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Geological and Ecological Perspectives on the Middle Pleistocene

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This paper evaluates the geological and paleoecological implications of a Wenner–Gren symposium *Stratigraphy and Patterns of Cultural Change in the Middle Pleistocene.* The deep-sea, glacial–eustatic, loess, alluvial, and palynological records suggest between six and eight cold–warm cycles since the Brunhes–Matuyama magnetic reversal of 700,000 BP. Till and outwash stratigraphies are inadequate to provide a valid nomenclature for the numerous glacials preceding the Würm. Since at least five of the glacials since 700,000 BP were sufficiently severe to produce permafrost in midlatitude Europe, the "glacial Pleistocene" begins with the Brunhes–Matuyama. Although earlier cold–warm cycles extend well back into the early Pleistocene, with extensive glaciation and repeated floral decimations in higher latitudes, the first record of permafrost in the Rhine Basin 700,000 BP argues that major climatic oscillations of the Brunhes epoch were of glacial–interglacial amplitude. It is therefore recommended that a Lower–Middle Pleistocene boundary be linked to the practicable and universally applicable chronometric horizon provided by the Brunhes–Matuyama reversal, while the Middle–Upper Pleistocene limit can continue to be drawn at the base of the last, Eemian Interglacial (130,000 BP). The tropical African record presently contributes little to general understanding of the Middle Pleistocene, while the climatic cycles of higher latitudes are of limited value in analyzing mid-Pleistocene records of the tropical continents. Problems of stratigraphic control and environmental contexts for archeological sites are discussed.

THE MID-PLEISTOCENE "PROBLEM": HISTORICAL BACKGROUND

The mid-Pleistocene time range, no matter how defined, has long presented a peculiar set of problems in terms of stratigraphic definition, paleoecological characterization, and archeological resolution. To consider these problems a multidisciplinary symposium on *Stratigraphy and Patterns of Cultural Change in the Middle Pleistocene* was organized by Karl Butzer and Glynn Isaac, under the sponsorship of the Wenner–Gren Foundation for Anthropological Research.

This conference was held at Burg Wartenstein, Lower Austria, July 2–11, 1973. Many of the most innovative and productive mid-Pleistocene specialists could not be invited due to very real limitations on space and the need to give as balanced a representation as possible. In the end it was necessary to omit specialists on eastern Asia and North America. Unfortunately, too, several of the original invitees were unable to attend, on relatively short notice, so that 18 participants finally assembled. The revised background papers, as well as chapters evaluating the geological and archeological contributions of the conference, are in press (Butzer and Isaac, 1974). In order to make a synopsis of the geologic implications more readily accessible to a wider audience of Quaternary workers in nonanthropological subfields, Mouton Pub-

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lishers of the Hague, and the Wenner-Gren Foundation, have both kindly consented to allow republication of the present paper. It should be emphasized that this evaluation is of a personal nature, although many relevant discussion comments and points of consensus are reflected in the conclusions.

The complex of issues tackled by the symposium find its origins in the development of Pleistocene studies over the past century. It is against this background that the import and significance of the symposium contributions can best be understood and evaluated.

Time-stratigraphic subdivisions are generally introduced as a matter of convenience. In the case of Europe, where basic Pleistocene concepts evolved during the late 19th and early 20th centuries, Pleistocene subdivisions were first formally considered by the International Quaternary Association meetings of 1932, in Leningrad. Available for discussion at that time were four or five Alpine glaciations, three major Fennoscandinavian glaciations, a number of paleosols, and disparate paleobiological evidence, including a rudimentary faunal zonation (for an overview of the state of the art in the 1920s, see Woldstedt, 1929). The Leningrad congress chose to define the penultimate glacial and penultimate interglacial as "Middle Pleistocene," relegating earlier glacials and interglacials to the "Lower Pleistocene." By the late 1950s the cumulative growth of information from the major world continents presented a far more complex picture of multiple, cold "glacials" and fostered a wide range of professional disagreement (see Woldstedt, 1958, for the critical overview most representative of the period). Successive attempts at Pleistocene subdivision since 1958 (see Butzer, 1971a: Table 4) have sought new grounds for agreement by emphasizing one or other regional litho- or biostratigraphic sequence. At the same time the Pleistocene was "growing longer," since the 1948 International Geological Congress in London had effectively recommended inclusion of most of the marine Calabrian in the Pleistocene and thus, implicitly, added much of the continental Villafranchian to the base of the Pleistocene column. It now appeared that a long "nonglacial" Pleistocene, characterized by alternating cold and warm phases, preceded the development of the first ice sheets in Scandinavia and the Alps. The development of potasssium-argon dating compounded this problem in the early 1960s by demonstrating that all earlier estimates of the absolute duration of the Pleistocene had been grossly incorrect, and that accepted Pleistocene deposits at Olduvai were almost 2 million yr old (see Evernden and Curtis, 1965).

Far from nearing resolution, the state of stratigraphic confusion has been increased in recent years as new avenues of research are followed up and the body of factual information grows at an exponential rate. In part this confusion has been a result of parochialism or disciplinary particularism, whereby leading researchers have assumed their own corpus of data to be complete and correct, without making a thorough appraisal as to why intraregional or interregional contradictions persisted. In part, too, the fault has been that of synthesizers who neglected to keep abreast with current research or who failed to grasp the nature of the underlying problems, hiding their own ignorance behind dogmatic statements or smart stratigraphic legalisms. In the meanwhile, regional or disciplinary research continues in a conceptual vacuum, with increasingly divergent results and seemingly insurmountable problems of correlation between high- and low-latitude continents and between the sea and the land. In default of an objective reexamination of criteria and results, the beginning student of the Pleistocene is faced by an almost unsurmountable morass of unintegrated and seemingly contradictory data, an unlimited number of alternative stratigraphic frameworks, and a nomenclature so debased as to be worse than useless.

Thus the mid-Pleistocene "problem" concerns that core of the Pleistocene lying before the span of reasonably resolved stratigraphic detail and ecological understanding of the late Pleistocene, and after the Plio–Pleistocene transition. This "problem" is more than a matter of suitable time–stratigraphic framework or nomenclature. Involved, too, are matters of fundamental understanding as to the nature of the mid-Pleistocene. Was there ever a "nonglacial" Pleistocene, i.e., a protracted span of early Pleistocene time without formation of significant ice caps on the landmasses of Eurasia and North America? Was the wave-length and amplitude of climatic cycles in the mid-Pleistocene constant and comparable to the late Pleistocene interglacial–glacial sequence? Were any of the demonstrable mid-Pleistocene warm intervals interstadials rather than interglacials? Are reconstructions of late Pleistocene, glacial-age climate or vegetation relevant for earlier glacials as well? Were mid-Pleistocene climatic oscillations of sufficient amplitude to leave a tangible record in the tropics as well as in higher latitudes? How were worldwide climatic anomalies reflected in distinct climatic provinces and regional litho- or biostratigraphic sequences? All these questions and corollary issues are as central to the mid-Pleistocene "problem" as are an adequate definition of stratigraphic boundaries and the exact number of cold–warm climatic cycles.

Finally, there is the whole sphere of biological events, including faunal evolution and dispersals as well as the complex issues involving the hominization process. These themes are developed more fully in a parallel evaluation by G. L. Isaac (1974a), but two points may be made here.

Firstly, it deserves emphasis that biostratigraphic zonation was from the beginning tied in with evolving concepts of mid-Pleistocene resolution. However, the advent of chronometric yardsticks began to reveal that faunal horizons are not everywhere synchronous. Thus, contrary to widespread, earlier expectations, biostratigraphic units could no longer serve as markers for the entire time–space continuum of the mid-Pleistocene universe. Clearly, it had become necessary to reappraise the mid-Pleistocene faunal record from more sophisticated evolutionary, ecological, and zoogeographical perspectives.

Secondly, it may be called to mind that subdivisions of the Old Stone Age or Paleolithic followed closely upon litho- and biostratigraphic delimitation within the Pleistocene. Consequently the Lower Paleolithic was widely equated with the Middle Pleistocene and, ultimately, with both the Lower and Middle Pleistocene. Stage concepts and temporal implications were commonly attached to industrial variants of the Lower Paleolithic such as "Abbevillian," Acheulian, "Clactonian," "Tayacian," or their Asiatic counterparts. Then, criteria for subdividing the Acheulian came under fire, while the mid-Pleistocene time range began to stretch from a few tens of thousands of years to a half million years or more. It became evident that the Acheulian, whatever it represented, spanned a million years and three continents, thus defying any ethnohistorical concept of a sociocultural group (Butzer, 1971: Chap. 26). Cultural change as well as human biological evolution during the mid-Pleistocene were now seen to be surprisingly slow. During the last 2 yr, the archeological and paleontological evidence from the Lake Rudolf area has even pushed the origins of man back to 3 million yr. Consequently, the nature of mid-Pleistocene hominization requires intensive, multidisciplinary scrutiny. It is here that new stratigraphic and paleoecological approaches also promise to be particularly rewarding.

THE MID-PLEISTOCENE "PROBLEM": SYMPOSIUM CONTRIBUTIONS

Several of the symposium papers synthesized the results of specialized approaches to the study of unusually long Pleistocene

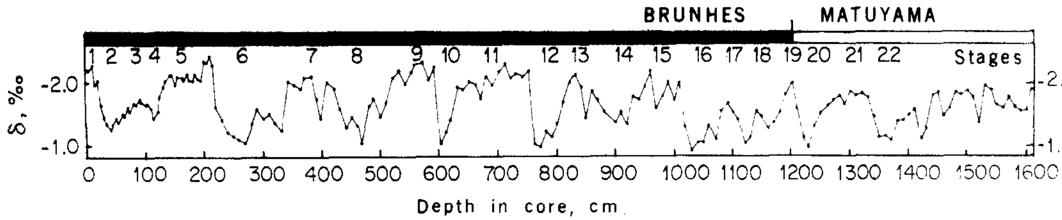

FIG. 1. Oxygen isotope record of equatorial Pacific core V28-238, defining stages 1–22 (after Shackleton and Opdyke, 1973: Fig. 9). Since the range in isotopic composition is about 1.3 per mil, the fluctuations can probably be attributed entirely to changes in ocean isotopic composition caused by the accumulation of northern hemisphere ice sheets.

records. These subdisciplinary techniques included deep-sea core analyses, glacial–eustatic stratigraphy, alluvial geomorphology, loess investigations, and palynology. Each method contributed its own partial picture of mid-Pleistocene events and so provided new insights for a more comprehensive understanding.

The deep-sea core records. Shackleton (1974, Fig. 1) has provided an incisive analysis of the deep-sea core records, and his detailed oxygen isotope record for equatorial Pacific core V28-238 covers at least the past 800,000 yr, as calibrated by the Brunhes–Matuyama paleomagnetic reversal. The 22 stages identified are paralleled by those of other cores, such as V23-100 from the tropical Atlantic, and reflect changes in ocean isotopic composition caused by the waxing and waning of ice sheets on the northern hemisphere continents. In very broad terms, Shackleton's stage 1 can be identified with the Holocene, his stages 2–4 with what is conventionally described as the Last Glacial in continental records, and stage 5 with the "Last Interglacial." Only the very beginning of stage 5 appears to correspond to the classical "Eemian" pollen profiles (Turner, 1974) and this brief phase marks the only segment of core V28-238 that argues for a greater melting of the residual ice masses than experienced during Holocene times. Shackleton (in Conference discussion) argued that the stage 5/6 boundary would conform most appropriately to the conventional Middle/Upper Pleistocene boundary.

Turning to the earlier record of core V28-238 it is apparent that cyclic glacial–interglacial alternations extend back at least to stage 22, some 800,000 y.a. The amplitude of variation between maximum glaciation and maximum deglaciation varies in detail, but remained basically comparable through time, suggesting some fundamental constraints to the planetary glacial–interglacial pendulum. However, there was no strict periodicity, and the wavelength of the superimposed fluctuations expressed by Shackleton's stage units is by no means constant. Several conclusions can be drawn from evaluation of this data: (1) Apparent glacial–interglacial oscillations extend backward in time for at least 800,000 yr. (2) At the very least nine such "cold" stages can be identified prior to the Upper Pleistocene, with a variable duration of about 18,000–67,000 yr, compared with 23,000–73,000 yr for the "warm" stages. (3) In its detail, each glacial and interglacial hemicycle was different, so that one cannot speak of repetitive climatic events. This is underscored by the variations in wind strength deduced from eolian components in cores off West Africa. (4) Correlation of Shackleton's multiple deep-sea units with existing, continental time–stratigraphic schemes is impossible, although cautious comparisons with detailed lithostratigraphic sequences—defined with some measure of radiometric control, do appear to be possible. (5) The absence of any striking events or discontinuities in the lower half of core V28-238 suggests that an arbitrary, radio-

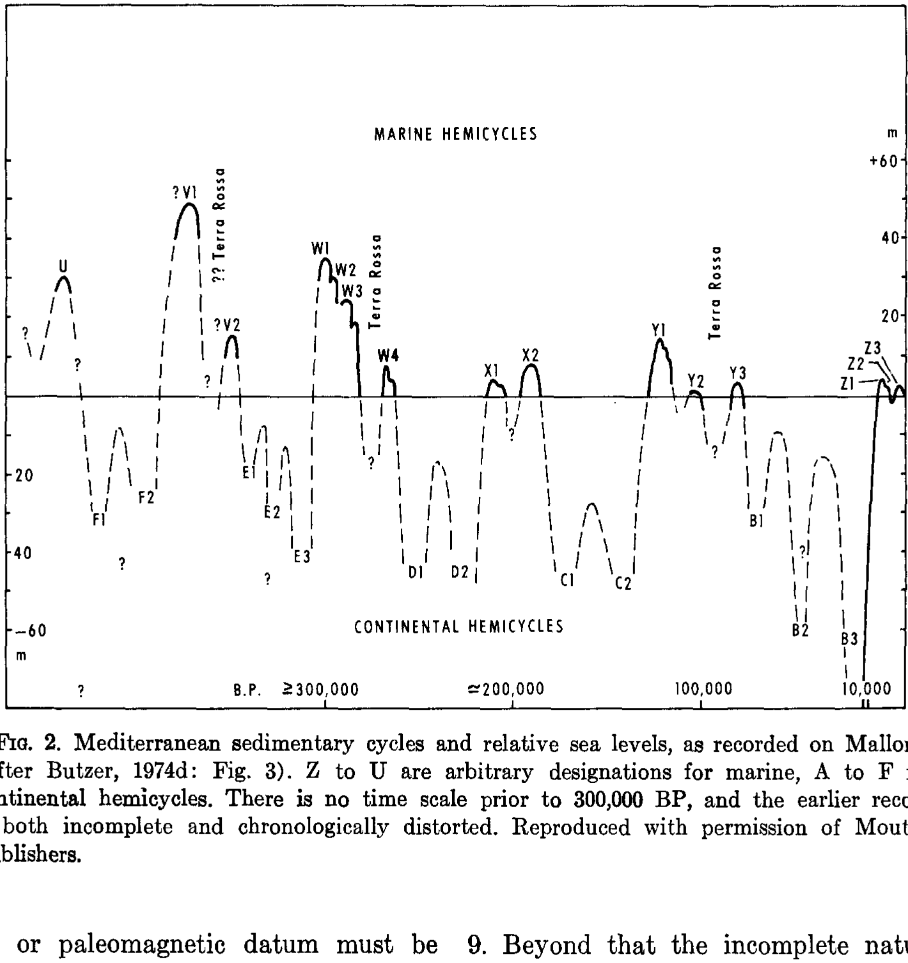

FIG. 2. Mediterranean sedimentary cycles and relative sea levels, as recorded on Mallorca (after Butzer, 1974d: Fig. 3). Z to U are arbitrary designations for marine, A to F for continental hemicycles. There is no time scale prior to 300,000 BP, and the earlier record is both incomplete and chronologically distorted. Reproduced with permission of Mouton Publishers.

metric or paleomagnetic datum must be chosen for the Lower/Middle Pleistocene boundary. Shackleton (in Conference discussion) suggests the Brunhes/Matuyama reversal for this purpose, on account of its ready worldwide applicability.

Glacial–eustatic stratigraphy. The complexity of the glacial–eustatic curve derived on Mallorca (Butzer, 1974d, Fig. 2) is approximately comparable to that of the deep-sea isotopic record, bearing in mind that the littoral sedimentary cycles of Mallorca provide only a minimal level of resolution and that the time axis is increasingly distorted prior to 250,000 BP. As Shackleton (1974) points out, the deep-sea isotopic record may also be read as a trace of glacial–eustatic changes of world sea level. Gross comparisons between V28-238 and the Mallorquin data can be made back to marine hemicycle W2 and deep-sea stage 9. Beyond that the incomplete nature of and lack of isotopic dating or paleomagnetic data for the Mallorquin curve limit its general evaluation. However, a certain measure of support is given to the conclusions offered above in regard to the deep-sea evidence. On a worldwide basis glacio-eustatic sea levels offer a relative stratigraphic tool for distinguishing glacial and interglacial alternations, but they are seldom suitable for specific time–stratigraphic purposes. Even on a regional basis, bio- or time–stratigraphic concepts such as Tyrrhenian or Monastirian offer no assistance in correlation and are often no more than a source of confusion.

The European glacials. Although no Conference paper specifically dealt with glacial geology, Brunnacker (1974), Gladfelter (1974), and Kukla (1974) touch on this theme from several points of view. As emphasized by Brunnacker (1974), the state of resolution of the till and outwash stratigraphies in the Alpine Piedmonts and the North European Plain is incomplete, contradictory at the scale of interregional comparisons, and unsuitable for time-stratigraphic applicability.

Nonetheless, most global stratigraphic schemes ultimately fall back on terminologies derived from a modified or amplified version of A. Penck's scheme of Günz, Mindel, Riss and Würm. Consequently Brunnacker (in Conference discussion) explained the rationale of the original, Penckian four-glacial scheme, its weaknesses, subsequent modifications, and invalid application to biostratigraphic horizons. These pertinent historical insights will be developed by Brunnacker in a separate paper, and can only be summarized here.

During the first decade of the 20th century Penck defined his four Alpine glaciations on the basis of a composite of criteria (*glaziale Serie*): (a) vertically superposed ground moraines and their surface expression, (b) horizontally arranged arcs of terminal and recessional moraines, and (c) vertically and horizontally differentiated glaciofluvial terraces. Each glaciation was defined from a different pdeidmont ice lobe. These lobate formations were poorly interdigitated, and no complete or reliable, direct correlation was ever established downstream along the Danube River. As a result, correlation of the incomplete sequences of pre-Würmian features from lobe to lobe remained controversial, so that not even the basic fourfold scheme has been successfully established through the northern Alpine piedmont. In the 1920s, W. Soergel found there were more than four alluvial terraces along the Saale drainage of Thuringia. These were aribtrarily designated Günz, Mindel, Riss and Würm, with additional I, II, or III subdivisions introduced as deemed necessary to accommodate all terraces present. This unacceptable "correlation" of terrace system and glacial sequence was then tenuously linked to certain macrofaunal horizons. Consequently, the subsequent popularization of the G–M–R–W bio- and time-stratigraphic scheme by F. E. Zeuner and others has little in common with Penck's original definition. Further complications were introduced shortly thereafter when B. Eberl added a pre-Günzian glacial complex (Donau I, II, III), using other criteria of definition than did Penck. Finally, in the early 1950s, I. Schaefer identified an even earlier Biber "glacial."

At this point the Alpine terminologies applied by various workers through much of Europe and even in Morocco had become quite meaningless. Recent fieldwork in each of the type-areas is therefore directed toward establishing local lithostratigraphic units to which the original Penckian terminology *may* ultimately be applicable.

Cold-climate alluvial terraces. Since both of the glacial stratigraphy and terminology have proved to be of little or no value for resolution of the mid-Pleistocene record, other lines of evidence have been intensively followed up by K. Brunnacker and his students among the alluvia and loesses of the lower Rhine Valley, and by J. Kukla and his associates in the loess of Czechoslovakia and eastern Austria. A unique sequence of Plio–Pleistocene deposits has already been established for the Netherlands, documenting progressive impoverishment of thermophile species among the Dutch flora during successive early Pleistocene cold intervals (Zagwijn, 1963; van der Hammen *et al.*, 1971). However, a more complete mid-Pleistocene record is preserved a little further upstream among excellent surface exposures near Cologne and in the Neuwied Basin. Here Brunnacker (1974) has demonstrated repetitive cycles of cold-climate alluviation or loess accumulation, alternating with warmer episodes of soil formation. Seven such cycles have occurred since the Brunhes–Matuyama geomagnetic reversal of 700,000 BP. Syngenetic ice-wedge casts indicative of permafrost first appear ca. 700,000 BP and are associated with all alluvia and loesses—except for those of the second of these cycles. No permafrost is indicated in earlier deposits, but ice-rafted debris first appears at the base of the oldest Main Terrace, which appears to date from the Jaramillo geomagnetic event almost 900,000 BP.

Unfortunately the early Pleistocene record of the Lower Rhine is not now satisfactorily correlated with the geomagnetic chronology, probably as a result of undetected breaks and inconsistencies in the Netherlands sequence (Brunnacker and Kukla, Conference discussion comments). In any event, cold climate phases sufficiently severe to decimate the Netherlands flora begin with the end of the Pliocene, severe winter freezing of Rhine and its affluents is verified for the cold intervals since 900,000 BP, and permafrost characterized most cold hemicycles since 700,000 BP. Brunnacker consequently suggests that the Lower/Middle Pleistocene boundary be set at the base of the first truly cold alluvium that straddles the Brunhes–Matuyama boundary. Problematic is the smaller number of major alluvial and loess cycles in the Lower Rhine (seven) than in the deep-sea record (eight) since 700,000 BP.

The deep-sea and Rhine evidence of increasing and surprisingly dramatic cold during the early Pleistocene finds support in the pollen record of Villarroya (Remy, 1958) and the faunal record of the French Massif Central (Bout, 1974). In fact, Bout recognizes frost-weathered slope deposits and cryoturbated basin beds in successive sedimentary units as old as 1.9 million BP, although clear indications for permafrost are lacking.

The loess record. Perhaps the longest and most complete continental record presently available for the mid-Pleistocene has been studied in unusual detail in the relatively dry lowlands of Moravia (Kukla, 1974). Here eolian loess, hillwash, soil horizons, and ecologically sensitive snail assemblages prove the existence of eight complete cycles of glacial-age loess and interglacial soils within the last 700,000 yr. Including the Krems profile of Lower Austria, it further appears that a minimum of eight additional loess cycles span the preceding million years back to the Olduvai geomagnetic event. This picture of complexity matches that of the deep-sea record and further illustrates the degree to which the till sequences are incomplete and therefore unsuitable for Pliestocene subdivision. This composite, normative loess profile also warns against simple intercorrelations of loess cycles in more humid parts of Europe, where the record is generally incomplete and snail faunas have commonly been leached out. Finally, the history of interpretation of even these Czechoslovak and Austrain loess sections shows the impracticability of any reliable external correlations without radiometric dating or geomagnetic marker horizons. Kukla (1974, and Conference discussion) gives six possibilities to define the Lower/Middle Pleistocene boundary, all linked either directly or indirectly to the Brunhes–Matuyama boundary or the Jaramillo event.

Palynology and the interglacial record. Turner's (1974) critical reevaluation of the northwest European pollen horizons shows beyond question that the mid-Pleistocene interglacial record is rather more complex than hitherto assumed. The Holsteinian interglacial, accepted as the antepenultimate warm phase, is fortunately rather distinctive and the uniform and well defined vegetational succession can be readily identified. With the Holsteinian as a datum, there are *at least* two pre-Holsteinian interglacials younger than the Brunhes–Matuyama boundary and at least one interglacial between the Holsteinian and Eemian. Including the Holocene, this gives a minimum of six interglacial horizons within the last 700,000 yr. Presumably further work will eliminate the remaining, apparent discrepancies between mid-Pleistocene records based on various categories of information. Of special interest are Turner's estimates of the duration of the Holsteinian as 17,000–25,000 and the Eemian as 9000–11,000 yr. This suggests that the palynologically defined interglacials occupied only a portion of the much longer minimum-glaciation intervals represented by the odd numbered deep-sea stages of Shackleton (1974). In fact, the Eemian interglacial appears to have coincided with the maximum deglaciation indicated for the initial stages only of Shackleton's stage 5 (e).

Although Turner (in Conference discussion) indicated that eradication of the last Pliocene floral elements (following the Waalian interglacial horizon of the Netherlands) would be a logical palynological criterion to define a Lower/Middle Pleistocene boundary, he concluded that a biostratigraphic boundary linked to the Brunhes–Matuyama geomagnetic reversal would be of more universal applicability.

THE MID-PLEISTOCENE RECORD IN HIGHER LATITUDES

The preceding review of the Conference contributions allows a number of general conclusions concerning the Pleistocene record in higher latitudes:

a. The European interglacial and Rhine alluvial records indicate a minimum of six, the Czechoslovakian loess a total of eight cold–warm cycles since the Brunhes–Matuyama geomagnetic reversal. Since eight comparable cycles are also indicated in both the Pacific and Atlantic deep-sea cores, this must be seen as evidence for eight glacial intervals of hemispheric or global significance during the past 700,000 yr.

b. With possible exception of the designation Würm, that can probably be applied to the last glacial complex, the till or outwash stratigraphies are hopelessly inadequate to provide a valid or practicable nomenclature for the preceding seven glacials.

c. At least five of the glacials since 700,000 BP were sufficiently severe to produce permafrost conditions in midlatitude Europe. For the lower Rhine Basin this implies a mean temperature depression of at very least 11°C. Consequently the "glacial Pleistocene" unquestionably extends back to the Brunhes–Matuyama boundary.

d. An uncertain but nonetheless substantial number of cold–warm cycles can be recognized prior to 700,000 BP, although the severity of the cold intervals did not match that of glacial phases during the Brunhes normal polarity epoch.

e. Each cold hemicycle prior to 700,000 BP appears to have led to floral decimations in western Europe while providing an environment suitable for loess accumulation in east–central Europe. Further, the deep-sea record indicates extensive glaciation for at least the later of these cold phases. The available evidence could in fact be interpreted with recourse to repeated cold impulses characterized by a progressive intensification of climatic stress.

In view of our present understanding of the mid-Pleistocene record in higher latitudes, two major lines of argumentation can be introduced to propose that the Lower/Middle Pleistocene boundary be linked to the Brunhes–Matuyama geomagnetic reversal by one or other set of criteria. In particular:

1. Whether or not it can ultimately be demonstrated that the Matuyama epoch saw high-latitude climatic oscillations of increasing amplitude, only by 700,000 BP were the cold intervals sufficiently severe to bring permafrost to midlatitude Europe. It can therefore be argued that the major climatic oscillations of the Brunhes epoch were of glacial–interglacial amplitude. Thus a variety of paleoclimatic criteria can be mustered to argue for a Lower/Middle Pleistocene boundary about 700,000 y.a.

2. The experiences of several decades of unsatisfactory boundary definitions show that practiable stratigraphic boundaries must be tied to chronometric horizons, despite established geological tradition favoring bio-, litho-, or climatostratigraphic markers or discontinuities. In addition, a

geomagnetic reversal or event can be identified in a diverse range of sediments not amenable to radiometric dating, thus providing optimal opportunities for valid, worldwide correlation.

If the responsible commission of the International Quaternary Association could propose a geologically acceptable Lower/Middle Pleistocene boundary, usefully linked to the Brunhes–Matuyama reversal, it would be of great practical value for interregional and intercontinental correlation. At the regional or subdisciplinary level it would remain possible or preferable to employ local or specific boundary criteria within the spirit of a more general definition. Such a recommendation has been unaminously made by the Conference participants to the Eighth INQUA Congress (New Zealand, 1973). In regard to the Middle/Upper Pleistocene boundary, the Conference participants suggested retaining of the base of the last, Eemian interglacial, as defined by Shackleton's stage 5(e), ca. 130,000 BP.

MID-PLEISTOCENE RECORDS OF TROPICAL AFRICA

The preceding discussion was deliberately limited to higher latitudes, where time–stratigraphic concepts and definitions have traditionally been developed. However, the potassium–argon chronology of sediments, faunas, and archeology in the Eastern Rift of Tanzania, Kenya, and Ethiopia is unrivaled and stratigraphic generalizations can no longer be carried out in ignorance of the tropical Pleistocene. It will accordingly be necessary to examine the Pleistocene record of tropical Africa, the only lowlatitude subcontinent with suitable stratigraphic data.

Several cautions must be stated before discussing the African evidence. There are no continuous sequences let alone cores of organic data for the mid-Pleistocene, despite isolated and discontinuous pollen information from Ethiopia (Melka-Kontouré, Omo Basin) and Zambia (Kalambo Falls). The faunas of tropical Africa even now retain a high proportion of Pliocene elements and the Ethiopian faunal province provides no useful temperature-sensitive forms (Maglio, 1974). Again, fossil faunal assemblages commonly include woodland, grassland, and riverine/lacustrine forms, and few quantitative analyses of total assemblages are available. Altogether, therefore, there is little biological evidence, throwing the major weight of paleoecological evaluation to sedimentology which, like all other single lines of evidence, is not unconditionally reliable. Additionally, modern ecological "balances" and climatic "stability" in East Africa are precarious and difficult to define. So, for example, a nonoutlet lake such as Lake Rudolf was 15 m higher than today in 1896 and 5 lower in 1955, while the range of fluctuation for the past two millenia is greater than 40 m (Butzer, 1971b, and Conference discussion).

The only record of mid-Pleistocene cold in East Africa comes from ancient, weathered, and dissected moraines in the high mountains. The longest sequence is provided by Mt. Kilimanjaro, where four periods of glaciation are verified and the second of which was older than 460,000 BP (Downie, 1964; Evernden and Curtis, 1965). In South Africa there is some evidence for several episodes of accelerated frost-weathering during the early to mid-Pleistocene time range (Butzer, 1973). Deacon (1974, and in Conference discussion) points out that the thermophile Knysna rainforest sets considerable restraints on the amplitude of thermal fluctuations during the South African Pleistocene. However, thermophile Pliocene elements in the Colchian and Hyrcanian forests of the Black and Caspian Sea littorals survived Pleistocene periglacial conditions, so that the problem may be one of identifying suitable refuges (Butzer and Helgren, 1972).

The longest and most complete sequence available from East Africa is that of Olduvai Gorge (Hay, 1972, 1973; Leakey *et al.,* 1972; also Hay in Evernden and Curtis, 1965, and Leakey, 1974). Unfortunately the long-term mesoenvironmental trends through time cannot be rigorously interpreted due to tectonic modifications of the basin floor and major changes in orographic expression of the nearby volcanic peaks. However the incompletely studied, detailed facies alternations of the middle and upper part of the Olduvai column do seem to imply shorter term environmental changes.

Perhaps equally informative for these purposes is the far more incomplete record of the Omo–Rudolf Basin. A possible model for Pleistocene climatic variation in East Africa is provided by the evidence for repeated high-level lakes during the past 12,000 yr (Butzer *et al.,* 1972). One high level of Lake Rudolf involved a transgression of 60–80 m from shortly before 9500 BP to a little after 7100 BP. A second transgression of some 60–70 m was accomplished in a few centuries after 6600 BP, terminating perhaps 4000 BP but followed by a brief positive oscillation of similar amplitude shortly before 3200 BP. These three transgressions of 60–80 m within a 7000-yr span had a duration of 1–3 millenia and with a cumulative thickness of 21 m constitute Member IV of the Kibish Formation (Butzer, 1974c, and in Conference discussion). Probably comparable is the record of member III (45 m thick, shortly before 37,000 BP) with two transgressions, Member II (22.5 m thick, date uncertain) with a single transgression, and Member I (over 26 m thick, ca. 130,000 BP?) with two or more transgressions. Consequently, most of the later Pleistocene has experienced a moisture regime comparable to that of the present day, although there have been repeated, relatively brief periods of conspicuous lake expansion at long intervals. These moister intervals included one or more high-lake events, each lasting a few millenia. If the earliest verified high Rudolf lake level of Kibish age dates from the terminal Middle Pleistocene, the question arises whether similar events occurred before this. Possible deposits in the center of the Omo Basin may well have been destroyed by repeated mid-Pleistocene faulting. However, a sedimentary record to this effect is also lacking from the more stable northwestern half of the basin, and Bonnefille (1972) has shown that mid-Pleistocene deposits of Melka-Kontouré were laid down when the Ethiopian uplands were drier than today. It is therefore possible, but by no means certain, that Lake Rudolf was generally low from 130,000 BP to about 0.8 million BP, when the last of the Plio–Pleistocene Omo Group deposits were laid down. The available evidence presently suggests that Lake Rudolf was somewhat deeper than today for most of the time from 4.5 to 5 million BP until 0.8 million BP. Long-term trends of lake level reflected both on hydrological changes and ongoing tectonic deformation, but an argument can be made that the amplitude of variation was reduced and that the duration of short and long-term fluctuations was greater than during the later Pleistocene (Butzer, 1974a, and in Conference discussion).

The Omo–Rudolf record, seen in conjunction with the evidence for multiple, mid-Pleistocene glaciation of Mt. Kilimanjaro, cautions against overgeneralization that the East African mid-Pleistocene was paleoclimatically uneventful. However, the magnitude of the changes implied should also not be overemphasized. As Isaac (1974b) convincingly argues, the complex vertical and horizontal zonation of ecological opportunities in East Africa practically assures the survival of all basic econiches through climatic vicissitudes of the scale indicated in the later Pleistocene record. The points to be made here are that environmental changes have occurred throughout the East African Pleistocene, that the details and rationale of these changes are still obscure, but that the scale of any such changes was insufficient to change the fundamental ecological mosaic. The full range of moisture fluctuations of the past 5 million yr has probably been experienced within the 10,000 yr of Holocene time. In view of the pollen and faunal record of the Holocene we can therefore assume a lack of permanent ecological repercussions for Pleistocene wet–dry fluctuations. Furthermore, Pleistocene thermal variations have left no tangible record away from the high mountains, and it must similarly be assumed that any such changes did not seriously affect the complex patterns of ecological opportunities.

Turning to southern Africa, the evidence is somewhat less satisfactory due to the absence of adequate radiometric controls, and the resulting lack of a stratigraphic framework. Unlike East Africa, where topographic and edaphic variation is pronounced, southern Africa is rather more uniform (Deacon, 1974), so that any significant environmental changes would necessarily have initiated wholesale zonal ecoshifts. Possible hints as to magnitude and wavelength of mid-Pleistocene variation are given by a recent evaluation of late Pleistocene paleoclimates (Zinderen Bakker and Butzer, 1973). Mid-Pleistocene sequences are presently available from the Vaal River (Butzer *et al.*, 1973), the Gaap Escarpment (Butzer, 1974b), and the southeastern Cape coast (Butzer and Helgren, 1972). These all indicate significant, long-term changes in stream competence or spring and eolian activity. So, for example, four or more tufa-accretion cycles of the Gaap are hardly explicable without a rainfall of at least 600–800 mm (compared with 300–400 mm today). Similarly, the coastal Knysna rainforest was subject to both semiarid planation and laterite formation during Plio–Pleistocene times. In the interior, short-term climatic oscillations were superimposed upon long-term trends, as is illustrated by the mixed lacustrine and subaerial sedimentary sequences at the Acheulian sites of Doornlaagte and Rooidam (Butzer, 1974a).

At the very least, this recent South African evidence suggests that mid-Pleistocene environmental patterns were far from stable or predictable. However, there are no useful temporal frameworks and interregional correlations are difficult or impossible. No realistic estimate can be made as to the number of major climatic cycles recorded in southern Africa, and the broad trends suggested here cannot now be linked with any global events.

Altogether, the mid-Pleistocene record of tropical Africa remains incoherent, despite some promising local sequences. There is no paucity of evidence for change as such, but the nature and patterns of such changes are still problematical. Many more years of fieldwork will be necessary before it can be decided whether or not regional climatostratigraphies can indeed be established, and it is highly doubtful even now that major climatic changes can be simply followed from one climatic province to another. Consequently the tropical African record does not yet contribute much toward an understanding of the mid-Pleistocene. However, it does clearly show that the climatic cycles of higher latitudes are presently of little or no value in analyzing mid-Pleistocene records of the tropical continents. This strengthens the Conference's plea for a radiometric–geomagnetic definition of intra-Pleistocene stratigraphic boundaries.

MIDDLE PLEISTOCENE ECOZONATION AND ARCHEOLOGICAL CONTEXTS

The basic ecozonation of Europe, Africa and North America during the maximum of the Last Galcial is understood or at least amenable to analysis (see Butzer, 1971a: Chaps. 18–22). By contrast, such information is either very scarce or nonexistent for the glacials or interglacials of the Middle Pleistocene. Frenzel (1968a, 1968b) has attempted to reconstruct the vegetation of midlatitude Eurasia during the Penultimate ("Saale") glacial and the Holsteinian as well as Eemian interglacials. His data is of uneven quality from one area to another, reflecting on the quantity and quality of the available pollen data and other lines of inference. Nonetheless, Frenzel's partial reconstructions do provide working hypotheses of considerable heuristic value.

At the specific level of application to archeological problems, continental reconstructions are of more questionable value. The level of temporal resolution of any reconstruction is necessarily low since there seldom is adequate data to fix pieces of information in a strictly contemporaneous picture of a single phase of a glacial or interglacial. In fact stratigraphic control is so poor and mid-Pleistocene climatic cycles so many that much of the data is best considered to be of uncertain age. Yet Gladfelter (1974) and Turner (1974) have both shown how complex the course of a cold or warm sedimentary or pollen sequence can be. Furthermore, the archeological record shows that even multiple occupations at any one site-complex span only brief intervals of time that coincide with a single set of ecological determinants. Consequently large-scale time–space reconstructions are utopian if not undesirable goals at our present level of understanding of the Middle Pleistocene.

A good part of recent geoarcheological research in mid-Pleistocene time ranges has concentrated on local lithostratigraphic work. Despite initial misgivings by most workers involved, it is becoming increasingly apparent that such "floating" geological contexts are, in default of radiometric opportunities, a successful means of approaching stratigraphic problems of the Middle Pleistocene. Floating stratigraphies also encourage a pragmatic interpretation of site contexts in terms of depositional environments and regional settings. If there are geological deficiencies to be lamented, these are first and foremost a reflection of the "general" geologist's lack of familiarity with sedimentological and pedological techniques or his inability to study sedimentary and geomorphological contexts at the level of detail that other scientists necessarily bring to bear on archeological sites.

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