African Research Review
International Multi-Disciplinary Journal,
Bahir Dar, Ethiopia
AFRREV Vol. 12 (2), Serial No 50, April, 2018: 153-162
ISSN 1994-9057 (Print) ISSN 2070-0083 (Online)
DOI: http://dx.doi.org/10.4314/afrrev.v12i2.15

Critical Outline of the Major Physical Features Used in Environmental Archaeology for the Reconstruction of Quaternary Climate

Okoroafor, Stanley I.
Department of History and Diplomatic Studies
University of Port Harcourt
P.M.B. 5323, Choba
Port Harcourt, Nigeria
E-mail: noobiieyiche@yahoo.com

Abstract

Climates in themselves are naturally somewhat elusive. Attempts to reconstruct such can sometimes be quite challenging. Different fronts have been taken by various experts around the world to determine climatic variations over time. That of Quaternary is shallow in the perspective of time and 'context' and thus more exposed to the vulnerability of obliteration and evasiveness. However, the dogged efforts of palaeoclimatic and related studies environmentalists especially the environmental archaeologists provide good hindsight with which the reconstruction is driven to some levels of objectivity. The major physical features of achieving this are on the strength of environmental sustainability critically outlined here, with a view to maintaining the equilibrium of the understanding and extending the frontiers of our knowledge in this regard.

Introduction

The "Quaternary" (the latest geological time scale period of Ca. 1.8 mil YBP age) Peters (1987), is primarily concerned with the climate of the earth – the variations as they affect the earth "environment". Such variations in the earth's climate have characterized parts, if not all of its surface to a large extent, for at least throughout the whole of phanerozoic. During the Quaternary period such changes are particularly significant. Reasons are that they are comparatively recent and are revealed by certain physical (geologic) features (although also by biologic ones) that are still at near the surface. Hence they are relatively less damaged by erosion and other forms of earth's physical features disturbances Flint (1971). Until the early 19th century, Earth scientists (including environmental archaeologists) have improved on the earlier biological evidence; finding physical ones that led to the conclusion that at times in the past, climates were different from those of today.

Some of these physical features are sometimes interpreted in broadly quantitative terms, whereas some are still only qualitative as they are limited to specifying climatic parameters which are positive or negative compared to those occurring today in the same area. The knowledge of the Quaternary strata is increasing every now and then and so are in details the records of climatic oscillation through the later part of Cenozoic time. This is necessitated by the fact that climate has pervasive influence on the global environment. Therefore, the knowledge of the climate as it affects the environment beginning from the past has become of very great importance.

As a departure from fauna and flora fossils (regarded as direct evidence), such knowledge of former climate can be drawn from less direct fossils (anything antiquated). For example palaeosol (fossil soil) or sediments deposited and from so-called hard evidence from physical features created at specific past times. Here in this paper, the major relicts of those physical features are critically outlined with regard to their use in the reconstruction of Quaternary climate. The two common parameters shown by such physical evidence include temperature (mean annual or summer), and precipitation (mean annual or seasonal) (Flohn 1979). Nonetheless, directions and minimum speeds of effective winds can also be reconstructed Talbot (1981). It is pertinent to state here that the issue of former climate is but a conceptual construct. Also, that the parameters of reconstructing former climate are not measured directly but inferred through proxy data Ingram *et al.* (1972).

Glacier relicts are about the most obvious physical feature evidence of past climate. The glaciers that form during glaciation period for instance in the Last Glacial Maximum (LGM) especially in the high Latitudes of northern hemisphere and a tip of the South of Africa (South Africa) and South of South America (Peru) and South Australia (Tasmania and New South Wales) in the Southern hemisphere, leave their impressions in the sediment or rather earth surface. The earliest basis of the concept of colder former climates was possibly through these means. These were the presence of scored and polished bosses of bedrock and large far-travelled boulders in and adjacent to the Alps for instance. These among other similar relict features engineered by glaciation, abound, at times conspicuously, evidencing climatic change marked mainly in the Quaternary.

The features of glacial erosion according to Flint (1976) include apart from scoring growing and polishing of bedrock and of boulder pavements, general smoothing and unsymmetrical rounding of hills and mountains. Others are alteration of stream valleys to 'U' form, creation of basins in bedrock, and creation of cirques uncontrolled by a stratum of Caprock.

The glacial sediment can be found the diamict till. The glacial diamicts (also known as moraines at deposition) include some faceted or striated clasts and a matrix that reflects intense crushing. Flint (197 1:152), noted that some of the malso are underlain by a striated bedrock floor. At the level of till in the erosion process, no distinctive topographic form is known contrary to the moraine level. Stratified drift is another characteristic sediment. This could be of ice-contact type and outwash type. Ice-contact possesses some of the internal glacial features found in till. As for the outwash type, glacialmicro textures on sand grains are contained in the upstream part of a body of outwash. Moraines C14 date have been used in knowing the age of phases during glaciations. For example, the cordillera vilcamota — Quelccaya ice cap region L.G.M. limit fixing Rodbell (1993, p.133) also Mercer (1984), Clapperton (1981); and Mercer and Palacios (1977). Irrespective of the benefit of the

Indexed African Journals Online: www.ajol.info

use of this method in the palaeo-reconstruction, the major demerits before now (in the use) had been no quantitative assessment of the relative degree of weathering of the moraine groups. Again in adequate radiocarbon age used in correlating data from other areas such as isotope stage coordinates and sometimes a seeming speculation based on form in determining time of deposition.

As the glaciers move down sometimes covering several miles, they create structures as they push and drag by, such structures in partly — or non-consolidated strata of glacial ornon-glacial origin abound too Flint, (1976).The structure includes both folds, and thrust faults with some exceeding100m.

In the ocean scorings (the scratching of bedrock by debrishood ice drifting in water common phenomenon in high and high-middle latitudes) have climatic implications similar to those of glacial striation. Bradly *et al*. (1942) described ice-rafted sediments cored from the floors of oceans and lakes in high-middle latitudes as having dropped from melting icebergs and sea ice. This kind of sediment is used in inferring glacial age climate as it contrasts with fossil bearing non-glacialse diment. This method has been used in North Atlantic where it was first seen extending to North Eastern pacific and the Southern Ocean.

There also are ice-rafted clasts in alluvium described as striated “erratic” cobbles and boulders occurring in Pleistocene alluvium along stream valleys. They are found mostly within a belt south of the southern limit of glacial in the eastern and central U.S.A. The related watersheds bear no glacial drift and the lithology of the “erratic” is restricted to the rocks exposed on those watersheds. The implication is that the striations were made by river ice and that the clasts were rafted downstream on ice pans, at times when winter climates were more severe compared to the present ones. The displacement of the regional snowline with the change in climate is another physical feature used in interpreting the Quaternary climate. One method of doing this is by plotting attitudes of cirques and thereafter, comparing them for glacialage with the snowline of today. Both small and large scale show results of consistent variation in the altitudes of the snowline, from near sea level in Polar Regions to high altitudes within the tropics.

Irregularity of the limit of a former glacier through time is reconstructed from field studies of glacial drift supported by C dates. When plotted as a curve the fluctuation shows broad variations of temperature and probably vegetation too. These variations are however, still qualitative. Because much of the critical evidence lies concealed beneath late Wisconsin, drifts can only account effectively for the period and not earlier ones which results are very sketchy. The geochemical methods of measuring oxygen-is otopic composition of foraminifera carbonate shells in sea-floor cores is another means of reconstructing the Quaternary climate categorized under physical evidence Flint (1975). The method aids in delivering former surface-seawater temperatures.

Emiliani and Shackleton (1974), presented a general agreement in the interpretation of the date based on the similarity of temperature curves, derived on certain assumptions. These extrapolations are made from the measurement bf cores in the Atlantic, Caribbean, and Pacific through the last 700,000 YBP. The problems in the use of this method are first, the 50,000 years range of C14 dating that is short compared to Wisconsin duration. The errors in C14 ages of Carbonate deposits resulting from the addition of modern carbon to the carbonate after their precipitation of setting initial 14c/c ratios in the Water,(reservoir effect) Benson (1993). Also isotopic fraction nation causes differences among 14c values of samples formed at the same time.

Another physical feature for palaeo climatic reconstruction which is most accepted because of its universal application is the eustatic fluctuation of sea level. Sea level rises and falls synchronously with net growth and net melting of glaciers on the entire continents. When the sea level rises or falls, it marks indirect evidence of major fluctuation of global temperatures. Many determinant geologic features yield varied accurate results although they still face uncertainties. The issue of uncertainty is as a result of its differentiating along the coasts between eustatic movements of sea level and movements of the crust, and inaccessibility.

Accessibility in the sense that at the present the sea level has risen and covers the features presenting all the glacial ages along continental borders. And so are the information contained in them. Bloom (1972) documented the errors of both measurement and interpretation arising from short timescale vis-a-vis the sea level rise following the post-Wisconsin deglaciation. The fluctuation of sea level as a parameter in reconstructing Quaternary climate is more qualitative than quantitative given the uncertainties surrounding the evidence.

Frost is one of the physical features created by lower temperature that freezes dews during glaciations in many are as mainly in high and middle latitudes. The frost in turn impressed of itself on the environment as inter alia the frost-wedged rubble which is the product of seasonal or longer term freeze and thaw, and occurs where the parent bedrock is strongly jointed.

Flint (1976:523), observed that the angular, plane-aced clasts, in places several meters in diameter, accumulate on shores as thin armour, or in greater concentrations as taluses and rock glaciers. The basis for this acceptance is the growth of lynches upon clasts and of forest trees between them and the sestratigraphic positions beneath active, modern accumulations.

Colluvium forms by the creep and flow of regolith during the season of summer thaw in areas mainly underlain bypermafrost. The unlaying frozen ground beneath does not allow infiltration by thaw water, which saturates the thawed surface layer and causes it to move down slope as sheets and lobes. Such colluvium is not present actively moving and is widespread in the arctic. Thin sheets of colluviums indicating cold glacial age climates are found in Western Europe and eastern North America. Colluviums possess a problem in its usage in reconstruction because of occurrence in Wet tropical highlands where the ground does not get frozen. This tends to suggest that flowed colluvium is not solely an indicator of former frozen ground.

Some other frost features are frost-cracks, ice-wedge casts, and patterned ground and common in the arctic. Their occurrences elsewhere are seen as relict given the prevailing atmospheric temperature they are formed in today as compared to those of their embodiment. Such calculations provide the temperatures of the climate in which they were formed. Apart from the fact that some of these features are not well understood and as such difficult to determine with accuracy, similar features originate in other ways irrespective of cold climates. Flint (1976), advises that great caution be taken in their usage in interpretations. He thinks that their acceptance as palaeo-temperature determining parameter should be hinged on: – (1) if they are truly the result of frost action (2) relateto specific temperature ranges and (3) If their dates of origin or Stratigraphic positions can be fired.

Tree lines associated to snowlines is another physical feature used in Quaternary climate reconstruction. The snow on mountain tops during cold climates deserved lower towards their valleys. As this happens, vegetation (mountain trees) that grows around such mountain, as it were, shifts

Indexed African Journals Online: www.ajol.info

downwards too, following the snow expansion. This forms a vegetation margin referred to as tree-line around such mountain. During warm climate period the snow melt and retreat and therefore the trees could then grow higher up beyond their former limit. This can be understood through today's analogue method as earlier indicated of calculating the degree of temperature variation and respondent shift upwards or downwards of the tree lines.

By implication therefore, the reconstruction bias of qualitative and quantitative application is noticed also in the tree line usage. Aeolian features exist in critical boundary zones that separate belts of coherent climate. The main Aeolian features consist of (a) wind-blown sediments that is sand dunes and layers of loess and (b) deflation basins. Wind-blown sediments relicts could be sand blown inland from beaches or sand of continental origin. Beach sand deposition can come in any climatic condition and thus, its relict is not specific enough to determine a particular climate unlike the continental sand and relict such as dunes.

Dunes can be identified based on form (shape), internal character (Pachur & Kropehn 1987), and surface microtexture of sand grains (if the depositional structures or initial form has be greatly disturbed (Krinsly & Donahue 1968). They occur in large groups also known as fields at the leeward sides of bodies of outwash, valley fills of coarse alluvium (Talbot 1981), or former pluvial lakes (Street & Groves 1976).

The inference drawn from their occurrence is that dunes related to outwash and pluvial lakes were formed during glacialages with comparatively cold climates; but those of alluvium, under relatively dry climates whether glacial or non-glacial. The dunes can be active in which case they are still being formed today or inactive being the reverse case.

The effective wind directions forming the dunes are determined by the spatial relation of the dune field to apparent origin of sand. Also they are determined by the direction of inclination of foreset lazninae in the dune sand and by the dunes forms and orientation Pachur and Kropelin (1987). They are classified based on their form into several groups as in Flint (1959, pp. 364-366). Longitudinal dunes are those common in Northern Africa and Central Australia. They are basically inactive hence they are relicts.

Rough estimation of the climatic condition at formation period can be derived by evaluation through present day annual rainfall and wind speed for instance. Some of the dunes axe covered with soil vegetation implying that the sand forming the dunes accumulated under drier climates compared to those prevailing today. However, extrapolation is made out of the outwash and characteristics of sand, some already mentioned, while using dunes as physical feature of reconstructing quaternary climate. Little information can be derived from the sand with regard to former climates.

Clay dunes are the type of dunes that due to the usefulness of their relict in climatic reconstruction deserve special consideration. The dune type is called clay dune because about90% of it, is of day. They are unique because they are rare with comparatively different morphology, mineralogy texturemd structure. Also they form ridges at creosotic right angles to the dominant wind direction on the margin of salt water bodies for example salt lakes. Unlike sand dunes they do not move far from source meas. This is because the seasonal absorption water stabilizes the deposition and makes it become plastic therefore, repeatedly following humid/dry cycle forming protective layers of crust on the dune. Active clay dunes are found in North America, and North and West Africa. In semi-arid humid region of Australia, dunes of C dates of between17, 000 and 15.000 years have been recorded.

In palaeoclimatic reconstruction: they aid in degree of seasonal evaporation, flooding wind vigour and wind direction, and vegetation growth. The climatic condition favouring clay dunes formation by implication and from active dunes evidence is seasonal evaporation considerably in excess of both precipitation and that of ground Water discharge into a basin; thus representing unique palaeo environrnental index. Nonetheless, clay dunes ideological factors are often local rather than regional.

Loess is another Aeolian deposit but of fine yellowish grey soil. Loess, more than the wind-blown sand, covers a larger area. It is commonly found adjacent to large bodies of glacial outwash in places such as Northwest Asia and Europe. Its common occurrence around glacial outwash is an indication that it is secondarily derived from outwash. This is associated with glaciations. Sometimes spot checks of the sediments aid in certifying the derivation (for example in North America and Europe). In eastern Asia however, loess is believed to be of non-glacial, desert origin. Also, in North Africa loess could be found in arid zones which were even more deserted during inter-pluvial periods thus proving the degree of aridity associated with increased wind intensity and other inter-pluvial conditions. However, ancient diamicts are said to be sometimes associated with Permian Tillie had been interpreted as an ancient loess (Wood-Worth, 1912, In Flint 1976), such interpretative confusion using the date bring difficulty in differentiating between glacial (cold climate) loess, and desert loess which inferences about temperature are apparently not derived from.

Basins are created by localized erosion by wind of some other fine particles. They are commonly found in semiarid and arid grassland. They range in diameter from a few metres to tens of kilometres in depth from less than a metre to more than50 m. Flint (1976) noted that their localization could be determined by breaching of the grass cover. This he said is likely to be through repeated dying-out of vegetation during exceptionally dry periods. They occur in both active and relict forms. They can befound on Great Plains on Montana and Texas areas of U.S.A, South Africa, Central Asia, Australia and Southern Argentina Flint (1959, p. 1366). The time of their primary cutting is suggested by some to be the warm, dry Hypertherrnal of 5000 YBP.

Pluvial, first applied to coarse alluvium in Western Europe has become a term with more meaning in limnology. Although Flint referred to it as “a climatic regime of sufficient duration to be represented in physical or organic record and in which the precipitation evaporation ration results in the same area today or in the preceding climatic regime”, many see it as referring to formerly extensive lakes now confined to a relatively small area due to dryness; Lakes me recognized as the earliest recognized and most apparent entity among other pluvial features. The complexity of the beginning of pluvial condition is generally seen as resulting from a combination of increased precipitation and reduced evaporation processes. The pluvial lakes imply former climates using the familiar system of analogue method of comparative study (Delcourt & Delcourt, 1991). Also, the stratigraphic relations and radiometric dates indicated that some lakes were synchronous with the last glaciation. In Syria high levels of pluvial lakes were said to be likely synchronous with the glacial maximum, essentially because of reduced evaporation. There are existing in the middle and low latitude spluvial lakes such as in Africa (north and east especially) Central Asia, Australia, South America. However, the dry region African pluvial lakes for example have been probably attributed to be synchronous with inter-glacial as they were caused by increased precipitation.

Change in climate inferred from pluvial lakes should be derived from not only the sediment of the lake floor but also the shore features around the sides of the lake basin. This was suggested by Flint (1976) in order to establish Strandlines at positions not controlled by an outlet. However it has been observed that this is not possible where basin slopes and floor sediments have been destroyed by erosion or buried beneath younger strata. As such, most well-established pluvial lakeshave been seen to be of late Wisconsin date. In Northern Africa, some ancient lakes however, have proved to have been the outcome of low-latitude climatic zones which were not in phase with those of middle latitudes instead of being probably controlled by changes in climate. However, pluvial lakes because of their widespread occurrence especially those of regions far from extensive former glaciation, have the potentiality of spreading more widely the evidence of former climate change. The characteristic features of pluvial conditions such as is evidenced by the pluvial lakes have helped in calibration of the late Quaternary periods (example Lower Inchiriam Neuchuotian), Fluvial features are said to be those extensive, marked abnormalities, which could be noticed in the patterns of streams or stream system or in their deposited alluvium.

Among these are (1) obvious variations in diameters of clasts inalluvium (2) the occurrence of stream patterns and alluvium in areas presently supposed to be rainless, (3) alternating cut sand fills in stream valleys, and (4) the occurrence of under-lift streams Flint (1971, p. 526). These features are relict features as they record departures from the steady-state condition. They indicate climate change in short and long term distribution temperature and precipitation values which may have ignited such changes.

However, other factors that influence streams are tectonic movements in all or part of a watershed. Experts in this field have observed that it is more difficult to differentiate between a climatic and tectonic cause of the above observed data when the stream system are larger. The data is only used when measurement are both precise and abundant.

Discussion

Other kinds of physical feature that can be regarded as Palaeoclimate proxy data are relict soils and colour of sediment, many of the soils that can now be seen at the surface, occur in zones that are related to temperature and rainfall. This is, however, a grossly oversimplification of the situation, the soils in relatively moist areas with relatively chemical conversion of constituent minerals. This, in association with the creation of clay and of iron oxides appears in brownish and reddish colours. Comparatively soils in dry areas indicate less decay however, and develop secondary calcium carbonate and yellowish and light-brownish iron oxides. Majority of the soils now at the surface together with all the buried ones are relict. A critical study of a relict soil is likely to reveal evidence of a former climate different from the present one.

The difficulty of using red-coloured sediment in determining variation in climate is related to the origin of red soils themselves. Red-coloured iron oxides are known to form in deposited sediment during the process of digenesis. However, the confusing factor here is that these same red - coloured iron oxides can form under-dry as well as under warm-moist climates. Walker (1974) observed that the similarity of the redoxides formed under both climatic conditions above are such that it has not been found possible to specify under which particular climate they were formed. They thus, sometimes, can only prove that the climate was relatively warm.

Sedimentary petrography has become increasingly important in its many aspects. These are the study of coarseelements, blocks and boulders, and the study of fine particles of sand or silts. Alimen (1971).Certain archaeological evidences are considered as physical features that can be used in the reconstruction of Quaternary climate. Archaeology is the physical anthropology studying the cultural remains of humans (A.M.H). The appearance of this A.M.H is known to coincide with the beginning of the Quaternary period and has actually been used in the stratigraphic placement of the Quaternary. This is because the periodization of the Quaternary in the geological time scale includes human artefacts in the geological strata. The Olduvaievent and the inferences denote a change in climate. At the two Eleru excavations, stratigraphic sequence saw change of tool such as the trapezoid marking change in climate of the West African sub-region Shaw and Daniels (1984).

The occurrence of caves bearing engravings and painting on their walls depicting sometimes aquatic faunal life together with terrestrial associated with the animals of forest zone all in a present time desert/Sahel environment. This suggests that at times, the desert area in which this cave, with the cultural characteristics was humid enough to accord the existence of the sort of life exhibited in the paintings and engravings, which dates back sometimes, to many thousands of years before present. This sort of life exists in the area especially for the time, social stability and relatively favourable environment. All these which no more are obtainable in the area are likely indications of change in climate from a humid type to an aridone.

However, some ethno-archaeological research for instance the Yankari National Game Reserve investigation conducted by Aremu (1997) showed that caves can be made artificially (conditionally) by humans. This in turn could mean that every cave and associated cultural traits may not be as a result of normal habitation in them by ancient people or their preference of the environmental niche as the people may have been forced by war into migration to the place together with their miniscence of their former occupational environment and culture.

Conclusion

Judging from the above evidence of reconstructing Quaternary climate, it has become clear that for some instances, the effect of changed temperature cannot be easily separated if at all from those of precipitation. The criteria for doing this sometimes are ambiguous, moreso, as they depend partly on today’s climate in the area of occurrence. Sometimes the evidence of former climate may be elusive. This is the more reason why a former climate is conceptual rather than objective and should not be made use of as the basis for constructing a unit in a stratigraphic column (Flint 1976).

One noticeable phenomenon is that cold climates leave many more imprints on the environment than the warm ones. This has made majority of the relict of reconstruction to have been derived from cold deposition relict. On a broad basis however, today’s temperature can be said to be a little on top of the Late Cenozoic range. Thus this manner of reconstruction has revealed features implying the limitation of a former temperature to specific value. About majority of them indicate temperatures that are comparatively higher while others are lower than before or after depending on the part of the world one is dealing with hence, their use in the reconstruction of Quaternary climate.

References

Bowler, J. M. (1996). Aridity in Australia: Age, origin and expression in aeolian landforms and sediments. *Earth Science Review*, 12: 279-310.

Butzer, K. W. (1972). *Environment and archaeology: An ecological approach to prehistory*. London: OUP

Clapperton, C. M. (ed.) (1990). Quaternary glaciations in the Southern hemisphere. *Quaternary Science Review* 9: 12 1-304.

Clamp, (1996). The surface of the ice-age. *Earth Science* 191 (4232).

Deacon, J. H. (1989). Late Pleistocene Palacoecology and archaeology in the Southern Cape, South African. In Mellars, P. & Stringer, C. (ed.) *The human evolution, behavioural and biological perspectives on the origins of modern humans*.

Emiliani, C. (1990). Pleistocene temperature. *Science*. 168 822-825.

Flenley, R. F. (1979). The late quaternary vegetation history of the equatorial mountains. *Progress in Physical Geography*, 3: 488-509.

Flint, R. F. (1971). *Glacial and quaternary geology*. New York.

Flohn, H. (1979). On time scales and causes of abrupt Palaeoclimatic events. *Quaternary Research* 12 (1): 135-249.

Goodie, A. S. (1992). *Environmental changes* (3rd ed.) Oxford: Clarendon Press.

Grove, A. T. (1958). The ancient erg of Hausaland, and similar formations on the south side of the Sahara. *Geographical Journal* 124: 528-533.

Grove, J. M. (1979). The glacial history of the Holocene. *Progress in Physical Geography*, 3: 1-54.

Ingram, J. M., Farmer, G. & Wigley, T. M. L. (1981). Climate and Mansince 5,000 yrs. In Wigley, T. M. L. Ingramand, M. J., Farmer, G. (eds.). *Climate and History.*

Marcy, S. (1909). Late quaternary climate changes in the African rainforest: Forest Refugia and the Major Role of Sea Surface Temperature Variations. In: Linen, M. & Sarnthein, M. (eds.). *Palaecoclimatoloqy and Palacometeroloqy. Modem and Past Patterns of Global Atmospheric Transport* (Dodrecht): 585-6 16.

Osborne, P. J. (1988). A late bronze age insect Fauna from the River Avon-Warmickshire, England its implications for the Terrestrial and Fluvial environment and for climate. *J. Arch. Science* 15 (6): 715-728.

Petterson, G. M., T., Webb Ill, J. E., Kutzbach, T., Van Der Hammen; Wijmstria, T. A. & Street, F. A. (1979). The continental record of environmental condition at 18, 080 yr. Bp. An initial evaluation. *Quat Res.* Vol. 12, 47-82.

Rodbell, D. (1973). Subdivision of late Pleistocene Moraines in the Cordillera Blanca, Peru, bases on rock-weathering features, soils and radiocarbon dates". *Quat.Res.* Vol. 39 (2) pp. 133-143.

Sabin, A. T., & Pisias, N. G. (1996). See surface temperature changes in the North-eastern Pacific Ocean during the Past 20,000 years and their relationships to climate changes in North Western North America". *Quat. Res.* Vol. 46 (1) 48-61.

Sarnthein, M. (1972). Sediments and history of the post-glacial transgression in the Persian Gulf and North-West Gulf of Omani. *Marine Geology* 12: 245-266.

Schubert, C. (1984). Environmental variations of the South. In Goudie, A. *Environmental change* (1992). Oxford: Clerendon Press.

Smalley, J. & Vita-Finzi, C. (1968). The formation of fine particles in sandy desert and the nature of "desert". *Journal of Sedimentary Petrology*38: 766-774.

Street, F. A. & Groove, A. T. (1979). Global maps of lake-level fluctuations since 30,000 yrs B. P. *Quaternary Research* 12: 83-118.

Sowunmi, M. A. (1981). Aspects of the quaternary Vegetational changes in West Africa. *J. Biogeog*, 9: 457-474.

__________ (1986). Changes of vegetation with time. *Plant Ecology in West Africa: Systems and processes.* (ed.):273-307.

___________(1987). The environmental present and past of West Africa". *WA J A.* Vol. 17 Special book issue.

___________ (1991). Late Quaternary environments in equatorial Africa: Palynological evidence. *Pal. Afri* 22: 213-283.

Wright, H. E. (1983). *Quaternary Environments of the United State*. London: OUP.