CLIMATIC CHANGE, ECOLOGY AND MIGRATION

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From the days of Herodotus[1] the influence of climate upon mankind has been recognised in varying degrees by philosophers, geographers and historians.[2] In the nineteenth century a number of historians and anthropologists gave a new impetus to the study of the environmental influence on man and, under their influence, a number of historians of Islam and of the ancient Near East, especially Hugo Winckler and Leone Caetani[3] developed theories of climatic change and demographic movement. Incursions of Semites into the fertile crescent, the Amorite movement, the Nabatean and Islamic invasions, were regarded as having been responses to changes in climate which made the environment hostile by desiccation, hence producing a pressure of population which could only be relieved by an explosive outward movement of people.

In the twenties of this century a school of geographers led by Ellsworth Huntington[4] and C. E. P. Brooks[5] advanced major hypotheses of climatic change and its influence on civilization. However, the warnings of the human geographers, especially of the French 'possibilist' school[6] against over-emphasising the degree to which human occupance may be determined by environmental and climatic factors inhibited the use of geographical deterministic concepts by historians. Moreover, there were severe technical problems in fixing chronologies of climatic change and of evaluating what is meant by climatic change. Again, whilst a causal relationship between climate and demographic distribution and

1. Herodotus, *The Histories*, 2:79 (in the translation of A. de Selincourt, Pelican Books, 1968 reprint).
2. A brief introduction to the subject is found in Sheikh Inayatullah, *Geographical Factors in Arabian History* (Lahore, 1942).
3. Hugo Winckler, *Arabisch-Semitisch-Orientalisch, Kulturgeschichtlich-mysthologische Unterachüng* (Berlin, 1901), and Leone Caetani, *Studia di Storia Orientale*, vol. 1 (Milano, 1911).
4. E. Huntington, *Palestine and Its Transformation* (London, 1911), E. Huntington and S. S. Visher, *Climatic Changes, Their Nature and Their Causes* (New Haven, 1922), etc.
5. C. E. P. Brooks, *Climate Through the Ages* (London, 1926—New ed. London, 1970).
6. A very brief sketch of the work of the great French master geographers is to be found in J. H. G. Lebon, *An Introduction to Human Geography* (London, 1964).

movement was postulated evidence of human movements and occupance was accepted as evidence of climatic change. The nature of the argument was often one of circularity. Furthermore, the theory of climatic change put forward was one of progressive desiccation; the basic evidence was striking but misleading. Whilst Roman bridges do appear in wadis that are currently dry and there are indeed signs of cities and settlements in lands which appear to be arid[7] appearances may well be deceptive. As Butzer has noted[8] many of these so called evidences of and testimonies to climatic change in the Mediterranean region appear within 200^{mm}-500^{mm} isohyet zone, a region well able to support life today, despite initial appearances.

In reaction to the obvious flaws in this hypothesis of progressive desiccation, ancient Near Eastern historians and archaeologists have been sceptical of climatic change in the Holocene era (which should be seen as beginning c. 11,975 B.P. $\mp$ 370 B.P.)[9] and little further discussion of the issue, except by way of denial,[10] took place until the late 1950's.

Since the middle of the 1950's not only has new evidence been accruing from varve studies, dendrochronology, geomorphology, geochemistry and glaciology, but substantial strides have been made in palaeometeorology, palaeolimnology and oceanography. Above all there has developed almost a portfolio of radiocarbon datings from all over the world. These developments have provided the tools with which palaeoclimatologists can examine the record of climatic change independently of the dubious and circular archaeological evidence.[11] Anthropologists have long turned these tools to the study of the Pleistocene environment in which palaeolithic man lived and archaeologists and historians are now taking up these tools for the study of the Holocene environment. In view

7. Huntington, *op. cit., passim.*
8. Cf. K. W. Butzer, *Climatic Change in Arid Regions Since the Pliocene*, in L. Dudley Stamp, *A History of Land Use in Arid Regions*, UNESCO (Paris, 1961), pp. 44, 46.
9. Cf. M. Neustadt, "The Lower Holocene Boundary", *INQA*, vol. 7 of 7th Congress, 1967, pp. 413-415.
10. Cf. W. F. Albright, *From the Stone Age to Christianity* (Baltimore, 1946), pp. 71-74. Also, A. Reifenberg, *The Struggle Between the Desert and the Sown* (Jerusalem, 1955), pp. 22-23.
11. Cf. the discussions in three recent surveys, *Changes of Climate* (Proceedings of the Rome Symposium, UNESCO, 1963—hereafter CC. UNESCO. *Solar Variations, Climatic Change and Related Geophysical Problems, Annals of the New York Academy of Science*, Vol. 95, pt. 1, 1961—hereafter CC.ANYAS. *World Climate from* 8000 *BC-BC* (Symposium of the Royal Meteorological Society, London, 1966) hereafter CC.RMS.

of the special interest in the Near East as one of the cradles of civilization a number of recent attempts have been made to describe the palaeoclimates of the region and the impact of these climates on man. To the new tools provided by the new sciences should be added the remarkable amount of statistical evidence which has been forthcoming from the Unesco arid-zone research programme. In the days of the progressive desiccation theory none of this statistical evidence was available.

Today the whole environmental basis of ancient life has come under detailed study (though there has not yet been a determined attempt to write an integrated history using the whole range of ecological principles and archaeological data) and some scholars have begun to define their disciplines as environmental archaeology or archaeological ecology. Developments in palaeoclimatology are but one aspect of this reassessment of the role of environment in history.[12] With this revival of interest have come new criticisms. In 1966 Rhys Carpenter published his *Discontinuity in Greek Civilization* propounding the view that climatic change in southern Greece caused the breakdown of the Mycenean economy. Immediately a number of criticisms appeared.[13] The theme has been taken up again in 1971 by Bell, who has launched the first of a series of studies of "Dark Ages in Ancient History" with a study of the first dark age in Ancient Egypt.[14]

It is the purpose of this paper to extend this discussion by considering the evidence for climatic fluctuation in the ancient Near East and the possibility of applying this evidence to explain demographic changes.

A prerequisite of the discussion is to clarify what is meant by climatic change. Le Roy Ladurie, applying the work of Pedela-

12. Cf. especially the work of Karl Butzer in the many symposiums on the subject for the integration of climatological and historical data.
13. Cf. especially H. E. Wright Jnr., "Climatic Change in Mycenean Greece", *Antiquity*, vol. 42, 1968, pp. 123-127. For a renewed discussion of other critical views, cf. R. O. Whyte, "Evolution of Land Use in South West Asia", in Stamp, *op. cit.*, p. 66f.
14. Cf., Barbara Bell, in *American Journal of Archaeology*, vol. 75, No. 1, 1971, pp. 1-26. Her second article in the series is to be on the period 1990-1750 BC (private communication). Cf. also M. Liverani, "Variazoni Climatiche E Fluttuazioni Demografiche nella Storia Siriana", *Oriens Antiquus*, vol. 7, No. 1. 1968, pp. 77-89; E. Demougeot, "Variations Climatiques et Invasions", *Revue Historique*, vol. 233, 1965, pp. 1-22; E. Le Roy Ladurie, "Aspects Historiques de la Nouvelle Climatologie", *Revue Historique*, vol. 225, 1961, pp. 1-20. A. D. Crown, "Towards a Reconstruction of the Climates of Palestine, 8000-0 BC" in press for *Journal of Near Eastern Studies*, 1972.

borde[15] to historical researches has observed that there are three types of climatic oscillation. The first of these, the 'geological', is that which is to be measured in millions of years and is of the type which brought periods of intense glaciation to the world in Pre-Cambrian, Siluro-Devonian, Permo-Carboniferous and Quaternary times and is beyond the scope of this discussion. The second type of fluctuation, "Les oscillations climatiques proprement dites" (p. 2) are fluctuations of some centuries in duration. The third type is the fluctuation lasting but a few decades but which may be of considerable ecological significance. An example of such a short-term fluctuation is to be found in the meteorological record of our own era. From the 1880's to the 1940's there was a net secular warming amounting to some 1°F. in the tropics.[16] This warming and the associated droughts of the 1930's had a profound effect on the agriculture of the American middle west. To these types of fluctuation should be added a fourth, which, in given circumstances, could be of considerable effect, namely, the year to year fluctuations around the mean climatic regime of a period.[17]

Whilst Ladurie's outline is useful as a rough guide it is not adequate as a key to what the historian means by climatic change. For one thing there must be some means of quantatitive estimation of changes. Such terms as wetter, drier and colder are poor alternatives to statistical estimates of deviation from current norms. If statistical evidence is lacking then we need evidence of vegetation patterns to give guidance as to the nature of the biotic environment.

Secondly, we must have some means of estimating what a given fluctuation would mean in specific biomes. Rainfall is significant only in relationship to its effectiveness (the season in which it falls, its distribution, and the evapotranspiration rate) and effectiveness varies from environment to environment. A change in the reliability of rainfall or in its distribution, might have little effect in one region but might have critical implications for human occupance in another. In marginal, semi-transitional lands such as in the Near East where the border between the desert and the

15. Le Roy Ladurie, *op. cit.*, quoting Pierre Pedelaborde, *Le Climat du Bassin Parisien; essai d'une methode rationelle de climatologie physique* (Paris, 1957).
16. J. M. Mitchell Jnr., "Recent Secular Changes of Global Temperature", *CC.ANYAS*, and *ibid.*, "On the World Wide Pattern of Secular Temperature Change", *CC.UNESCO*, pp. 161-181.
17. Cf. D. H. K. Amiram, "Effects of Climatic Change in an Arid Environment on Land Use Patterns", *CC.UNESCO*, pp. 439-443. Also F. H. Perring, "The Advance and Retreat of the British Flora" in C. G. Johnson and L. P. Smith, *The Biological Significance of Climatic Change in Britain* (London, 1965), p. 61.

sown is a critical factor which has been called a biological threshold, even a very small change in the amount of distribution of rain can have a significant effect on the hydrographic balance, hence on the biome. The growing season could be extended by some weeks or there could be a change in the biome by replacing xerophytic vegetation adapted to long periods of drought with less drought resistant types.[18] Such a change could theoretically take place within a period of fifty years.[19]

Again, the tolerance of vegetational climaxes is such that in one region a fluctuation in temperature might have little significance whereas in another it might have substantial impact. It has been estimated that an annual increase of 1°C. from current norms in Britain would increase the growing season by two weeks per annum.[20] In those parts of the Near East where climate is modified by altitude a short term fluctuation in temperature might have substantial implications for the environment.

It is clear from the foregoing that there is no absolute quantitative structure by which we can define climatic change. Climatic change is relative to its own environment; its effects rather than its size are the means of judging the significance of a climatic deviation from the 'norm'. We may, then, define climatic change as a fluctuation in climate which affects the possibilities which any given environment offers to man for his livelihood so that man is forced to adjust to the change in possibilities. It should be noted that the size of a fluctuation needed to affect the possibilities open to man in semi-arid environments is not great.

In view of the diverse regional effects of climatic change it is clearly a matter of some importance to define the region under discussion. For the purpose of this paper the Near East is defined as the "Basic (Mediterranean type climatic) region between the Mediterranean Sea in the west to the Iranian borders with Pakistan, Afghanistan and the Union of Soviet Socialist Republics in the east".[21] To the north parts of Anatolia are to be included, and to the south, Arabia north of Mecca where the boundary between climates of Mediterranean and tropical bias may be said

18. Cf. Robert Raikes, *Water, Weather and Prehistory* (London, 1967), p. 72.
19. Cf. R. L. Specht, "Microenvironment (soil) of a Natural Plant Community" in *Australia UNESCO Symposium on Arid Zone Climatology with Special Reference to Micro Climatology* (Canberra, 1956), p. 15d.
20. Cf. Perring, *loc. cit.* and Raikes, *loc. cit.*
21. G. Perrin de Brichambaud and C. C. Wallen, *A Study of Agroclimatology in Semi Arid and Arid Zones of the Near East*, WMO—No. 141 Technical paper 66, 1963, p. 2.

to fall.[22] Despite this very strict regional determination, most of the Mediterranean basin from Spain and Morocco in the west is clearly part of the same climatic zone which is characterized by 'sub-tropical' summer temperatures with gently subsiding air and a winter regime in which wind and pressure factors are dominant in giving a homogeneous rainfall pattern though there are times when convectional influences might be considerable.[23] It is reasonable to suggest that, provided the same climatic controls have pertained throughout the Holocene, data may be extrapolated from this wider region to study the smaller region as defined. It is less feasible, as Naveh has demonstrated,[24] to extrapolate data from homoclimes on other continents, though the process is not impossible.

There are many evidences for climatic change in the Holocene. A basic general study that gives a very rough but sound guide to the palaeoclimate of the Holocene is the reconstruction by Lamb *et al*[25] of the changes in atmospheric circulation in response to known conditions of land and sea heatings, ice and ground moisture conditions and vegetation cover at dates around 6500 BC, 4000 BC, 2000 BC and 500 BC (thus excluding the early Holocene on the grounds that it showed obvious features of rapid change and warming).

This palaeometeorological study indicates that until about 6000 BC there was a habitual joining of the anticyclones of the Azores-Biscay with N.E. Europe, which would have generated summer cyclogenesis with associated rainfall conditions. This would have affected the Near East by inducing some summer rainfall. The southern Mediterranean region and Palestine up to about 5000 BC would thus have come under the influence of both broadened trade wind belts and equatorial regimes with some summer monsoon rains.[26] From then until something after 4000 BC the circulation is held to have weakened and have become

22. Cf. *Ecological Study of the Mediterranean Zone, Bioclimatic Map of the Mediterranean Zone, Explanatory Notes, UNESCO FAO* (Paris, 1963), p. 36.
23. For fuller descriptions of the climate of the region, cf. A. de Philippis, *Rapport de groupe de travail sur la delimitation de la region Mediterraneene,* FAO (Rome, 1951).
24. Z. Naveh, "Mediterranean Ecosystems and vegetation types in California and Israel", *Ecology,* vol. 48, 1967, pp. 446-458.
25. H. H. Lamb, R. P. Lewis and A. Woodroffe, "Atmospheric Circulation and the Main Climatic Variables, Between 8000 BC and 0 BC: Meteorological Evidence", CC. RMS pp. 174-218.
26. Cf. H. H. Lamb, "On the Nature of Some Climatic Epochs Which Differed from the Modern (1900-1939) Normal", *CC.UNESCO,* p. 125f.

more zonally oriented with a return of high pressure belts to lower latitudes. The westerly regime would have spread further into Europe and, in winter, into north west Asia with a consequence for the Mediterranean region of longer summers and drier winters than today. The data for this discussion are regarded as being reliable until about 2000 BC, at which time the data are regarded as less reliable. According to Lamb, at the beginning of the first millennium BC European winters were colder than in the two preceding millennia, and there were marked thermal contrasts in summer between the land mass of North America, then at its warmest Holocene phase, and the Arctic Ocean. The result was active cyclogenesis with a consequence for the Mediterranean region of winters somewhat longer than they are today through an extension to the south of the belt of cyclonic activity, though summer conditions may have been similar to those currently prevailing.

It is impossible to indicate reliable quantitative differences from current norms in regard to temperature or precipitation. Raikes,[27] whilst rejecting the idea of significant fluctuation after 3000 BC, has indicated his belief that precipitation at the beginning of the Holocene was as much as 60% more than today in the wetter parts of the fertile crescent and up to 33% more in the drier parts. If this general estimate be admitted as a datum of reference then by correlation with Lamb's calculations and other estimates the volume of rainfall c. 4000 BC may be seen as only 50% of today's norms, whereas shortly after 2000 BC it might be as much as 10% above.

A second general study of which note should be taken is that of J. D. Wiseman,[28] who studied the rate of sedimentation of $CaCo_3$ in the oceans. Wiseman noted that the deep sea bed was not a quiescent environment with a continuous rain of biological and mineral debris but that sedimentation rates varied with changes in temperature. From radio-carbon dating of cores taken from the Atlantic Ocean Wiseman has been able to reconstruct a graph of temperature changes which seems to correlate well with secular temperature changes assumed from other sources. However, since a clear relationship between ocean temperatures and secular temperature changes is not yet established, it would be wise to refer to Wiseman's results only sparingly. Suffice it to say that the pattern established by Wiseman shows a steady rise in temperature throughout the Holocene to a maximum about 4000 BC when

27. *Op. cit.*, p. 52.
28. J. D. H. Wiseman, "Evidence for Recent Climatic Changes in Cores from the Ocean Bed", *CC.RMS* pp. 84-98.

temperatures appear to have been somewhat higher than those pertaining today. After 4000 BC temperatures declined.

A third general picture is that derived from a study of the depositional processes of the Dead Sea by Neev and Emery,[29] who reconstructed the hydrological history of the Dead Sea and its catchment area with the aid of radio-carbon dating of the organic matter in the sediments. This study is made doubly valuable by including a climatological interpretation of the hydrographical history integrating the study of run-off rates, sediment and geological structure. A brief correlation with the historical data is also attempted.

From the beginning of the Holocene to about 5000 BC a series of greenish grey laminated sediments was laid down, indicating a long humid episode though no deductions about temperature can be made. From about 5000 BC the climate seems to have become steadily drier on the basis of an increasing number of salt tongues and substantial changes in the run-off pattern. Neev and Emery estimate[30] that the driest period in the Holocene was the millennium between 4500 BC and 3500 BC. Subsequently they estimate that there was a return to the previous humid conditions (though again no temperatures are indicated) and this humid spell lasted until about 2300 BC when there was another marked dry episode. From 2300 BC until a few hundred years ago Halite has been continuously deposited in the southern Dead Sea basin, from which fact Neev and Emery infer that the climate of Palestine has been relatively static since the end of the renewed dry period, sometime between 2300 BC and 2000 BC. They have characterized this 4000 year epoch as 'mostly dry with some humid episodes'.[31]

The basic study of climatic change in North Africa (north of the Sahara) is Butzer's.[32] However, one must treat his many writings with some caution as he does not rely on physical agencies alone for his evidence but assesses human activities concurrently with the physical agencies. The dangers inherent in this process have already been noted. However, with due caution exercised, one sees a general pattern emerging from his work. He has suggested on the basis of detailed work on dune movement, the development of red palaeosoils and the presence of a particular species of moisture-loving snail that there was a moist interlude in Egypt

29. D. Neev and K. O. Emery, *The Dead Sea. Depositional Processes and Environments of Evaporites* (Jerusalem, 1967).
30. *Ibid.*, pp. 26-30.
31. *Ibid.*, p. 29.
32. Cf., K. Butzer, "Climatic Changes in the Arid Zones of Africa during Early to Mid-Holocene Times", *CC.RMS* pp. 72-74.

from 7000 BC which terminated 'in stages' between 2900 BC and 2300 BC. During the period between the first and the fourth dynasties a number of animal species became extinct in Egypt, species which need a different biome from that pertaining today. He has suggested that c. 2350 BC the climate became hyper arid and the Nile floods failed from 2350-2180 BC. Butzer's work has the great merit of presenting isohyet maps from which it might be possible to reconstruct the whole isohyet pattern of the ancient Near East.

Butzer's indication that in the deserts west and east of the Nile are stumps of trees dated to pre-dynastic and Badarian times does not necessarily allow the interpretation which he gives that there was a Savannah type environment some 200 miles further north than such an environment can be supported today.[33] Man has been active in altering the Egyptian environment for many centuries and these trees might have been supported by 'fossil' ground waters from the period following the end of the glaciation.

In recent years there has been a programme of investigating the vegetation history of western Iran. Especially lake sediments at Zeribar and Mirabad have been cored and tested, their pollen rain analysed and studied and the vegetation patterns reconstructed.[34]

All the studies from these lakes tend towards the same series of integrated conclusions; despite modifications as the investigation has been pursued the basic conclusions have stood. Present results indicate that under the effect of the last ice age there was a depression of the temperature in the Zeribar region of the order of 6°C. per annum.[35] The climate was cool and the mountains treeless until about 10,000 BC when the climate resembled the cool steppe of Anatolia today.[36] From c. 10,000 BC until about 3000 BC temperature and precipitation steadily increased until they reached modern norms, though there is some uncertainty as

33. *Op. cit.* (n. 8), p. 39.
34. Cf., R. O. Megard, "Late Quaternary Cladocera of Lake Zeribar, Western Iran," *Ecology*, 48, No. 2, 1967, pp. 179-189; K. Wasylikowa, "Late Quaternary Plant Macrofossils from Lake Zeribar, Western Iran," *Review of Palaeobotany and Palynology*, vol. 2, 1967, pp. 313-318; W. Van Zeist, "Late Quaternary Vegetation of Western Iran", *Review of Palaebotany and Palynology*, vol. 2, 1967, pp. 301-311; H. E. Wright Jnr., "Stratigraphy of Lake Sediments and the Precision of the Palaeoclimatic Record", *CC.RMS*, pp. 157-173. *Ibid.*, The Natural Environment of Early Food Production, North of Mesopotamia", *Science*, vol. 161, No. 3839, 1968, pp. 334-339.
35. Megard, *loc. cit.*
36. *Ibid.* and Van Zeist, *op. cit.*

to whether summer temperatures were ever higher than they are today. Wright,[37] on the basis of a sharp increase in pollen rain, suggests that the climate may well have been warmer c. 9000 BC. From about 5000 BC the environment began to take on the appearance of a woodland savannah climax with moisture conditions between that of cool steppe and oak woodland with a marked increase in the percentage of oak in the vegetation complex. About 3500 BC the percentage of oak increased abruptly at the expense of the chenopods. Indications are that about 3500 BC humidity was somewhat higher than the norm today in the Zeribar region though there is no evidence as to whether this was the result of increased precipitation or of raised temperatures. (From other evidence it might be possible to suggest that an increase in mean annual precipitation was the source of the increase in humidity.) The Zeribar sequences do not indicate climatic fluctuations after 3000 BC but the Mirabad sequences indicate two further short oscillations which affected the oak forests in the drier part of the distribution area. The water level fluctuated and the lake dried out. Even the vegetation on the lake bottom was burned in the era represented by the sediments between 4.40 metres and 3.80 metres of the core, which depth appears to represent the period between 4500 BP and 4000 BP (2500 BC-2000 BC).

From the French *pays Basque* comes another palaeolimnological study which tends to confirm the picture emerging of the Holocene climatic history in the Near East and Mediterranean basin. Oldfield[38] has identified eight zones in the core showing a clear sequence from treeless tundra following the glacial retreat to the time when man began to affect the forest by his activities in clearing, c. 3000 BC. The most significant of his results for this study are the identification of the onset of slightly drier conditions than those previously pertaining, c. 5700, after a period of increasing warmth and humidity (precipitation) and a sharp hiatus in the stratigraphy c. 4345 BC ∓ 130 years after a period of peat formation. This peat formation is ascribed by Oldfield to a lowering of the water table as a result of drier conditions[39] and the hiatus may well represent extreme aridity. From c. 3915 BC ∓ 170 years, the spread of alnus, oak and hazel would seem to indicate a cooling and moistening of conditions. A carbon 14 date

37. *Op. cit.* (1968).
38. Frank Oldfield, "Late Quaternary Vegetational History in South West France", *Pollen et Spores*, vol. 6, 1964, pp. 157-168.
39. *Ibid.*, p. 158.
40. *Ibid.*

from the Mouligna mud bed of 3150 BC $\mp$ 130 years[40] represents a later stage of the same conditions. These results agree remarkably well with data derived from other sources and give an overall general picture of considerable consistency.

Cecilia Western's analysis and interpretation of charcoals from Ancient Jericho[41] gives supporting evidence of conditions from the late Chalcolithic age to the Early Bronze Age in Palestine, i.e., c. 3500-2850 BC. On the basis of the type of timber from which the charcoal was drawn she has given a rough indication of the vegetation pattern of the Jericho region and has indicated that the rainfall of the region was somewhat greater than it is today. She has supported this estimate by pointing to evidence of erosion on Tell Jericho during part of the period. Western's work also has the merit of some quantitative indications. She postulates a movement eastwards of the isohyets so as to bring the 200^{mm} isohyet well down into the foothills of the central range in Palestine, with a consequent eastern movement of the Irano-Turanian vegetation belt.

Whilst archaeological evidence has been avoided in this discussion on the basis that it represents the activities of man and interpretates those activities, and thus distort the argument, there is a clear case for considering the floods of the Tigris Euphrates valley. It is true that these floods occurred at a time when city life was well established and the environment had been modified to some extent by irrigation. Nevertheless there are variations in the pattern of the floods which may be outside the scope of human activity and hence admissible as evidence.

Floods in the Tigris Euphrates system are represented by breaks in the stratification of the mounds of city sites. Such breaks occur at the site of Kish, Ur, Shuruppak and Nineveh.[42] We have no knowledge of a flood at any of these sites before 3500 BC though the first settlement at Nineveh seems to have been established in the sixth millennium BC and at Ur in the mid fifth millennium.[43] The last of the periodic inundations seems to have been that of 2400 BC at Kish. There seems to be no reasons from the known historical record why floods should have ceased at this time for something like a millennium. (There are, of course, floods

41. A. Cecilia Western, "The Ecological Interpretation of Ancient Charcoals from Jericho", *Levant*, vol. 3, 1971, pp. 31-40.
42. M. E. L. Mallowan, "Noah's Flood Reconsidered", *Iraq*, vol. 26, No. 2, 1964, pp. 62-81.
43. E. Porada, "The Relative Chronology of Mesopotamia, Pt. 1, Seals and Trade", in R. W. Ehrich, *Chronologies in Old World Archaeology*, pp. 133-200.

today.) The known irrigation works contained weirs[44] which may have had some effect on flooding but would not account for the cessation of floods at any given date. In any case, flooding in the Mesopotamian plains is caused today not only by the volume of water moving down the rivers but by the impermeability of the soil and the high degree of run-off[45] and there seems to be no reason to suggest that the nature of the soil has changed drastically despite some salinization. The flood record could well be interpreted as showing a period of increased rainfall between 3500 BC and 2400 BC not only in the mountains where the Tigris Euphrates river systems rose, but throughout the whole catchment area. The rainfall may have been far more substantial than in preceding eras. (An alternative view could be that the distribution changed so that the same rainfall total or even a little less fell on fewer wet days, thus increasing run-off. Since this would indicate greater insolation the picture emerging from the rest of the Near East would need to be drastically different. The first interpretation seems preferable.)

For the period from 2000 BC the climatic indicators used for this study are of doubtful value or are not available. We are out of the range of the Zeribar and Mirabad sediments, though there is is no doubt that more palynological evidence will be available in the future from the Near East which will enable us to reconstruct the biomes of later eras. There is also the problem that from 2000 BC in the Near East we are well into the period of population explosions and man's altering of his environment. Man is not a passive agent but has always taken an active part in modifying his environment to suit himself. Hence there must be some circumspection in discussing evidence for the last two millennia BC. The best that can be said with any degree of confidence is that the Dead Sea sediments indicate a period of recovery after the extreme drought at the end of the third millennium BC, but the recovery curve should not incline us to see conditions as much wetter or cooler than today. Wiseman[46] has noted that there was a sharp cooling trend in the Atlantic from c. 2000 BC-1750 BC and whilst this may not be taken as direct evidence for conditions in the Atlantic it must caution us to keep an open mind on the

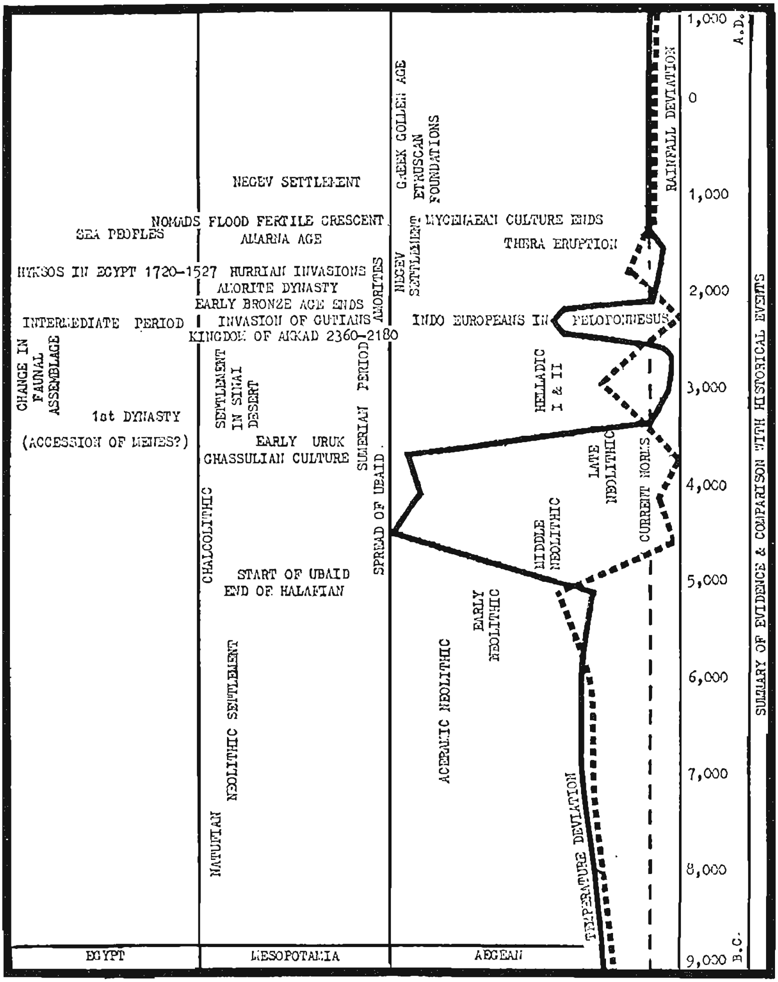
44. Cf., Thorkild Jacobsen, "The Waters of Ur", *Iraq*, vol. 22, 1960, pp. 174-185, and also Jacobsen and R. M. Adams, "Salt and Silt in Ancient Mesopotamian Agriculture", *Science*, vol. 128, No. 3334, 1958, pp. 1251f.
45. Cf. P. Buringh, "Living Conditions in the Lower Mesopotamian Plains in Ancient Times", *SUMER*, vol. 13. No. 1, 1937, p. 37, and S. A. Harris, "The Distribution of Certain Plant Species in Similar Desert and Steppe Soils in Central and Northern Iraq", *Ecology*, vol. 48, 1960, p. 99.
46. *Op. cit.*, p. 93.

question of change after 2000 BC, especially when seen in juxtaposition with claims of 'jungle' and herds of elephant on the middle Euphrates in the 15th century BC.[47]

The cumulative study produces a reasonably cohesive body of circumstantial evidence for a series of significant fluctuations in climate from the beginning of the Holocene onwards. C. 8000 BC the climate began to warm up in the Holocene recovery from the Quaternary glaciation with both temperatures and rainfall increasing to a maximum c. 7000 BC. At about this time the climatic controls which we accept today as normal came into play and in the Mediterranean region there developed an inverse ratio between temperature and precipitation.[48] Henceforth, as temperatures continued to climb precipitation diminished. From about 5700 BC a slight decline in temperatures over a seven hundred year period may have brought an increase in rainfall until about 5000 BC. The evidence is that about this time a change in the pressure and wind system brought long dry summers and short dry winters to the Mediterranean area by 4500 BC. These winters may well have been more cloudless than the norm today for the evidence points to a substantial increase in insolation and an increase in secular temperatures well above current norms. For a millennium from 4500 BC-3500 BC hot dry conditions pertained. About 3500 BC conditions ameliorated, temperatures fell, rain increased, and in Zagros mountains conditions were sufficiently cool and wet for the spread of oak forests. The newly literate cities of Mesopotamia were subject to sudden flooding. Somewhere about 2300 BC there was another rise in temperature. In the Zagros mountains lakes dried out and their reedy beds caught fire. In France stands of timber died in the long drought. In Palestine salt beds formed in the Dead Sea and in Egypt people complained of famine and orderly government collapsed. About 2000 BC conditions again ameliorated and the rainfall became more reliable with a lengthening of the winter regime. At this point the record may be to a degree obscured by the activities of man.

It is one thing to show that there was a pattern of climatic fluctuation, it is another to suggest that these fluctuations were sufficient to influence man and thus affect the course of history. Yet, when the climatic fluctuation pattern is represented diagramatically (expressed as a non-mathematical deviation pattern from

47. Cf. the quotation of a personal communication between Wooley and Whyte, *op. cit.*, p. 68.
48. On the extrapolation of current data for the study of palaeoclimates, cf. Crown, *op. cit.*



current norms[49]) and correlated with known historical, or interpretive archaeological data there is a very high correlation indeed. From a study of the diagram alone it may well be said that a *prima facie* case for a relationship between climatic change and human mobility-migration has been established.

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49. The size of the deviation is not entirely arbitrary but is based on the run-off graph in Neev and Emery, *op. cit.* The chronological data are based on Ehrich, *op. cit.*

Most striking is the coincidence of known population movements or movements inferred from the archaeological record, at periods which palaeoclimatologists believe to have been drier and hotter than 'normal'. Thus, in the period 2200 BC-2000 BC there seems to have been a general movement of peoples across the ancient Near East and into Greece, and a period of instability in Egypt.

In Mesopotamia the Sumerian hegemony came to a temporary end when Sargon of Agade defeated Lugalzagessi of Uruk and established the first Semitic dynasty about 2360 BC. Barely a century and a half later the Gutian hordes, probably an Indo-Aryan people, swept down from the northern hills and plunged Akkad into darkness and desolation.[50] In Palestine the Early Bronze Age came to a violent end at the hands of the Amorites, who entered the fertile crescent somewhere to the west of Babylon and to the east of Palestine. From about 2300 BC-1900 BC the country fell into the hands of the nomads,[51] who first destroyed the urban life of the country and eventually carried their nomadic life into the 'arid' Negev. In Egypt, organised government collapsed and in a period of some sixty years, about 2190 BC-2130 BC, a series of at least thirty-one kings ruled.

Bell[52] ascribes the chaos in Egypt to the results of a severe drought and famine which undermined central authority. In Greece the end of the Helladic II period seems to have been brought about by the first incursion of Indo-European peoples into the Peloponnesus, c. 2200 BC.[53]

Equally striking is the degree of synchronous change in the cultures of Palestine, Mesopotamia, Greece and parts of Antolia[54] from about 4800 BC, when the Near East seems to have fallen under a new climatic regime with hot summers and reduced precipitation in winter. In the absence of texts, population movements have to be induced from the archaeological evidence. In Palestine and the Levant, the millennium 4600-3600 BC was one of general improverishment of culture and was semi-nomadic in aspect.[55] In Mesopotamia, the centre of gravity of population

50. Cf. R. T. O'Callaghan, *Aram Naharaim* (Rome, 1948), p. 16.
51. For a resurvey of this difficult period, cf., B Mazar, "The Middle Bronze Age in Palestine", *Israel Exploration Journal*, vol. 18, No. 2, 1968.
52. *Op. cit.*
53. Data from Ehrich, *op. cit.*, p. 303.
54. Anatolian conditions are not represented per se in the diagram but cf. James Mellaart, *Earliest Civilizations of the Near East* (London, 1965). p. 12.
55. *Ibid.*, pp. 123-125.

and civilized life seems to have moved from the north to the south as the Halaf culture fell to the ᶜUbaid peoples, who brought the first unitary culture to the whole of the Mesopotamian region. It is claimed that this culture was based on irrigation. According to Mellaart[56] it was irrigation which had produced the surplus of population which led to the expansion of the ᶜUbaid peoples and their sudden movement to bring the Halafian culture to an end. It seems most likely from the results seen above, that climatic factors were involved, especially since a civilization based on irrigation tends not to be mobile. In Greece, the early Helladic peoples seem to have replaced the late Neolithic folk completely, with little if any mingling between the two.[57]

By contrast, in the millennium 3400 BC-2400 BC designated by the palaeoclimatologists as one of recovery from desiccation with a sub-pluvial increase in rainfall there seems to have been considerable cultural stability. In Palestine, the Ghassulian culture established itself and there was an extension of settlement into the Negev and the Sinai.[58] In Egypt, the first dynasty was established and the Old Kingdom developed a magnificent civilisation. In Mesopotamia there came the great flowering of Sumerian culture which contributed so much to the subsequent development of civilization.

Despite this remarkable correlation between cultural changes, demographic movements and fluctuations in climate we should remember the need for considerable caution, in view of the fact that environment is seen by the human geographers not as a determining factor in human life, hence history, but as a factor offering man many possibilities of adjustment, from which possibilities he accepts one or more at any given time. The same region may concurrently support mineral extractors, nomadic herdsmen and sedentary agriculturalists, and Gordon East[59] has reminded us that if man so desired he could control his environment sufficiently to grow potatoes at the north pole. There is good evidence that Neolithic man traded, hunted and harvested either wild or sown wheat so that the environment provided him with a number of possibilities of occupance, even though these may have been at the subsistence level. By Chalcolithic days, copper extraction was added to the uses to which man could make of his

56. *Loc. cit.*
57. Cf. Ehrich, *op. cit.*, p. 305.
58. Cf. Beno Rothenberg, "An Archaeological Survey of South Sinai", *Palestine Exploration Quarterly*, Jan.-June, 1970, pp. 4-30.
59. Cf., Gordon East, *The Geography Behind History* (London, 1951, reprint).

environment. We must therefore suspect that neither climatic change nor environmental factors alone were the sole controls of migration and settlement. Economic demand, political stability and security may be as important in determining occupance in a region as environment.

Evenari, Aharoni *et al*[60] have shown that there were a number of periods of intensive settlement in the 'arid' Negev of Palestine (see the diagram). However, it is clear from the nature of the settlement in the Iron Age and the Nabatean era, the reliance on extensive irrigation works and the system carefully constructed to make the most of water provided by flash desert floods, that there was no question of this settlement being in response to climatic amelioration allowing desert colonisation. The settlements in both these periods were secondary to the route network through the Negev[61] and were related to the trading needs of the Judean monarchy and the strategy developed for defending the southern approaches of the country. On the other hand the Chalcolithic and Middle Bronze I settlements which were pushed into areas now regarded as truly arid, and where no such system for irrigation is associated with the signs of settlement, were probably extensions of the border of the settled zone in response to improvements in the distribution of rainfall, or in the total precipitation.[62] It is clear that no single piece of evidence of settlement in arid areas may be accepted without close scrutiny of the related political/historical circumstances.

Likewise, one may not accept apparent evidence of migration of nomads without a careful scrutiny of every individual circumstance. The diagram shows that during the late third millennium desiccation when Gutians and (other?) non-Semitic peoples moved —irrupted—into the fertile crescent from the north the Semites led by Sargon of Agade established their kingdom. What were the factors which brought about the fall of Sumeria at this time? Was it the sheer weight of numbers of the invaders both from the north and from the south, Gutians and Semites, destroying Sumeria together, impelled by the need to find food in a period of crop failure? Was there another environmental factor involved, namely, the salinization of the soil in response to over-irrigation? Crop yields in Sumeria seem to have fallen from an average of 2537

60. M. Evenari, Y. Aharoni, N. Tadmor, L. Shanan, "The Ancient Desert Agriculture of the Negev III Early Beginnings", *Israel Exploration Journal,* vol. 8, No. 4. 1958, pp. 231-269.
61. Cf., my "Some Factors Relating to Settlement and Urbanization in Ancient Canaan in the Second Millenium BC", *Abr Nahrain* II, 1971, pp. 29-30.
62. Cf., my "Towards a Reconstruction, etc.," *op. cit.*

liters per hectare of barley c. 2400 BC to 1460 liters per hectare c. 2100 BC. (Did the new aridity itself play an important part in the need to irrigate, and the increasing evapotranspiration rate which produced a rapid salinization?) Were the Sumerians under severe economic pressures as a result of failing crops and silting irrigation channels?[63] Was it the political opportunism not of newly arrived nomads but of semi-established groups, who, after a long period of infiltation and assimilation in the manner of the desert nomads of the area,[64] chose a time when Sumeria was beset by a variety of problems to seize power? The answer in this instance can scarcely lie in a simplist equation of climatic fluctuation and nomadic movement but is probably a complex association of environmental, political and economic factors. Again the caution must be given that every case of apparent response to climate must be examined on its general merits.

Finally, it is necessary to consider the potential effects of climatic fluctuation on man in any given environment beyond the obvious relationship, bad weather, bad harvest, before it is possible to make sound judgments on the correlation between mass migration and climatic fluctuations. The problem is a complex one which demands more than the space available here.[66] Moreover, we are forced to ignore a secondary but important factor of kinship relationship in primitive migrating groups which may have an influence on the size of any given migratory group of people.

All communities based on subsistence economies are closely subject to the risk of the harvest. The slightest climatic aberration (or the attack of a disease or of an insect pest) is immediately reflected in the demographic curve.[67] Whilst man can adapt to poverty he cannot adapt to famine and in times of famine man will move in search of food. It is probable that primitive man, i.e., man not living in an urban or urban stimulated society, or living in a pre-urban society, lives always at or close to subsistence level. In the ancient Near East urban life was well established by about 4000 BC but the peoples who lived on the fringes of the region may have lived at subsistence level for another two and a half millennia.

The semi-arid areas of the Mediterranean region (and the adjacent steppe lands) are attractive grazing lands in good years and draw in nomads and hunters. Mediterranean grasses (and

63. Cf. Jacobsen and Adams, *op. cit.*, p. 1252.
64. Cf.. O'Callaghan, *op. cit.*, p. 25.
66. For some discussions of this point, cf., E. S. Hills, Ed., *Arid Lands a Geographical Appraisal*, UNESCO and Methuen (Paris, 1966).
67. Cf. J. B. Garnier, *Geography of Population* (London, 1966), p. 55.

native cereals) are 'opportunist' surviving severe drought but reacting quickly to a good season in giving a plentiful supply of forage of high nutritive value.[68] It is the variation of rainfall in these areas which makes them hazardous to man. In intermediate years, where rainfall is not entirely lacking but is not plentiful, these lands are easily overgrazed, leading to reduced water penetration of the soil, higher soil temperatures and a more rapid reduction of the vegetation canopy, thus accelerating aridity.[69] These areas, then, are very vulnerable to climatic fluctuations of a small order. It is in these areas that pastoral nomadism is the chief means of occupance, though even in the ancient Near East there were probably few areas of true monoculture for nomadism may have involved some seasonal planting. Pastoral nomads are mobile and respond quickly to famine stresses brought on by climatic conditions. As urban life developed in the ancient Near East, the nomads on the fringes of the urban area must have been under some degree of control by the city/kingdom authorities. That degree of control may well have been adequate to contain them. The nomads beyond the monarchic authority may have been more vulnerable to climatic fluctuations since their opportunities for 'diversification' through trade were more limited. They may well have been the more dangerous to sedentary life.

In the more arid parts of the ancient Near East, occupance was based on wells, pools in wadis or rare springs. Even today there is little monoculture in the true desert of Arabia—settlement includes hunting, some herding and seasonal planting. The inhabitants of the arid regions are less susceptible to the vagaries of climate than the nomads of the transition zones and the true arid areas may be regarded as being zones of stable occupance.

Arid zone occupance is based on water table water supplies rather than on aerial water supplies, and, whilst the water table may fluctuate in bad seasons, its fluctuation would not be sufficient to take it out of the reach of the inhabitants. It is postulated that the Saharan water supplies are in fact fossil waters that have survived since the last ice age, in which case they have survived all climatic vicissitudes since then. In the Arabian peninsula, in a bad season well water supplies seem to fall by up to 20" but this does not take the water out of reach of the

68. Cf., J. P. Cooper, "Climatic Adaptation of Local Variety of Forage Grasses", in *Johnson and Smith, op. cit.*, p. 169 f.
69. Cf. C. S. Christian and R. O. Slatyer, "Some Observations on Vegetation Changes and Water Relationships in Arid Areas", in *Australia UNESCO Symposium, op. cit.*, p. 16 (a) f.

inhabitants,[70] and a study of Roman wells indicates that the pattern of variation has been remarkably stable since Roman days.

In the ancient Near East, then, we may expect two kinds of demographic responses to climatic pressures. The first is the constant infiltration of nomads from the semi desert fringes that might be accelerated a little by a series of bad years or which might be accelerated rapidly by pressures of other peoples behind them. The second is the irruption of pastoral nomads from outside the region who are forced to move, or die of starvation, in times of famine brought on by climatic stress. Because of kinship relationships these peoples tend to move in mass migrations.

70. Cf. K. S. Zwitchell, "Water Resources in Saudi Arabia", *Geographical Review*, vol. 34, 1944, pp. 365-386.