, all are dependent on the winter-season incursion of upper westerly steered cyclonic stormtracks from the west and northwest, coupled with the parallel retreat of the summer-dominant subtropical arid pressure systems (predominantly high pressure) towards the equator. These displaced troughs in the upper westerlies also bring rain to winter-season northern Europe, just as the expanded Azores subtropical anticyclone is responsible for prolonged periods of warm, dry weather in northwest European summers.

Essentially there would seem good reason for establishing a palaeoclimatic model linking unusually wet and cold winters in northern Europe with a similar tendency in southern (Mediterranean) Europe and the Levant, and a corresponding correlation between Mediterranean winter rainfall decline and a decrease in Europe north of the Alps. This *Model One* (figure 1) envisages a simple northward or southward displacement of present-day circulation patterns. It is one of the key climatic changes isolated by Lamb (1977, p.400; Lamb and Dickson 1975, p.142; Lamb 1978b, p.184).

A complicating factor arises if we consider another source of precipitation, that of the equatorial rains (primarily the monsoons). At present such rain affects only the southernmost area of the Middle East, and even there only where relief is significant. But if, as seems likely, there have been periods in the past, especially that of the supposed climax of warmth and ice-melt during the Atlantic era (c. 7450–5450 BP (5500–3500 bc)), when the circumpolar vortex of broadly latitudinal climatic zones contracted towards the poles, then it would be appropriate for the monsoon/equatorial rains not only to have an effective influence further north in the east Mediterranean and Saharan Africa, but to operate there also irrespective of local relief. This is an important corollary of Model One.

Model Two relates to the strength of the zonal circulation of the upper atmosphere. It has been argued (cf. Lamb 1977, 1979), that the vigour of the Earth's circulation is correlated with the existence of marked contrasts between low latitude heat surplus and high latitude heat deficit (hence the concentration of atmospheric disturbances due to mixing of cold and warm air, in middle latitudes). The efficient running of this heat engine is therefore at its maximum when both equatorial insolation and polar ice development are well balanced. During the climax of glacial eras and the maximum warming of interglacials, it is argued that one or the other tendency would gain the upper hand tending to produce a marked decline in circulation vigour. Under ideal conditions (e.g. the early decades of this century rather than in the present climatically abnormal period), there is an apparent tendency for the strong equator-polar heat contrast to create a vigorous flow of airmasses between them, that is converted by effects such as the Earth's rotation into a broadly latitudinal or 'zonal' flow. A decline in this heat exchange vigour would weaken the zonal flow (west to east in the northern hemisphere, hence the 'upper westerlies'), and encourage a strong development of meridional flow, that is north-south airmass exchanges. This disruption of the smooth passage round the hemispheres of important zonal features, such as the rain-bearing westerly winds, would be a greatly-accentuated version of lesser interruptions and deviations that are always found in these windstreams. At all times the upper westerly flow is disturbed by recurrent or semi-permanent wave-like meanders. These arise as a consequence of the relative disposition of land and ocean masses, variations in physical relief, a 'balancing' of wave disturbances in different segments of each hemisphere, and the relative distribution of regions of intense warmth and cold (e.g. ice-sheets). Under 'ideal' conditions, a powerful zonal flow is interrupted by three to four low amplitude waves per hemisphere, but under conditions of sluggish flow these can increase to five to six high amplitude waves. The meanders themselves represent diversions of airflow around relatively static pressure systems such as expanded belts of warm high pressure, or polar cold low pressure (which can be the direct cause of the sluggish flow in the first place), or physical barriers as noted above. The larger the diversions, the greater the scope for meridional exchanges in the place of westerly flow. This results in the areas concerned being subject either to the relatively static extreme climates or to mobile airmasses from unaccustomed directions and with a tendency to notable divergence from previous zonal flow character (warmer from the south, colder from the north, in the case of the northern hemisphere). These situations of highly disturbed flow are termed 'blocked', and it is an important feature of such patterns that major shifts can occur on a season-by-season, or longer-term basis, in the location of the blocking warm, subtropical or cold, polar anticyclones and hence the areas where the disturbed flow is concentrated. Severe drought may be followed by remarkable flooding in the same region, under such a régime, on a short-term basis.

The implications of this for Mediterranean latitude climates during periods of known expansion of subtropical or polar anticyclones are clear, and will be pursued in application later in this paper. But it will be obvious that a particular complication arises in the correct identification of the ultimate cause of surface effects indicating a 'blocked' circulation. They may originate from an unusual increase in equatorial warming or cooling, that is they can be indicative of either mini-glacial or climax warming phases. Winstanley has in fact demonstrated the relevance of the joint operation of our *Model One* and *Model Two* climatic patterns in an examination of climatic fluctuations in the

Middle East and north Africa between 1950 and 1970 (Winstanley 1973). He stresses that precipitation curves for localities throughout this region tend to show a similar path for the period, subject as they are to the same incursion of westerly stormtracks.

Model Three (and note that all of these models may be applicable at the same point in time) considers the possible effects of an out-of-phase relationship between the north and south hemisphere circulation. There seems to be some evidence within the Holocene and the late Pleistocene for warming and cooling tendencies to have been out-of-phase in the short term (i.e. one to several centuries) on either side of the equator, but in-phase on longer timescales (such as the one to several thousand year cycles of climatic phases defined by the classic pollen zonation of north-west Europe). A notable exception to this rule existed with the universal Little Ice Age.

A commonly-accepted practical effect of this imbalance might be a shift in the average position of the meteorological equator, that is, the dividing line between the broadly zonal circulation systems extending in a mirror-fashion polewards from the equator, the ITCZ or Intertropical Convergence Zone. Such an effect might either reinforce or tend to negate the general climatic tendency for each hemisphere in its effect on low latitudes (and here the Sahara region is frequently cited, cf. Rognon and Williams 1977), but could extend into lower-middle latitudes such as the Mediterranean and Middle East region in more extreme cases. Thus in a cold period in the northern hemisphere, the climatic belts might broadly move south, with a tendency for the arid Sahara to migrate south into the savannah zone; but if the southern hemisphere ice cap was far more extended than the Arctic, the pressure for displacement from the south to the equator would outweigh these effects by shifting the ITCZ northwards, allowing equatorial rains to persist in the south Sahara fringes and creating a compressed Sahara desert zone.

One further specialised effect, *Model Four,* can be proposed, especially when considering situations such as Model Three, where unusual proximity of the normally remote westerly and equatorial rain systems is created, or Model Two, where meridional flow might likewise bring into proximity these two rainfall sources. On analogy with present-day processes – though feeble in magnitude and significance now – it has been suggested that interactions might take place between these two systems, especially at changeover seasons such as spring and autumn, which would bring rainfall to intermediate regions such as the central Sahara, normally deprived of major precipitation by their distance from either source (cf. Sudan-Sahel depressions, and the suggestions of Flohn and Nicholson 1979, and Rognon and Williams 1977).

In the remainder of this paper, I shall discuss the broad lines of the environmental, archaeological and historical evidence relating to major climatic fluctuations in the east Mediterranean region, from a mature phase of the Holocene up to the last few centuries of relative warming. This period is treated in terms of the major subdivisions widely recognised as reflecting significant secular climatic changes. (For a discussion of possible factors behind these shifts, especially the semi-regular c. 2000-year and 1000-year cycles detectable during the Holocene and final Glacial period, see Lamb 1977 and 1978a, b.)

Sub-boreal period, c. 5450–2950/2700 BP (3500–1000/750 bc)

In the scientific literature for this period from north-west Europe, there is a clear difficulty in interpreting the environmental indicators in simple climatic terms. A similar difficulty from variety of indicators characterises the east Mediterranean region, and may in fact be characteristic for a particular régime of blocked and variable weather.

In the Levant, the first half of the period represents archaeologically a major phase of expansion into the southern deserts and generally an advance in settlement. We have the same effects and time-range in north Africa and Syria. There is evidence for this humid phase lasting till the latter part of the third millennium bc in the Negev (Price-Williams 1973) and the Khabur basin (Oates 1976). Likewise the Jordan alluvial phase described by Vita-Finzi and Copeland (1978) dating back probably to Chalcolithic times, has a date of 3950 BP (2000 bc) in its upper levels. The Dead Sea may have been higher from 5000–4250 BP (3500–2300 bc) (Crown 1972) and therefore cooler or in a moister catchment, or both. In fact there is some evidence from studies off the Israeli coast (Magaritz and Kaufman 1973) for cooler sea temperatures between 4950 and 2950 BP (3000 and 1000 bc).

Price-Williams (1973) suggests that the Middle and Late Bronze Age and Iron Age occupations of the south Levant deserts were not primarily agricultural, but concerned with trade routes and defence, although Evenari has argued for the MBA at least being partly agricultural in character and the first to have applied run-off systems on a large scale (1971). But it does seem as if there was a clear decline in land use in the region through the second millennium bc and beyond. Just north of the Negev, a study of wood charcoal from archaeological sites (Lipschitz 1979) distinguishes between the Late Bronze Age and the Iron Age, giving a shift from more Mediterranean to more Saharan vegetation c. 3150 BP (1200 bc), the earlier period thus being moister than now (or merely cooler?). However, no allowance was made for the importation of wood from varying distances. In Syria, despite possible fluctuations noted above, pollen spectra furnish in general a semi-arid climate comparable to that of today (Bottema 1977).

Moving into the northern region we find, as with the preceding Atlantic period, a continued improvement in moisture recorded by increasingly full or climax woodland conditions. In Turkey pollen diagrams show climax woodland achieved by the end of this period, and in Greece the climax was reached in the latter part of the Atlantic (Van Zeist and Bottema 1977, 1980; Bottema 1978). Some possible wider implications might be drawn from the Persian Gulf core data, which could be read to indicate a dry early, and moister late, Sub-boreal, reflecting upland precipitation around the Mesopotamian Plain (Diester-Haass 1973). The change from aggradation to incision in the Deh

Luran section of that plain (Kirkby 1977) is taken by that author to suggest a moister climate, with greater vegetation mat and reduced run-off, possibly correlating with the Gulf indications.

In Arabia, present-day arid conditions are already established, and the indications from Red Sea isotope studies are appropriately dry, although the data for the Gulf of Aden could be read to show fluctuations of dry to moister conditions (Deuser 1976, Schoeli 1978, Olausson and Olsson 1969).

Possible interpretations

'After about 3000 BC the circulation seems to have become weaker, permitting some drier periods and colder winters in central and northern Europe and Asia. In northern Turkey . . . the change was to moister conditions . . . probably an early symptom of a return to more meridional circulation patterns and a winter trough in the upper westerlies near longitude 20–40°E' (i.e. the east to central Mediterranean) (Lamb 1977, p.390).

In north-west Europe, after the Piora decline, forests regained ground, but in the latter part of the period, especially after 3450 BP (1500 bc), they decline in altitude and yield to peat growth and podzolisation (Lamb 1977, p.416). Although there are indications of greater warmth, comparable to Boreal times (hence the term Sub-boreal), there are also clear recurrent fluctuations, especially of rainfall such that: 'More variable, and presumably more meridional, circulation patterns than in Atlantic times seem an obvious interpretation' (*op. cit.*, p.373). Underlying this pattern, for Lamb, would be blocking situations arising from a weakened circulation. In the earlier half of the period he ascribes this to extreme retreat of the ice sheets and northern advance of the belts of climate, but for the latter period there is sufficient evidence from glacier advance and treeline depression, and supportive environmental indicators, for an overall shift of climatic belts south again as a prelude to the Sub-atlantic climate. (For northern hemisphere glacier advances see Hecht (1979), between 3450-2450 BP (1500–500 bc); in the Swiss Alps, a climatic decline based on pollen evidence and glacier stratigraphy, see May (1979), between 3350–3250 and 2850–2250 BP (14–1300 and 9–300 bc); for a cooler climate between 3450–3100 and 2750–2650 BP (1500–1150 and 8–700 bc), on European oak density studies see Rothlisberger (1979); in the White Mts of California tree-ring studies show climate decline c. 3250 BP (1300 bc) after La Marche (1974).)

The implications for the Mediterranean latitude are not clearcut. One might expect from the Piora fluctuation onwards a marked variability at different longitudes of the Mediterranean (*Model Two*) with unusually dry zones adjacent to unusually wet zones, and a generally expanded subtropical anticyclone belt interrupted by 'bitrack' depressions steered round them. 'Bitrack depressions' are cyclonic disturbances envisaged as being diverted both north and south of a dominant, blocking anticyclone, rather like a stream around a rock in its path. In the latter half of the period, however, a general advance of the depression belt further south into the Mediterranean winter might be expect-ed, and a retreat of the monsoons.

In the Levant and inland Syria the indications of a cooler and moister climate occur in the earlier part of the Sub-boreal, perhaps as a continuation of the Piora conditions. This is difficult to relate to the north European situation, unless we assume a bitrack concentrated in the south-east Mediterranean. Seemingly the later shift of the depression belt on a broad front into the Mediterranean, as predicted above, had no significant effect on this area. The indications of precipitation increase in the Mesopotamian Plain's mountainous hinterlands are perhaps significantly concentrated in the latter half of the period, coincident with the suggested rainfall increase throughout the Mediterranean (*Model One*).

In the rest of the northern part of the region, the continued rise of woodland is recorded, seemingly reflecting a continued rise in moisture. Whereas this is reasonable for the latter part of the period with its supposed increase in rainfall, the earlier Sub-boreal might have been supposed to be associated with a dry interval, unless bitrack conditions favoured the regions where palynology has been concentrated. There does seem to be a problem here with an overall early Sub-boreal interpreted as a major northward shift of the location of winter rainfall, and at present the north-east Mediterranean data is more consistent with a continual southward shift of cyclonic depressions from Sub-boreal into Sub-atlantic times, with minor moves in the opposite direction that do not seem to be registered in the woodland record.

Such a conclusion would also be consistent with the evidence from the Nile headwaters and the south Sahara, with the monsoon in serious decline, as with the equatorial rains (Rognon and Williams 1977). Although the general retreat of the monsoon to present levels of northward migration is seen as occurring by 3950 BP (2000 bc) (Rognon and Williams 1977, Butzer 1978), this may not be merely a reflection of an early Sub-boreal with a generally contracted northern hemisphere circumpolar vortex, for there may be a phase of Antarctic cooling that could have created an ITCZ displacement northwards from 8–4000 BP (6–2000 bc). Certainly the decline of the monsoon is recorded by the continual fall in Nile levels in Egypt during the third millennium bc, and again after some recovery in the latter part of the second millennium bc. The serious political implications of this decline for the prime subsistence basis of Egyptian civilisation have been excitingly explored by Barbara Bell (1971, 1975). Likewise the decline of the monsoon, especially from c. 3950 BP (2000 bc), has been plausibly linked to the collapse of the Indus civilisation of north-west India and west Pakistan (McGhee 1979).

Particular attention has been paid by climatologists, historians and archaeologists, to the possible role of climatic fluctuations in precipitating the collapse of the Mycenaean and Hittite civilisations around 1200 BC. The initial drought hypothesis of Carpenter (1966) was given support from research by Bryson, Lamb and others into modern parallels for a mosaic of drought and normal rainfall over the east Mediterranean as postulated by Carpenter from historical and archaeological evidence (Lamb 1967, Bryson 1974, Lamb 1977).

Such a pattern was not uncommon this century and was primarily a consequence, in its short-term manifestations, of the distribution of relief in the region. However, the continued operation of such a climatic pattern over a matter of centuries to enforce the post-civilisational collapse of the Dark Ages, was tentatively ascribed in one paper to a blocking régime across the westerlies created by a southward displacement of the north hemisphere climatic belts (Bryson 1974). In any case the climatologists have shown that Carpenter's initial drought theory assumed a general warm climate with subtropical aridity extending further north after a retreating winter rainfall belt, whereas in fact the mosaic of wet and dry areas is most plausibly, on present analogues, due to an expanded polar high that blocks winter rainfall from a smooth progression through the east Mediterranean. Archaeological objections have been raised to the reality of the mosaic pattern, in terms of settlement continuities and discontinuities (Dickinson 1974), which have more weight than the apparent absence of change in Aegean woodlands (Wright 1968). The latter data give no evidence for any perturbations of climate in this or the Sub-atlantic period, contrary to very clear indications from historical and geomorphic data. One must conclude that at the level of fluctuations *within* the major Holocene periods, woodland evidence is only notably sensitive in marginal environments, for example desert margins of the south Levant, upper treeline margins in northern Europe. In the intermediate situation, such as the north-east Mediterranean, the lesser-scale changes may be insufficient to disturb established woodland. As we have seen, there is in fact good evidence for climatic decline in the northern hemisphere from 3450 BP (1500 bc) onwards, which could be appropriate for the blocking situation discussed by Bryson and Lamb. The resolution of the discussion must await more detailed information to clarify these opposing claims, but it may be difficult to find environmental data in the east Mediterranean sensitive enough to the correct chronological scale and locally varying effects involved. Perhaps new historical sources may appear to resolve the issue.

Sub-atlantic period: c. 750 bc–present

The general environmental and archaeological evidence from the Levant is of a climate comparable to the present day, less extreme in either cold/moist or hot/dry conditions than earlier such phases such as the Copper Age. However, it is not always clear whether the development of human cultural skills and initiative is sufficient an explanation for the perseverance of settlement and agriculture in areas of minimal rainfall such as the Negev, or that a habitat was milder owing to a minor climatic oscillation.

The southern deserts show little evidence for resettlement until the rise of the Nabataeans in the closing centuries BC. From then until the collapse of the Byzantine civilisation in the region in the sixth–seventh centuries AD, and possibly till the eighth–ninth centuries AD (Evenari 1971) there is a remarkable flourishing of agricultural settlement, tied to the increasingly sophisticated run-off systems carefully investigated by Israeli archaeologists. It cannot merely be claimed that the Arab invasion of these regions was sufficient to create settlement decline, as Dayton (1975) has convincingly shown, for in Arabia and Jordan the Islamic period in the longer term saw continuing settlement and considerable irrigation systems constructed, together with settlement advance into marginal areas. Was there a climatic element? Dayton argues that increasing drought marks this change of cultural control, for which there is some historical support in the southern Arabian peninsula, with migration of tribes to Tunisia and clear accounts of drought. On the other hand, Goldberg (1980) has drawn attention to considerable deposition of fluvial silts, now in terraces incised up to 4–5 m high, over the Negev and Sinai, associated with radiocarbon dates of 1700 and 600 BP (ad 250 and 1350) and traces of more substantial vegetation than today. While noting the links to Byzantine activity, Goldberg raises the possibility of climatic change, comparing his alluvia with the 'Younger Fill' around the Mediterranean of Vita-Finzi (1969a), broadly dated by the latter from AD 400–1800.

But these dates and the evidence of the 'Fill' itself point, if anything, to a change to a much moister climate throughout the Mediterranean (which could conceivably be linked to the Late Roman/Early Byzantine climax of desert occupation), and the decline of the Levant must in fact be associated with cultural discontinuity, even if there are areas where the Arab encroachment was not economically disastrous. One need only recall the cultural and political gesture of resettlement of the Negev in the late nineteenth century, and in recent decades (Price-Williams 1973, Evenari 1971), times of no consistent precipitation improvement, often rather of decline, to be wary of attributing too much to the presence of settlement where developed civilisations are concerned.

Dayton (1975) fails to distinguish between possible drought in the Levant, under the influence of cyclonic rain, and the Arabian peninsula, under opposing cyclonic and monsoon rain. His best drought evidence seems to be from the monsoon zone and its northern margins. One might perhaps correlate a possible rise in winter rainfall for the south Levant 'Younger Fill' with a monsoon decline to the far south. According to Vita-Finzi (in De Cardi *et al.* 1975), the Younger Fill is also found in Arabia, but may be medieval in inception.

The Younger Fill is virtually the only well-attested feature of possible climatic significance in Syria at this period (Besançon 1980), and its universality and clear indications of its origins in erosion/run-off/rainfall are more acceptable than localised explanations such as that of Brice (1978), with the alluvial burial of ancient Antioch ascribed to earth movements.

In the north of the eastern Mediterranean, vegetational history shows no significant changes attributed to climate; which would agree with the gradual rise to modern precipitation by the later Sub-boreal and its overall maintenance to the present day. But the record is increasingly difficult to interpret because of human interference with woodland distribution. More sensitive indicators stem from geomorphic activity. In Iran the historical alluvium or 'Younger

Fill' has been well studied (Vita-Finzi 1969b, 1975; Brookes and Dennell 1977) and conforms to the general time span elsewhere for this formation of c. AD 400–1800 or later. But Brookes indicates what could be drier intervals within this long period of supposedly cooler and moister climate. Similar signs may be observable from the Persian Gulf cores (Diester-Haass 1973) in which the Sub-atlantic is associated with generally moister conditions interrupted by drier intervals. In the Mesopotamian Plain in general, a peak of complex agriculture based on run-off and canal systems is dated to later Roman and early Islamic times (cf. Kirkby 1977), which might perhaps have been aided by the same moister climate indicated by the Younger Fill. In the Iraqi sector, notable flooding of the lower Plain around AD 600 might conform, but there is evidence also from historical sources for an unusually warm period c. AD 1000 in the same region (Oates 1976). Finally, ocean cores from the Gulf of Aden cover only the early part of the period, and suggest a dry climate, with no unusual extension of the monsoons (Olausson and Olsson 1969).

In Turkey, once again, the woodland record offers little apparent sensitivity to changes detectable in river régimes and other geological evidence. The historical Younger Fill is well represented (Vita-Finzi 1969c). There is evidence from glacier development, for example from Mt Ararat, that seems to record the worldwide climatic cooling of the Little Ice Age (c. AD 1550–1850) (Farrand 1979). The more plentiful historical records now available suggest the following phases of unusual climate or secular changes of climate: after a climate in Roman times comparable to that of today, higher rainfall is suggested from c. AD 750–1300, but with drier intervals associated with frequent droughts (Erinc 1978). Likewise there is unusual wetness in the fifteenth and seventeenth centuries AD, also associated with pronounced drought years (Eisma 1978, Griswold 1979).

In Greece, too, the pollen record provides little indication of climatic fluctuation, and the prime evidence for such stems from the abundant Younger Fill alluvium (Vita-Finzi 1969a; Bintliff 1975, 1977; Dufaure 1976), dated in most exposures from Late Roman to recent times. A number of recent papers critical of the chronology of the Younger Fill (Raphael 1973; Eisma 1964; Davidson 1971, 1976, 1980) may be criticised in their turn for confusing it with earlier colluvial and deltaic deposits (Bintliff 1977, 1981; and for some realisation of this see Eisma 1978).

The best historical evidence for Greece, at least in terms of scholarly accessibility, refers to the period of Classical and Hellenistic Greece, from after 700 to 200 BC. Careful study of literary sources gives strong evidence for a climate during this era comparable to that of the present day (Meigs 1961, Guinis 1976), but rather curiously the assumption is made that therefore the Greek climate has not changed *since* the Classical period. In fact the prime evidence to disprove that assumption stems from the period of the Younger Fill, later than these carefully studied sources.

Possible interpretations

We might first consider the evidence from other parts of the Mediterranean. Little data are available for the period before the Roman Empire. The Imperial Roman period seems generally to have been one of warmth and precipitation comparable to or slightly drier than that of today. The post-Roman centuries, or Dark Ages of the West, have been associated with severe drought in the Byzantine Empire by Carpenter (1966) without adequate evidence, but in Spain there is data from which to deduce seasons of severe drought in the sixth to seventh centuries AD (Barcelo 1979). On the other hand, in all the lands of the central and west Mediterranean the Younger Fill is well represented (Vita-Finzi 1969a), implying moister and cooler conditions for much of the Dark Ages and medieval era. The apparently contradictory evidence may be reconcilable (see below) and Lamb points out that during the Little Ice Age period the Spanish historical sources clearly indicate frequent juxtapositions of severe drought and flooding seasons (1977, p.468). The Mediterranean counterpart to the north European 'Early Medieval Warm era' of c. AD 900–1200 has not hitherto been clearly demonstrable, except for interludes in deposition of Younger Fill about this time, which may mark drier conditions (cf. for example, Barker 1978, Potter 1979). On the other hand, Lamb has suggested that the Mediterranean continued to benefit from rainfall above recent levels, in some longitudes, during this warming era, because of 'bitrack' depressions, and relates this to indications of more active river flow in Sicily and peat growth in the Azores (1977, p.428). The subsequent Little Ice Age is the best documented climatic change over Europe as a whole during the Holocene, and historical evidence for cold, wet conditions abounds throughout the west and central Mediterranean (often coupled with drought reports, as noted above) (Lamb 1977, p.466ff; Pichard 1979), until the nineteenth-century warming period, and contemporary with the latter part of the Younger Fill.

Historical sources have their obvious weaknesses, although they should assist in the identification of the most extreme years. Nonetheless it is clear from the last two centuries that individual years of climatic extremity can stand isolated amid a consistent period of different norms. An examination of Weikinn's (1958) historical listing of years of remarkable climate in Europe not surprisingly offers only a general impression of a greater incidence of more northerly-type climate in southern Europe, coincident with similar but better attested phases in north-west Europe. Lamb claims a better match but the agreement is patchy (1977, p.427). How are we to evaluate, for example, the isolated information that in 829 and 1011 there was ice on the Nile (loc. cit.)? The former date would fall into the transition from a colder to warmer climate in north-west European terms, and the latter was in fact also a year of severe cold in much of Europe north of the Alps, but within a well-established *warm* era there.

In north Africa, the Nile flood fluctuations and the inferences concerning the expansion and contraction of monsoon/equatorial rains to be drawn from them, do seem to be in accordance overall with the predictions one might make from the behaviour of the westerly circulation for north-west Europe (Lamb 1977, Brooks 1949): from the seventh century AD to c. 800, low Nile levels, followed by a rise corresponding to the climatic improvement of the European 'early medieval warm era'; then a decline c. AD 12–1400 and c. AD 15–1600 comparable to the Little Ice Age and its late medieval precursor; even the milder era c. AD 1500 may be represented by a higher Nile flow. However, from the latter part of the Little Ice Age into the present era, Nile floods are high; but this contrary prediction to north European events may be connected to a displacement of the ITCZ, owing to the delayed decline of the corresponding Little Ice Age in the southern hemisphere (Lamb 1977, 449ff).

Since the last century, the extensive traces of Roman settlement and agriculture (field systems, irrigation works), thoughout north Africa, have inspired theories of climatic decline to account for subsequent abandonments and less intensive land-use and settlement (Shaw 1978). The study of classical references to the area seems to have supported such ideas, but makes no allowance, for example, for surviving fossil water (Lamb 1977, p.387). On the other hand, it is, as with the south Levant, precisely during the later period of Roman occupation and the subsequent 1400 years in north Africa, that the extensive Younger Fill was largely being deposited (Vita-Finzi 1969a), which, though possibly assisting late Roman agriculture and that of the sub-Roman cities and their cultural successors under Islamic rule, should also have offered an incentive for equally widespread land use till recent times. Once again, climatic change may have been important for the maintenance of an already successful adaptation, but was less powerful than cultural factors in the long-term survival of intensive agriculture. The references of Arab sources to moister than present-day climate in north Africa overlap with the 'early medieval warm era' of north-west Europe, and are seen as further support for a localised bitrack depression series (Lamb 1977, p.440ff.) The juxtaposition of humid indicators and drought in literary sources for the Little Ice Age period in north Africa compares well with the other evidence for the same phenomenon, both in other parts of the Mediterranean and north of the Alps (Lamb 1977, pp.469; 1979).

This general survey of the Mediterranean and Near Eastern data for the Sub-atlantic period does seem to bring out some broad consistencies in climatic trends over the whole region. A climate comparable to that of the present day, perhaps warmer and drier, predominates until late Roman times, followed by a period up to 150 BP (AD 1800) or so, in which abundant evidence exists from historical sources and geomorphic data for greater rainfall, often associated with suggestions of cooler climate but also for severe drought. Less clear is a possible interval of warmer conditions around 950 BP (AD 1000).

It is well worth comparing this summary with Lamb's reconstruction of the climatic sequence, based predominantly on north-west European evidence:

> There was a gradual, fluctuating recovery of warmth and a tendency towards drier climate in Europe over the 1000 years after 600 BC, particu-

larly after 100 BC, leading to a period of warmth . . . around AD 400. After some reversion to colder and wetter climates in the next 3–4 centuries, sharply renewed warming from about AD 800 led to an important warm epoch which seems to have culminated around AD 900–1200 in Greenland and AD 11–1300 in Europe. In these few centuries the climates in the countries concerned evidently became briefly nearly as warm as in the postglacial warmest times . . . (but) the Little Ice Ages centuries . . . followed. (1977, p.374)

It is important for the Little Ice Age that Lamb argues for conditions 'when the extent of ice on the Arctic seas and of ice and snow on land seems to have been greater than at any time since the last major glaciation' and with weather features which 'indicated a significantly wide range of year to year variability in the Little Ice Age, which seems to have been associated with a reduced frequency of westerly winds in Europe and increases in the frequency of winds from most other directions', producing 'alternations of extreme seasons' (Lamb 1979).

In general, Lamb considers the Sub-atlantic to be marked by a southward shift in the belts of climate, but with pronounced fluctuations of warmth and cold, dryness and moistness, associated both with fluctuations in this zonal shift (*Model One*), and with the effects of blocking of the westerlies, either by expanded subtropical anticyclones in warming phases, or polar highs in cooling phases (*Model Two*). Compare, for example, his analysis of the Early Medieval Warm Era:

All these observations of the medieval period could probably be explained by a circulation pattern in which the northern hemisphere subtropical anticyclones were on the whole displaced somewhat to the north during the time of warm climate in Europe, Greenland and North America. During most of the time the middle latitudes westerly winds were presumably weaker and less prevalent in latitudes between 40° and 60°N than now or than they became from AD 1200–1300 onwards. While central and northern Europe were enjoying more frequent anticyclonic influence, and rather sluggish westerlies or more variable winds, the Mediterranean zone . . . may well have experienced more frequent cyclonic activity of various types – e.g. slow moving cut-off cyclones and khamsin depressions [cf. our 'bitrack' and 'Sudan-Sahel' trans-Sahara depressions]. (Lamb 1977, p.440)

If one is seeking confirmatory evidence of northern hemisphere – and indeed global – cooling, and hence expansion of the circumpolar vortex in the Dark Ages and the later Medieval to Early Modern period, the evidence is impressive (May 1979, La Marche 1974, Porter 1979).

Finally, some further discussion of the interesting phenomenon of the Younger Fill is required. Despite accumulated criticism of this seemingly too simple alluvial formation, the continuing accretion of consistent dates for the Fill (cf. recently Roberts 1979) appears to be stimulating a rethink in favour of Vita-Finzi's original dating, allowing for more localised earlier formations

(Eisma 1978; Davidson, pers. comm.). Tentative diachronic appearance of the Fill in different latitudes has also led Vita-Finzi to elaborate on his southward cyclonic displacement model, with the most extreme displacement belonging to the time of the Little Ice Age and hence suiting the first clear traces of the Fill in Arabia (Vita-Finzi 1976).

But the origin of the Fill cannot simply be assigned to stormtrack displacement south, for, as we have seen, this could be argued to have occurred recurrently throughout the Holocene in the Mediterranean latitudes. This may be an opportunity to seek some middle ground between a purely climatic causation and those who have persistently ascribed the Fill to human erosion. The obvious criticism of the erosion viewpoint has been the clear evidence from archaeology and history of considerable deforestation and continual slopewash from agricultural activity, dating well back into the Atlantic period in most countries concerned, long before the main dates for alluvial deposition.

Martin Bell's research (see this volume) into the history of English chalkland hillwash is a major contribution to the source and chronology of colluvia, and to a lesser extent alluvia. But there are a number of problems apparent from his exposition to which I would like to draw attention. First, from the viewpoint of an archaeologist, if major land clearance and widespread mixed farming were seen to be responsible for the bulk of the European colluvia and alluvia, I would expect this to be rampant in the Neolithic era, the later fourth and throughout the third millennia bc; but dates obtained on both types of deposit commence generally in the second millennium and increase into the first and beyond. Yet the North American sediment-supply graphs discussed by Martin Bell exhibited a remarkable peak of erosion immediately after clearance then a drop to a much lower level hereafter: there will be many Neolithic specialists who won't take kindly to a vision of Neolithic southern Britain populated by a few busloads of people living in small clearings in the primeval woodlands! Now we have exactly the same sequence in the Mediterranean region, with clear evidence for major forest clearance and dense farming populations from the Neolithic onwards, but the vast bulk of the alluvial aggradations in valleys dated to Late Roman times and later. And we now also have well-dated colluvial deposits there from the Bronze Age onwards.

Secondly, I think we now have to move much further into understanding the processes involved in erosion, slopewash, and river alluviation. Martin Bell seemed to indicate that erosion downslope was a direct precursor of river alluviation. In fact this is commonly not the case, and colluvial deposits accumulate and remain up against walls as lynchets, or stabilise at a certain angle of repose on hillslopes. But even if there is enough later sediment or run-off, pushing these further, colluvial sediment that reaches river systems need not be deposited as a terrace deposit or aggradation. In fact, in my experience in Britain, and that of many other people interested in British river terraces, most sediment now entering streams is in quantities within the competence of those bodies of water to shift continually downstream to base level, a lake or the sea. So at the present day we are not usually seeing erosion building up river aggradation, and the late prehistoric and historic alluvial material exists as a freestanding terrace above the presently incised course. Only if the input of sediment is far beyond stream capacity will alluviation normally develop along the full length of a river system. Likewise, Mediterranean Younger Fill is a fossil deposit above modern incising streams.

It is in response to these considerations that, as part of an interdisciplinary project in central Greece, we have been trying to achieve a more detailed explanation of the subtle interaction of soil erosion, colluviation, alluviation, human activity and climatic change. We now believe that from the first clearance of open woodland in Greece, and even before in the driest regions, there existed exposed soils that were available for rain and wind erosion. Human cultivation and grazing would have furthered the natural processes of hillwash, creating a continual creep of colluvial sediment on all but the gentler slopes. In many areas terracing will have been an early adaptation to this threat, but elsewhere the material either came to rest as it accumulated at a shallower angle on the hillslope, or at the break of slope below, or else found its way into the river systems. But the extremely limited exposures of inland alluvial sediments dating to the pre-Classical period, in contrast to the dense build-up at the coast, argues for the amounts in stream bedload being within stream capacity to transport onwards.

All this changes dramatically in Late Roman and Medieval times, with the build-up along virtually every Mediterranean stream of a continuous sequence of well-bedded alluvium generally 1–3 metres high. We can be fairly certain that this is not the time of too dense a rural population and an unparalleled intensity of agriculture, ruling out the direct ploughwash theory. Some have suggested that the known late antique depopulation meant massive field abandonments and neglect of terrace walls, thus releasing centuries if not millennia of pent-up soil to choke streams. Our project botanists reject this, as it is clear that abandoned terraces are very rapidly colonised and stabilised by the ever-present ruderal plants and scrub that occupy terrace peripheries. A possible key may lie in our observations in 1980 in the 'Theban Badlands': here we can see a district of soft rock hill-land, quite typical for deposits favoured by early European farmers, betraying the massive erosion cones of Badlands topography. It is clear that till recently there was very active movement on all these slopes into the valley below. But also clear is the fact that all this has now stopped and vegetation is colonising and stabilising the whole area. It is my hypothesis at present that in the not too distant past the local climate was highly variable, with severe droughts inhibiting scrub colonisation and loosening the topsoil, alternating with dramatic rainfall, producing these great colluvial sediment flows; such a climate may have characterised the latter part of the Little Ice Age in the Mediterranean up till the middle of the last century; the current less extreme climate is encouraging scrub growth and is insufficient to push further sediments downhill. Archaeological evidence suggests that this colluvial sequence is largely post-Classical in date. The juxtaposition of abnormal wet and dry seasons we have already seen to be both feasible for earlier periods of deteriorating climate in Europe and a recorded feature of the Mediterranean historical record.

The peak periods of British hillwash and river alluviation, may, perhaps, reflect a similar interaction of a pronouncedly variable Sub-boreal climate, a possible concentration of wet conditions in the early Sub-atlantic and mid first millennium AD, and accumulated field erosion and slopewash.

Finally, what link, if any, could be made between Mediterranean civilisational decline and climatic change? Both Vita-Finzi and I (Vita-Finzi 1969a; Bintliff 1977, 1981), have suggested that the loss of hill-land and valley fields due to enhanced erosion, poorly controlled, aggrading rivers, and the decline in warmth that could have had deleterious effects on crops (cf. the frost killing of Provence oranges and olives during the Little Ice Age cited by Lamb 1977, p.466; Pichard 1979), must have been significant in the decline of the Roman and Byzantine empires. The suggestions of Lamb on pronounced meridional flow and blocking régimes, to be associated with this southward displacement, whilst accounting for apparent contradictions in the Mediterranean evidence for this period, also indicate a further source of problems for human communities, with the unparalleled and unpredictable shifts from year to year of drought and flooding, parching and freezing.

REFERENCES

Barcelo, M. (1979) Locust plagues in mid-west Hispania in the 6th and 7th centuries as a climatic factor. Paper presented at the 1979 *International Conference on Climate and History,* University of East Anglia.

Barker, G. *et al.* (1978) A Classical landscape in Molise, *Papers of the British School at Rome* 46, 35-51.

Bell, B. (1971) The Dark Ages in Ancient History: 1. The First Dark Age in Egypt, *Am. J. Archaeol.* 75, 1-26.

— (1975) Climate and the history of Egypt: the Middle Kingdom, *Am. J. Archaeol.* 79, 223-69.

Besançon, J. (1980) Stratigraphie et chronologie du Quaternaire continental du Proche Orient. Paper given at the 1980 *Lyons Symposium on the Prehistory of the Near East.*

Bintliff, J. L. (1975) Mediterranean alluviation: new evidence from Archaeology, *Proc. Prehistoric Soc.* 41, 78-84.

— (1977) *Natural Environment and Human Settlement in Prehistoric Greece.* British Archaeological Reports, Suppl. Ser. 28 (1-2), Oxford.

— (1981) Archaeology and the Holocene evolution of coastal plains in the Aegean and Circum-Mediterranean, in Brothwell, D. & Dimbleby, G. (eds) *Environmental Aspects of Coasts and Islands.* British Archaeological Reports, Int. Series, 94, Oxford.

Bottema, S. (1977) A pollen diagram from the Syrian Anti Lebanon, *Paléorient* 3, 259-68.

— (1978) The Late Glacial in the eastern Mediterranean and the Near East, in Brice, W. C., ed. (1978) 15-28.

Brice, W. C., ed. (1978) *The Environmental History of the Near and Middle East.* London: Academic Press.

Brookes, I. A. & Dennell, R. W. (1977) Spatial and temporal relations between geomorphic elements and human occupation in part of Central West Iran. Paper presented to the 10th INQUA Congress, Birmingham.

Brooks, C. E. P. (1949) *Climate Through the Ages*. 2nd ed. London.

Bryson, R. A. *et al*. (1974) Drought and the decline of Mycenae, *Antiquity* 48, 46-50.

Butzer, K. W. (1978) Environmental history of the Near East since the Last Pleniglacial. Paper given at the Tübingen Conference on *The History of Environmental Conditions in South West Asia*.

Carpenter, R. (1966) *Discontinuity in Greek Civilisation*. Cambridge: University Press.

Crown, A. D. (1972) Towards a reconstruction of the climate of Palestine 8000 BC–0 BC, *J. Near Eastern Studies* 31, 312-30.

Davidson, D. A. (1971) Geomorphology and prehistoric settlement of the plain of Drama, *Rev. Géomorph. Dyn.* 20, 22-6.

— *et al*. (1976) Erosion and prehistory in Melos: a preliminary note, *J. Archaeological Science* 219-27.

— (1980) Erosion in Greece during the first and second millennia BC, in Cullingford, R. A. *et al*. (eds) *Timescales in Geomorphology*, 143-58. London: John Wiley.

Dayton, J. (1975) The problem of climatic change in the Arabian Peninsula, *Proc. Seminar for Arabian Studies* 5, 33-60.

De Cardi, B., Vita-Finzi, C. & Coles, A. (1975) Archaeological survey in Northern Oman, *East and West* 25, 9-75.

Deuser, W. G. *et al*. (1976) Glacial and pluvial periods: their relationship revealed by Pleistocene sediments of the Red Sea and Gulf of Aden, *Science* 191, 1168-70.

Dickinson, O. T. P. K. (1974) Drought and the decline of Mycenae: some comments, *Antiquity* 48, 228-30.

Diester-Haass, L. (1973) Holocene climate in the Persian Gulf as deduced from grain-size and pteropod distribution, *Marine Geology* 14, 207-23.

Dufaure, J. J. (1976) La terrasse holocène d'Olympie et ses equivalents méditerranéens, *Bull. Assoc. Géogr. Franç.* 1976, 85-94.

Eisma, D. (1964) Stream deposition in the Mediterranean area in historical times, *Nature* 203, 1061.

— (1978) Stream deposition and erosion by the eastern shore of the Aegean, in Brice, W. C. (ed.) *The Environmental History of the Near and Middle East*, 67-81.

Erinc, S. (1978) Changes in the physical environment in Turkey since the end of the Last Glacial, in Brice, W. C. (ed.) *The Environmental History of the Near and Middle East*, 87-110.

Evenari, M. *et al*. (1971) *The Negev*. Harvard: University Press.

Farrand, W. R. (1979) Blank on the Pleistocene map, *Geogr. J.* May 1979, 548-54.

Flohn, H. & Nicholson, S. (1979) Climatic fluctuations in the arid belt of the 'Old World' since the last glacial maximum. Paper circulated at the 1979 *International Conference on Climate and History*, University of East Anglia.

Goldberg, P. (1980) Late Quaternary stratigraphy of Israel: an eclectic view. Paper given at the 1980 Lyons *Symposium on the Prehistory of the Near East*.

Griswold, W. J. (1979) Climatic variation and the social revolutions of seventeenth century Anatolia. Paper given at the 1979 *International Conference on Climate and History*, University of East Anglia.

Guinis, S. C. (1976) New evidence on the stability of the Greek climate in historical times, *Praktika tes Akademias Athenon* 51, 323-9.

Hecht, A. D. (1979) Palaeoclimatic research: status and opportunities, *Quaternary Res.* 12, 6-17.

Kirkby, M. J. (1977) Land and water resources of the Deh Luran and Khuzistan Plains, Appx. 1, in F. Hole (ed.) *Studies in the Archaeological History of the Deh Luran Plain, The Excavation of Chagha Sefid*, Memoirs of the Museum of Anthropology, University of Michigan, 9.

La Marche, V. C. (1974) Palaeoclimatic inferences from long tree-ring records, *Science* 183, 1043-8.

Lamb, H. H. (1967) Review of Rhys Carpenter, *Discontinuity in Greek Civilisation*, *Antiquity* 41, 233-4.

— (1977) *Climate: Present, Past and Future*. *2. Climatic History and the Future*. London: Methuen.

— (1978a) The variability of climate, in Fryendahl, K. (ed.) *The Nordic Symposium on Climatic Changes and Related Problems*, 116-44. Copenhagen.

— (1978b) Towards an understanding of climatic change, in Frydendahl, K. (ed.) *The Nordic Symposium on Climatic Changes and Related Problems*, 181-204. Copenhagen.

— (1979) An approach to the study of the development of climate and its impact on human affairs. A paper given at the 1979 *International Conference on Climate and History*, University of East Anglia.

Lamb, H. H. & Dickinson, R. R. (1975) Recent hydrometeorological events in the North Atlantic sector, *Bird Study* 22, 142.

Lipschitz, N. *et al*. (1979) Fluctuations in the aridity line in Israel during the Late Bronze Age. Paper given at the 1979 *International Conference on Climate and History*, University of East Anglia.

McGhee, R. (1979) Archaeological evidence for climatic change during the past 5000 years. Paper given at the 1979 *International Conference on Climate and History*, University of East Anglia.

Magaritz, M. & Kaufman, A. (1973) Changes in the isotopic composition of East Mediterranean seawater during the Holocene, *Nature* 243, 461-4.

May, R. M. (1979) Arctic animals and climatic changes, *Nature* 281, 177-8.

Meigs, P. (1961) Some geographical factors in the Peloponnesian War, *Geogr. Rev.* 31, 370-81.

Oates, J. & D. (1976) *The Rise of Civilisation*. Oxford: Elsevier-Phaidon.

Olausson, E. & Olsson, I. U. (1969) Varve stratigraphy in a core from the Gulf of Aden, *Palaeogeogr., Palaeoclimat., Palaeoecol.* 6, 87-103.

Pichard, G. (1979) The part played by climate in the social and agricultural stagnation of Provence 1680-1718. Paper given at the 1979 *International Conference on Climate and History*, University of East Anglia.

Porter, S. C. (1979) Glaciological evidence of Holocene climate change. Paper given at the 1979 *International Conference on Climate and History*, University of East Anglia.

Potter, T. W. (1979) *The Changing Landscape of South Etruria*. London: Elek.

Price-Williams, D. (1973) Environmental archaeology in the Western Negev, *Nature* 242, 501-3.

Raphael, C. (1973) Late Quaternary changes in coastal Elis, Greece, *Geogr. Rev.* 63, 73-89.

Roberts, N. (1979) The location and environment of Knossos, *Ann. British School at Athens* 74, 231-41.

Rognon, P. & Williams, M. A. J. (1977) Late Quaternary climatic changes in Australia and North Africa: a preliminary interpretation, *Palaeogeogr., Palaeoclimat., Palaeoecol.* 21, 285-327.

Rothlisberger, F. (1979) Dendroclimatological chronologies in the Holocene period. Paper given at the 1979 *International Conference on Climate and History*, University of East Anglia.

Schoeli, M. & Faber, E. (1978) New isotopic evidence for the origin of Red Sea brines, *Nature* 275, 436-8.

Shaw, B. D. (1978) Climate, environment and prehistory in the Sahara, *World Archaeology* 8, 133-49.

Vita-Finzi, C. (1969a) *The Mediterranean Valleys*. Cambridge: University Press.

— (1969b) Late Quaternary alluvial chronology of Iran, *Geol. Rundschau* 58, 951-73.

— (1969c) Late Quaternary continental deposits of central and western Turkey, *Man* 4, 605-19.

— (1975) Quaternary deposits in the Iranian Makran, *Geogr. J.* 141, 415-20.

— (1976) Diachronism in Old World alluvial sequences, *Nature* 263, 218-19.

Vita-Finzi, C. & Copeland, L. (1978) Archaeological dating of geological deposits in Jordan, *Levant* 10, 10-25.

Van Zeist, W. & Bottema, S. (1977) Palynological investigations in Western Iran, *Palaeohistoria* 19, 19-85.

— (1980) Palynological evidence for the climatic history of the Near East, 50,000–6000 B P. Paper given at the 1980 Lyons *Symposium on the Prehistory of the Near East*.

Weikinn, C. (1958) *Quellentexte zur Witterungsgeschichte Europas*, Vol. 1. Berlin: Akademie Verlag.

Winstanley, D. (1973) Recent rainfall trends in Africa, the Middle East and India, *Nature* 243, 464-5.

Wright, H. E. (1968) Climatic change in Mycenaean Greece, *Antiquity* 42, 123-7.