BONNER GEOGRAPHISCHE ABHANDLUNGEN

Herausgegeben vom Geographischen Institut der Universität Bonn

durch Carl Troll und Fritz Bartz

Schriftleitung: Helmut Hahn

Heft 24

K.W. Butzer

Quaternary Stratigraphy and Climate in the Near East

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14 Tables, 4 Maps, 2 Profiles, 2 Diagrams, 16 Figures

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To my Parents

Table of Contents

List of Tables, Maps, Profiles, Diagrams and Figures

Foreword

This investigation on Pleistocene and Holocene climatic variation in the Near East, originally presented to the Math.-Naturwissenschaftliche Fakultät of the Rheinische Friedrich-Wilhelms-Universität, Bonn, as a doctoral thesis, was complected under the supervision of Prof. Dr. *Carl Troll* and as coreferee, of Prof. Dr. *P. Woldstedt,* with the financial assistance of a scholarship and special extension over a 21 month period from the Deutschen Akademischen Austauschdienst. To all those individuals and institutions who have made this so very fruitful, profitable and pleasant period of study in Germany possible, I owe a sincere debt of gratitude.

Altough the study is primarily palaeoclimatological in scope, it has been possible to obtain an invaluable insight into the Quaternary morphology of the Near East during a private field-trip to Egypt and Jordan in the winter of 1956. It was not intended to perform any specialized field investigations during this time, rather it was attempted to obtain a good perspective of the associated morphological problems and to reexamine the sites and field-results of previous researchers. In this way the Mediterranean coastline between Sidi abd el Rahman and El Alamein, the Fayum oasis, the Nile Valley at El Badrshein, El Balyana, Qena, Luxor and Assuan, the desert stretches between Gizah and Fayum, Cairo and Suez, as well as the lower Jordan Valley were the subject of direct personal investigations or reexaminations that were complemented by a bird's eye view of the uncomparable panorama of arid land morphology unravelled by two low-level flights over the Sinai Peninsula. Although a supplement of my own photographs serves the purpose of illustrating much of the evidence presented, I have refrained from substituting personal observations where previous information could not be reasonably improved within the limited time available. The chapter on postpluvial climatic variation was originally treated in a brief and preliminary form in a Master of Science Thesis "Some aspects of postglacial climatic variation in the Near East considered in relation to movements of population", presented at McGill University 1955 (unpublished).

The capable and generous supervision of Prof. Dr. *Carl Troll,* whose invaluable acquaintance with the relevant literature and whose emphasis upon the systematic framework of the study, particularly the vital connection between pluvials and glacials provided by glacio-eustatic fluctuations of sea-level, are gratefully acknowledged. Prof. Dr. *Paul Woldstedt* provided me with profitable suggestions and criticisms, and his interest during our many spirited discussions proved to be very stimulating. Prof. Dr. *H. Berg,* who provided me with the greater part of my synoptic and aerological training, kindly read the manuscript of chapters 2 and 7 and discussed the relevant problems. Further, I am thankful for suggestions, information or encouragement received from Professors *E. Kirsten, E. Edel* and *F. Bartz* (Bonn); *H. Flohn* (Frankfurt), *M. Pfannenstiel* (Freiburg i. Br.), *H. Gross* (Bamberg), *G. Knetsch* (Würzburg), *A. Desio* (Milano), Miss *G. Caton-Thompson* (Cambridge), *G. Manley* (London), *R. J. Braidwood* (Chicago), *S. A. Huzayyin* (Cairo), *G. W. Murray* (Aberdeenshire) and a number of my own colleagues. Last but not least the stimulating lectures and criticism of Prof. *F. Kenneth Hare*, Mc Gill University, Montreal, under whose supervision my first graduate work in meteorology was carried out, and whom I owe my interest in palaeoclimatology, are sincerely appreciated.

Bonn, May 1957 K. W. Butzer.

Chapter I. Introduction and Retrospect of the European Chronology

1.— *Introduction, Methodology and Scope*

Geomorphologic processes during each distinctive period of the earth's history are determined by earth movements on one hand, by the prevailing climate on the other. It is for this reason that world and regional climates are of such importance during each geological period. Provided essential tectonic and biological stability, stratigraphy would reflect little more than changes of climate. For the duration of the most recent interval of geological history, the Quaternary, tectonic activity has been slight in comparison to the great mountain-building phase of the Tertiary, particularly in regions little effected by the Alpine folding. Consequently the stratigraphical differentiation of the Quaternary is primarily a reflection of climatic changes. Biological evolution has generally been very slow during geological history, and during the approximate span of one million years since the beginning of the Pleistocene, faunal changes are no longer sufficient to permit the identification of most deposits. This deficiency is often bridged by the traces of human industry which occur in the stratigraphical horizons, and one may say that prehistory replaces palaeontology to a good extent during the Quaternary. If is this, the appearance of man upon the scene, which sets off the Pleistocene and Holocene from the rest of geological history.

The geomorphologic processes, climatic sequence and human history of the Quaternary are an harmonious symposium to which students of geology, meteorology and prehistory have each contributed their share. All three fields, despite their great variations in methodology and scope, are intimately bound with the earth and the soil. Prehistory and archaeology are largely synonomous, prehistory *per se* consisting of archaeology, supplemented by analogies from present-day, primitive relict ethnic groups. As such the importance of prehistory cannot be overemphasized, as it embraces the history of mankind from its inception to the beginnings of historical documentation, a time span which includes all but a fraction of one percent of the existence of man. And in this regard it is highly commendable that the prehistorian has not disdained to work together with the earth sciences not only in his field investigations proper, but in admitting the paramount importance of the geographical environment to early man, little aided as he was by technological advances. This environment consisted in part of the fundamental *static* habitat provided by nature in the overall distribution of land and water, plain and mountain, rock and soil. Yet of greater importance was the *changing* physical environment provided directly and indirectly by a climate subject to effective long-term variations in the form of a direct physiological atmosphere and in its ultimate dominance in the evolution of morphological forms, and the distribution of plant and animal life. In response to this demand various new branches arose among the g e o s sciences in the forms of studies of former or p a l a e o distributions and arrangements of climatic zones, vegetational belts, meteorological phenomena, and of the physical landscape, giving rise to the sciences of palaeoclimatology, palaeobotany, palaeometeorology and palaeogeography. In this development geography and geology, and more recently meteorology, have played an equal and cooperative role, geography presenting the outlook, universal scope and philosophy dominating the purpose, methodology and spirit of the geological and geomorphological investigations that provided the structure which has been analyzed and interpreted by the meteorologist.

The aim of the present investigation is chiefly palaeoclimatological and stratigraphical in tenor, and it is not intended to provide either a full-fledged palaeogeographical or palaeobotanical study, altough incidentally brief incursions into and contributions to these intimate cognate fields shall be made. The essential purpose of the study is a history of Quaternary variations of climate. The extent and sequence of such variation are investigated and analyzed, and interpreted in the form of a regional description of the atmospheric circulation phenomena and of the associated general circulation changes. It is attempted to present a modest chronology and reconstruction to bridge the obvious general deficiency in such matters for a sector of the tropical and subtropical latitudes, namely the Near East. This area, comprising Libya, Egypt, Syria-Mesopotamia, Inner Anatolia and Iran circumscribes the southeastern quadrant of the Mediterannean climatic province with its westerly circulation and rainy season in winter, its trade-wind, subtropical desert climate in summer. Southwards and eastwards the climate grades into desert and eventually into the peripheral sphere of the great monsoonal provinces, northwards into regions with rainfall maxima during the summer or during the transitional seasons. And as such, this region provides the necessary prerequisite of essential unity and identical character of climate variation in the overall sense of the word.

Those familiar with the extensive specialized literature on the Pleistocene and postglacial chronology of Europe and North America will probably find the methodology employed in this treatise rather different and probably even less definite and not sufficiently quantitative, but this is inavoidable through the difference of the geographical factors, and thereby of the climatic indicators involved. Although the penetration of cold air masses effects cyclogenesis to no inconsiderable degree, and temperature conditions regulate the rate of evaporation, the direct morphological evidence of temperature variation in the Near East, in contrast to Europe, is very secondary to that of rainfall fluctuations. Yet the effects of increased precipitation and decreased evaporation are largely identical, and often reflect an identical primary cause, so that one can draw no sharp line between these two processes in the Near East.

Undoubtedly the lack of botanical evidence is of the greatest hindrance and inconvenience since pollen-analysis, the cornerstone of the European climatic succession, has not yet been applied to Near Eastern deposits. Despite many unfavourable conditions for preservation of pollen under existing oxidational factors, similar research in the arid south-west of the U.S.A. seems guite promising. Since the stratigraphical profile can never supply the precise chronological dating of the pollen profile, resort must be made to the new technique of radiocarbon dating, and such dates as are assigned in the climatic succession established below are largely provided by C_{14} or by direct physical or cultural association with the world-wide chronology. The last great advantage of pollen diagrams comes from the relatively good quantitative estimates that can be made of existing climatic conditions according to the movements and relative percentage of well-known, botanical species. Morphological processes in themselves are continually the subject of strong controversy, and too little unamity has been achieved in regard to the climatic environment associated with them.

Next to the almost absolute absence of palaeobotanical evidence, the morphological evidence itself is not in every way comparable in quality with that of higher latitudes, the stratigraphical record being much less complete than that of Europe and North America, so much so that little or nothing is known about the Lower Pleistocene while even the Middle Pleistocene is somewhat vague and often remains inferential. The reason for this deficiency is two-fold. Firstly the number of intensive field investigations in the area are still far too few, whereas the value of extensive, often superficial surveys is unfortunately sometimes limited in application. Even more disconcerting is, however, that much of the evidence has long been destroyed by the great amount of denudation by wind and water which has scoured off the exposed surface of the landscape. That this denudation proceeds at a rate inconceivable in temperate latitudes can be seen from the Suez Isthmus where the landbridge watershed attains a maximum of 16 meters, and where there has been no connection of the Mediterranean and Red Seas at least since Miocene times on faunistic grounds (*Sandford & Arkell* 1939, p. 26 ff).

Many field investigations in the Near East have been concluded with reviews of a small number of related results from elsewhere and in this manner a number of different, often quoted and sometimes little substantiated 'results' have gained access into the literature on the Near Eastern Pleistocene. Yet it must be remembered that the only existing systematic study of the Saharo-Arabian Pleistocene has been that of *S. A. Huzayyin* (1941) which has been often bypassed in many a reference to the area in question. Faced by such an abundance of contradictory conclusions we have been forced to take a rather drastic and critical attitude of all such conclusions and hold them suspect until substantiated or disproven by a reinvestigation of the field evidence amply substantiated by evidence from elsewhere. In short, although a few papers will have inevitably escaped our attention or have been unobtainable within the period of investigation, we have tried to give attention to as complete as possible a list of relevant literature from a most varied group of direct and indirect contributions to the subject. These field investigations have been restudied in detail according to a coherent, unified set of principles derived from modern theoretical geomorphology and supplemented by personal experience in arid land physiography. That we have been obliged to discard many conclusions and often take a seemingly overly-critical attitude should not be taken as a sign of disrespect for that great number of selfless, capable and experienced explorers, scientists and others who have gone before. But we feel that only through constructive criticism, more overall analysis and reinterpretation can their work be given its fullest merits and deserving recognition. In the light of further field research, it is inevitable that much of the material of this study will one day require revision. But it shall have more than fulfilled its purpose if it serves to clarify the problem in some way, stimulating new ideas and further research.

2.—Retrospect of the European Chronology.

After this brief review of the purpose and methodology of the study, it will be advisable to outline the contemporary European Quaternary and particulary Würmian and postglacial chronology, giving a list of the more important relevant literature. Although this topic has been and still is incredibly controversial for many decades, there are very strong indications of a satisfactory solution during the last few years. The first great heresy in relation to the Pleistocene chronology was the improved solar radiation curve of *M. Milankowitsch* (1920 ff) still accepted by a number of researchers to-day, whereby a three-phased Würm was postulated. However amid the early waves of enthusiasm, already *P. Woldstedt* (1929) and *C. Troll* (1930, 1931) expressed grave misgivings about these theoretical reconstructions, and *F. Firbas* (1947) has been able to show the inapplicability of the radiation curve for the late glacial and postglacial period by comparing it with the movements of the altitudinal treeline, while *M. Schwarzbach* (1950, p. 182—6) and *Woldstedt* (1954, p. 336—342) have more recently provided a wealth of material presenting insurmountable difficulties for the solar radiation curve hypothesis.

During the last few years the dispute of an undivided Würm, a two-phased, and a three-phased Würm has been actively revived. Briefly, *Woldstedt* (1950, 1956), *R. F. Flint* (1953, 1956), *E. Ebers* (1955), *H. Gross* (1956) and others have, with the help of radiocarbon datings, succeeded in establishing the existence of a two-phased Würm separated by an interstadial, which stands in contradiction to the position of *J. Büdel* (1950, 1953) and others who maintain an undivided, single-phased Würm Glaciation. *Penck* and *Brückner* had already postulated a 'Laufenschwankung' with overridden older Würm end-moraines some fifty years ago, and *C. Troll* (1936) describes Würm outwash gravels underlying the Würm end and ground-moraines of the Inn Valley glacier which can nowhere be connected with the outermost end-moraines and which overlie interglacial gravels (of Riss/Würm age on account of their fauna). *Troll* considers these outwash gravels, at least in part, as gravels of older date belonging to the early Würm advance. Following *E. Ebers* (1955), the evolution of the Würm piedmont glaciers of the northern Alps can be described al follows. During the 'Early-Würm', moraines and outwash fans were deposited and locally overlain by a younger boulder clay, following which the ice edge retreated to the foot of the Alps during the Göttweig Interstadial. The second and maximal advance of the glaciers during the 'Main Würm' led to the deposition of three systems of moraines and outwash fans which covered all the deposits of the 'early Würm'. Subsequently during the 'Late Würm' phase the glaciers retreated in stages into the mountain valleys, leaving large trough lakes behind. Similarly *P. Woldstedt* (1956) has been able to show the association of the lower Younger Loess of Central Europe to the Early Würm and the Mousterian period, whereas the upper Younger Loess corresponds to the maximum extent of the glaciation during the Brandenburg, Frankfurt and Pommeranian stadia associated with the Aurignacian industries (s e n s u l a t o), the Szeletian and Solutrian. To the Early Würm is ascribed the overridden Stettin stadial of northern Germany, while the beginning of the 'Middle Würm', as *Woldstedt* calls the Göttweig Interstadial—Main Würm complex, was characterized by a distinctly warmer period during which the ice margins retreated appreciably. The latter is variously designated as Aurignac, Göttweiger, Stillfried and Laufen interval in Europe, and corresponds to the 'Sydney' weathering zone of North America (*Flint* 1956). Lastly the retreat from the Pommeranian moraines marks the beginning of the 'Late Glacial' period which is characterized by the Magdalenian, and which lasts until the close of the Salpausselkä stadial. The detailed investigations of *H. Gross* (1956), *E. Schönhals* (1956) and *F. Brandtner* (1956) likewise confirm these main subdivisions.

The Late Glacial period in the sense of *H. Gams* (1952) commences with the retreat from the Gotiglacial moraines and the beginning of the Bölling Interval, which is dated at shortly after 13,000 B. C. by radiocarbon (*R. Schütrumpf* 1955, *H. Gross* 1955) and a little earlier by the geochronological system. This Bölling Interval represents a weak warmer phase within the 'Lower Dryas', the earliest phase of the postglacial chronology of Northern and Central Europe. After a brief relapse to cooler conditions, the important Alleröd Interstadial followed, dated at 10,300—9000 B. C. geochronologically, 9900—8800 B. C. by *H. Gross* (1954) taking a mean with the newer radiocarbon dates. During this period *PINUS* and *BETULA* spread right over Central Europe and replaced the typical tundra vegetation of the previous period while the Alpine treeline rose to 1600 m, only 200—300 m below that of to-day (*Gams* 1950, 1952). However the extensive distribution of the northern ice masses and the summer heat loss through their ablation kept the local summer temperatures low, some 6° C. lower than the present in Southern Scandinavia, 4,5° in Pommerania and 2.5° in the Black Forest (*Firbas* 1949). After the two temperature submaxima of the Alleröd, an almost catastrophic reversion to colder conditions took place during the Upper Dryas now dated at 8800—8100 B. C. on a mean of the radiocarbon and geochronological dates (*Gross*

1954). This phase corresponds to the Salpausselkä I, II and III endmoraines of Finland, which corresponds to the Alpine Schlern and Gschnitz stadia (*v. Klebelsberg* 1942, *Gams* 1952, *H. Paschinger* 1952) and to the Mankato readvance of North America (*Flint & Deevey* 1951). These three Alpine stadia had snowlines some 900, 600 and 300 m lower than those of A. D. 1900. In England the snowline was lowered by some 300 m ('Highland Readvance') in comparison to the Alleröd and was some 1000 m lower than to-day (G. *Manley* 1953). The treeline was similarly some 900—1100 m lower than to-day in Central Europe and a tundra vegetation replaced the pine-birch association of the Alleröd, accompanied by a local summer temperature some 6—7° C. below those of the present (*Firbas* 1949). This drastic world-wide lowering of temperature, apparently quite moist to permit the rapid readvance of the glaciers, ironically occured at the same time as a solar radiation curve maximum (*Firbas* 1947). Obviously other factors must exert a more dominant role in climatic variations.

During the Preboreal, c. 8100—6800 B. C., the glaciers retreated rapidly while *BETULA* and *PINUS* recolonized the ground lost during the Alleröd. The dominance of birch suggests that the summers were still quite cool due to the melting of the northern glaciers, although no preciser information is available with regard to the winter temperatures (*Firbas* 1949). The Boreal phase, c. 6800—5600 B. C., whereas still relatively dry as its predecessor, was continental rather than cool as far as temperature goes, as the rapid spread of *CORYLUS, QUERCUS, ULMUS* and *TILIA,* in addition to *PINUS,* suggests o high July temperature (*Firbas* 1949).

The Atlantic, c. 5600—3000 B.C., and Subboreal phases, c. 3000—8/500 B. C., were characterized by world temperatures somewhat above those of the present in the so-called 'Climatic Optimum'. The altitudinal treeline was some 400 m higher in the Alps (*Gams* 1952) and the latitudinal treeline was considerably northwards as well. However it is difficult to separate the absolute increase in summer temperatures usually estimated at 2—3° C. (e. g. *H. Flohn* 1952), and the lengthening of the period of growth. *C. E. P. Brooks* (1949, p. 171—2) even believes, on theoretical grounds, that the Arctic Ocean was seasonally ice-free, which condition possibly lasted into the 13th century A. D. During the Atlantic, mixed oak forests were dominant in Central Europe, and the colonization of the drier lowlands by *PICEA, ABIES* and *ALNUS* implies a moister climate (*Firbas* 1949). The succeeding Subboreal period was in all eventuality characterized by a drier climate, interrupted by a number of quite moist intervals, and *Gams* and *Nordhagen* (1923, p. 296—303) have shown that European lake levels generally stood some 2 m or more lower than the present during ad part of this period at least. A mixed oak and beech forest represented the Central European climax formation and the northward movements of submediterranean forms suggests drier and warmer summers, but there was no large-scale change in the associations due possibly to the low intensity or short duration of the droughts (*Firbas* 1949).

Table I: *The European Pleistocene and Holocene*

(based upon *Woldstedt* 1954 *a*, 1956; *Gross* 1954, 1956; *Brooks* 1949; *Firbas* 1949; *Flint* 1951, 1956; *Schwarzbach* 1950; and others)

	Subatlantic	(cooler, humid)	c. 8/500 B. C. —
	Subboreal	(warm, drier)	c. 3000—8/500 B. C.
	Atlantic	(warm, humid)	c. 5600—3000 B. C.
	Boreal	(continental, dry)	c. 6800—5600 B. C.
Postglacial	Preboreal	(cool, dry)	c. 8100—6800 B. C.
Late Würm	Upper Dryas[1] — Salpausselkä (Mankato)		c. 8800—8100 B. C.
	Alleröd Interstadial (Two Creeks)		c. 10,000—8800 B. C.
	Lower Dryas		c. 13,000—10,000
	Bölling Interstadial		
	Gotiglacial		
	Interstadial		
Main Würm	Pommeranian moraines		c. 23,000—16,000
	Frankfurt moraines		
	Brandenburg moraines		
Göttweig Interstadial (Sydney)			began somewhat after 40,000 B. C.
Early Würm (Weichsel, Wisconsin)	Stettin moraines		
	Earliest advance stadia		
Riss/Würm Interglacial (Eem, Sangamon)		maximum perhaps 100,000 years ago	
Riss II	Warthe moraines		
	Lamstedt moraines		
Interstadial			
Riss I (Saale, Illinois)	Drenthe (main Saale) moraines		
	Reburg moraines		
Mindel/Riss Interglacial (Holstein, Yarmouth)			
Mindel Glaciation (Elster, Kansas)			
Günz/Mindel Interglacial (Cromer, Afton)			
Günz (Weybourne, Nebraska).			

[1]) The Upper Dryas has been generally separated from the Late Würm in the subsequent chapters on account of its position which is already ‚postpluvial' but not ‚postglacial'.

The character of the climatic deterioration at the onset of the Subatlantic period has been discussed by *G. Smolla* (1953) for southwestern Germany. The water-table rose leading to renewed activity of travertine springs, while the rising of lake levels to their present height, the deposition of gravel beds and floodplain alluviation, and the destruction of forests and heaths on present-day moors all testify to a quite moist relapse, and a lowering of the altitudinal treeline by at least 1—200 m can be inferred indirectly while *J. Iversen* (1944) estimates a 2° C. fall in mean temperature for Denmark. Subsequent to this, the European climate showed small variations about this mean until the readvance of the glaciers in the Fernau stadial during the early 17th century A. D. In general the period from A. D. 1100—1550 was a little warmer than the present in Central Europe, interrupted only by brief colder spells c. 1250, c. 1330 and 1420—1464 (*Flohn* 1949). After 1550 the winters became colder, the summers cooler until the climax of the 'Small Ice Age' glacial readvances between 1590 and 1650 during which England enjoyed cold winters and cool, wet summers (*Brooks* 1949). Between 1680 and 1740 the climate improved somewhat but reverted to more continental conditions between 1740 and 1890, since when there has been a considerable rise in world temperatures and a rising of the climatic snowline by some 100 m. It should be noted, however, that a climatic amelioration means a rise of temperature in Europe, in contrast to the Near East where a climatic amelioration represents an increase in moisture. According to *Brooks* (1949) the years 600—1000 and 1450—1750 A. D. were dry in Britain, whereas those of A. D. 1075—1300 were moist.

These few guidelines, which are only intended to serve as as framework necessary for comparison with the Near Eastern chronology, are presented in a summarized form in Table I above.

Chapter II. The General Atmospheric Circulation of the Near East

1.—Introductory Remarks

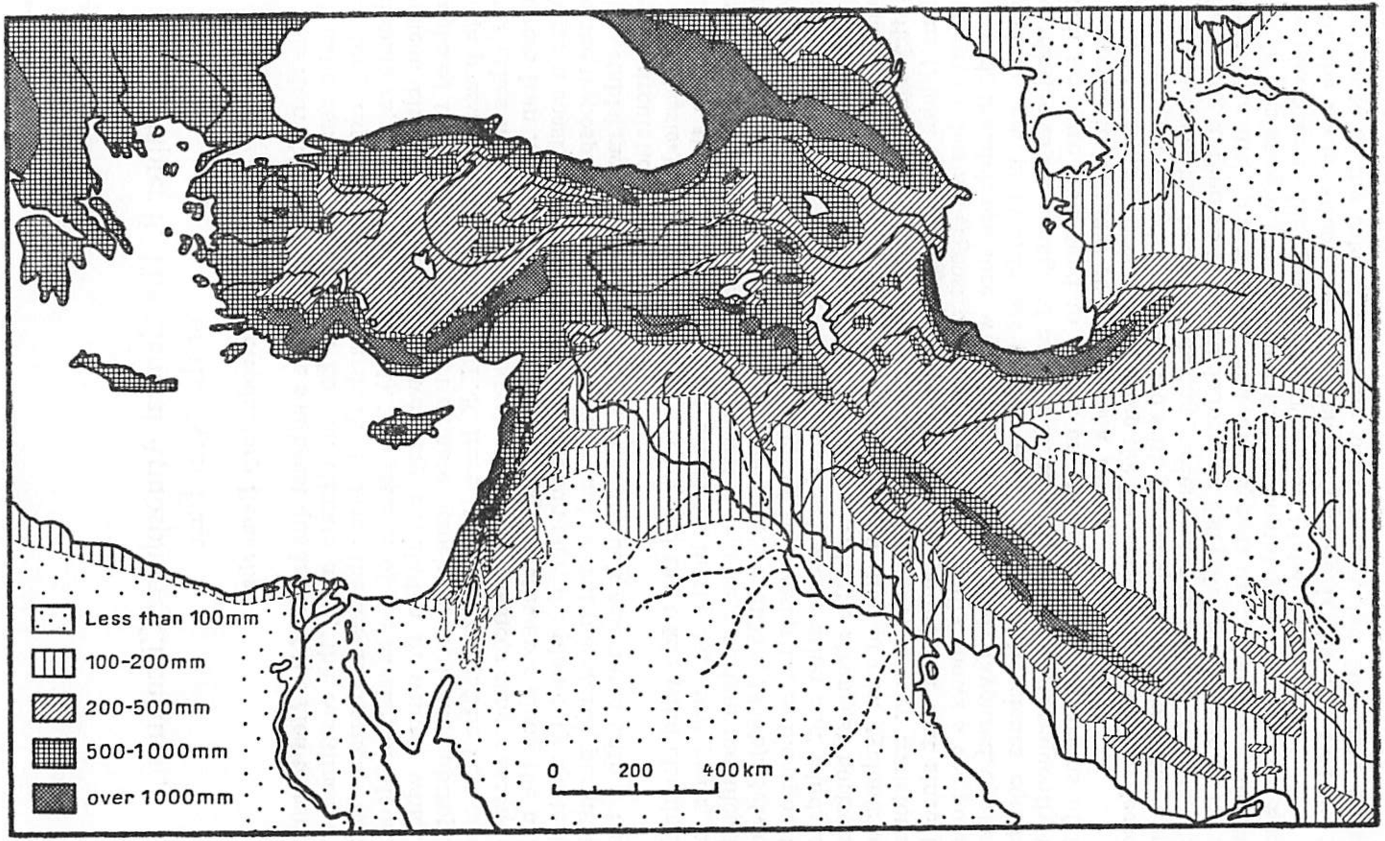
The Near East falls within the southeast quadrant of the Mediterranean climatic zone, and enjoys an Etesian climate along the coastlines with westerly exposure, while towards the interior the desert character of the climate rapidly increases (Map 1). The essence of the Etesian or Mediterranean climate is a disturbed westerly circulation in winter, which is replaced by a subtropical desert climate associated with the subtropical high pressure belt in summer (*F. K. Hare* 1953, p. 172—3). The belt of the westerlies with the associated extratropical disturbances ranges eastwards across Iran into the Punjab and the Pamirs, southwards along the north African coast during winter. During the summer, the planetary westerlies of the troposphere weaken considerably and retreat polewards, permitting the estabishment of a cellular high pressure belt associated with a trade wind circulation.

The classical concepts of the jet stream and the trade wind circulation have been the subject of detailed attention in the last few years, and especially the notions regarding the latter require a certain modification according to the investigations of *H. Flohn* (1953 a, 1955 a, 1955 b). Between 30° and 60° latitude the kinetic energy of the westerlies is incorporated in the jet stream, characterized by maximal acceleration and windshear in both horizontal and vertical directions with the strongest horizontal temperature gradients, the most frequent formation of new cyclonic and anticyclonic whirls, and a maximum of atmospheric energy transformations (*Flohn* 1955 b). Furthermore *Flohn* has pointed out that since the jet stream has supergeostrophic velocities, it usually shows a component towards the high pressure, while cyclogenesis is highly favoured. Cyclones tend to veer polewards out of the westerly belt, anticyclones equatorwards due to the change of coriolis force with latitude. Consequently the high pressure cells tend to collect on the equatorward margins of the westerlies in latitudes 30—40°. (*Flohn* 1955 b).

2.—The Westerly Circulation during the Transitional and Winter Seasons

Strong westerly winds associated with the polar front blow in the upper troposphere of the Near East during winter and spring (*J. K. Bannon* 1954). According to *Bannon* these winds form an 800 mile wide stream at 190 mb centered a little north of 32°, and with speeds up to 100 knots; in other words this stream is wider and the horizontal gradients of wind speed are less than in the typical jet streams of higher latitudes.

In the lower atmosphere the general picture is characterized by the dominance of the cold, dry Asiatic anticyclone below 500—2000 meters,



Map. 1: Mean annual rainfall in the Near East. Designed: K. W. Butzer

frequently interrupted by depressions travelling west to east from the Mediterranean to the Persian Gulf, Iran, Northwest India and Turkestan (*G. Bauer* 1935). Over the Mediterranean proper a secondary center of low pressure arising from thermal-kinetic conditions favours the passage and regeneration of a great number of cyclonic disturbances.

During the autumn transitional season the first short, heavy showers of the instability type, usually associated with thunderstorms, bring relief from the parching summer drought in late September or early October. These showers are connected with hot southeasterly currents meeting relatively cold Mediterranean air-masses. The paths of these weak autumnal cyclonic disturbances, resulting from troughs in the upper westerlies, quite frequently pass through the Adriatic and Ionian Seas across the Eastern Mediterranean into the Levant. Similarly brief but severe rainfalls may occur when warm damp air supplied by southeasterly surface currents, due to northward intensifications of the Sudan monsoon low, are undercut by cool westerly currents from the Mediterranean (*El-Fandy* 1948). Such movements of the oscillatory Sudan low between September and November are usually induced by the passage of troughs in the upper westerlies, and the 2—4 mb falls of pressure and rapid uplift along the fronts of convergence lead to thunderstorms in Syria, Palestine and particularly in Egypt. During these months the southern Caspian littoral is frequented by numerous depressions passing through the Black Sea across the Caucasus into Khorassan, an area which enjoys a secondary rainfall maximum at this time. In fact *L. Weickmann* (1923) gives an average of 35 passing minima for the autumn months in northwestern Iran and northern Anatolia, compared with only 16 during the winter. The subtropical high pressure cells over the Libyan Desert and Anatolia gradually weaken in October, and the summer monsoon low over southeastern Iran and eastern Arabia retreats southwestwards into the eastern Sudan. Pressure patterns and stream lines receive their winter characteristics as the cold, shallow Siberian high invades Iran and Asia Minor in October-November, while the first Mediterranean depressions already gather enough energy to reach the Persian Gulf and the Zagros ranges.

By December the real winter rainy seasons sets in, and a succession of barometric minima and cold fronts invade the Near East following a number of well-known, classical paths. Some storms pass from the Atlantic right along the Mediterranean, skirting close to the African coast and enter the Levant, Iran and often go even further. The 2000 mile track along the Mediterranean usually takes 4—5 days, at most 6 days. However Atlantic depressions of this type may weaken before arriving in the Eastern Basin as the cold air behind the fronts is rapidly modified and the lows fill up. Of greatest importance therefore are depressions regenerated or resulting from cyclogenesis within the Mediterranean itself. Cold fronts of polar troughs can release sufficient energy for cyclogenesis, and *Hare* (1953, p. 175) points out that the temperature contrasts provided by mPK and cP airmasses over Europe with the local warm mPW air presents a situation highly favourable for frontogenesis. Most common in this category are Genoan lee depressions and Cyprus lows. The former are an oft-investigated and well known phenomena, while the latter, which we shall discuss briefly, have only been recently treated and assigned their full value and significance by *M. G. El Fandy* (1946), whose presentation is followed in the next paragraph.

cP air outbursts from the Siberian anticyclone normally are halted along a 'quasi-polar front' lying across the Taurus, Rhodope and Dinaric Alps. Thus cold fronts radiating out of this sector frequently regenerate the shallow stationary depressions in the Aegean near Cyprus forming under the influence of the neighbouring mountains. Another possible mode of occurence is cyclogenesis resulting when southeastern tropical currents meet the northeasterly cold waves in the same area. The former case is typical when the pressure over the Balkans and Central Mediterranean is high, the latter when it is low. Most of the cold fronts which pass through Egypt and the Levant to the Sudan and Iraq emerge from the Black Sea area in company with Cyprus lows. Temperatures fall progressively lower and the low deepens the more cold air continues to blow around the Cyprus low in its initial stationary stages. A southeasterly current is dynamically induced over Iraq and northern Arabia leading to the formation of shallow areas of low pressure there. The lack of water vapour, except from the Persian Gulf source which favours thundery upper air instability conditions in Iraq, precludes any precipitation potential of these shallow minima. When the Cyprus low begins to move away from that island it tends more southeast due to the dominance of westerly winds in the upper air, as well as to the large south-north horizontal temperature gradient which reverses the pressure gradient at lower altitudes. In Egypt local heavy showers may set in from large Cb clouds resulting from turbulence in the polar air, which subsequently passes on into the Sudan and Red Sea area where the freshening of the circulation may lead on to local duststorms over the deserts, and local showers along the Red Seas coasts. Successive cold fronts simultaneously cross over Palestine and Syria to northern Arabia and Iraq in company with successive shallow lows. The surface winds are much stronger than the expected gradient wind so that their passage resembles that of squall phenomena. In fact the precipitation associated with the Cyprus lows is usually brief, heavy and irregular. Gales and line-squalls predominate over the sea, and the rainfall decreases rapidly in the interior after heavy rain has fallen in thunderstorms accompanying the passage of cold fronts over the coastal hills of the Levant.

Although *El Fandy* places such strong emphasis on depressions and cold fronts with shortest possible sea track, the number and importance of depressions originating or regenerated in the Central and Western Mediterranean is large and not to be minimized, especially when European cP is drawn into the rear of such depressions. In fact the disturbances which travel so far eastwards are usually associated with pronounced minima in the upper atmosphere and not with the shallow Cyprus lows. Between October and April some 30 depressions reach Iraq or the Persian Gulf, and of these 20 to 25 are sufficiently deep and vigorous to pass further to northwestern India (*Weickmann* 1923). Similarly a number of cold waves and upper air troughs originating in higher latitudes may leave their normal west-east path and penetrate equatorwards into the tropics between two subtropical high pressure cells (*Flohn* 1950, 1955 a, 1955 b).

Before passing on to the spring season, however, reference must be made to the local conditions modifying the cyclonic winter rainfall. The topography of the coasts in particular, as well as the relative positions of land and sea are of primary importance. Rainfall occurs most frequently under conditions of instability upon uplift over the coastal ranges, and the adiabatic warming and stabilization resulting from downward flow into the interior plains at the lee of the hills is the prime factor in determining the position of the great inland deserts. In this way the west-facing ranges of Anatolia, Iran and the Levant, and even the Red Sea Hills, are comparatively moist, while the flat plains of Egypt, the Syrian hamada and the interiors of Anatolia and Iran are comparatively arid. In other words, in most cases precipitation is orographic as well as cyclonic. Another such factor influencing precipitation in Arabia, Iraq and Iran is the cold, dry anticyclonal circulation dominant there during the early winter months which tends to block the passage of depressions, delaying the rainfall maxima by one to two months going from west to east, until such time when the anticyclone begins to weaken and disintegrate. This anticyclonal circulation brings a dry, stable desert climate to Southwest Arabia and becomes known as the Northeast Monsoon as it penetrates into East Africa. Locally in Iraqi Kurdistan the strong temperature gradient and high relief lead to an intensive, uniform anticyclonic winter rainfall (*H. H. Boesch* 1941).

During April and May the Siberian anticyclone has almost entirely withdrawn from southwestern Asia, but simultaneously the westerly circulation shows unmistakable signs of weakening and the depressions begin to take more northerly paths avoiding the Eastern Mediterranean Basin for the Black Sea, giving Anatolia and the Caspian littoral its annual rainfall maximum. Nevertheless, these months still fall well within the rainy season further south and on the average, 12 cyclonic disturbances penetrate across the Levant into Iran during April-May. Convectional rainfall takes on a certain importance during the spring months, as *M. H. Ganji* (1955) has shown to be true for northwestern Iran, and which also holds for large parts of Anatolia. Characteristic of the spring transitional season are the hot, dry dusty southerly winds often going over into outspoken sandstorms, which are generally known as Khamsin depressions in the Near East. These winds, whose occurrence and strength also seems to have been subject to greater fluctuations during the Quaternary, have been studied by *El Fandy* (1940, 1951) and *Hare* (1943). According to the latter, Saharan depressions of the Khamsin type form chiefly on fronts separating mP from cT air. As these depressions move into the Mediterranean they bring a wave of cT out across the African coast in their warm sector. The Khamsin winds blow 3—4 days before the actual approach of the depression, and the hazy or dusty character is due to the cool Mediterranean air, while the stable lapse rate in the lower layers of the cT air cooled from below while moving northwards prevents the upward diffusion of suspended dust (*El Fandy* 1940).

3.—The Summer Circulation and Conclusions

Between April and July the westerly jet stream moves northward to achieve a maximum current in latitude 34° N, and is replaced by a latitudinal zone of light, variable winds in the upper atmosphere centered at about 200 mb (*Sutcliffe & Bannon* 1954). In the lower atmosphere the nucleus of the Asiatic monsoonal low lies athwart Baluchistan, Southern Iran and Eastern Arabia during the months of June to September, while an outlier of the Azores high lies across the Western and Central Mediterranean. The relatively strong pressure gradient thereby set up in the Eastern Mediterranean gives rise to the persistant northerly and northeasterly Etesian winds, characterized by a strong inversion at low levels (1000 to 2500 meters) above which the westerlies still dominate. *Schneider-Carius* (1948) has shown that the Etesians thereby posses the character of trades in as far as flow patterns and precipitation go, while dynamically they form an integral part of the great Asiatic monsoonal system. All in all the circulation of the lower atmosphere throughout the Near East is northerly or northeasterly, whether it be within the Asiatic monsoon, the Etesians or within the tradewinds of the horselatitudes. Over the seas the lower layers of the air are moist and relatively instable but strong inversions at 7—800 meters preclude any precipitation (*Schneider-Carius* 1948), while the occasional passage of troughs in the upper westerlies (*El Fandy* 1950) shows little activity beyond the formation of high and medium cloud, due to the low vapour pressure of the atmosphere within the continental interiors. Only convectional thunderstorms due to local overheating break the monotony of the weather in Anatolia and northwestern Iran, and an occasional such storm may bring a brief shower in the highlands of Kurdistan or Syria. Another source of moisture are the appreciable dewfalls resulting from the high relative humidity and great diurnal range of temperature. Local northwesterly and westerly coastal winds bring these dewfalls many miles inland, especially in the region of Gaza.

The overheating of the subtropical landmasses and their quick reaction to the summer insolation produces the annual displacement of the great planetary wind and pressure belts (*Flohn* 1955 a, b). This leads to such a great poleward displacement of the ITC over the land areas that the equatorial westerly stream follows the pressure gradient and in the sense of *H. Flohn* produces the great annual circulation changes of the tropical monsoons. By the time the air from the Southwest Monsoon entering India has reached Baluchistan and Iran, it is almost completely devoid of moisture, and apart from a fair rainfall on uplift long the Baluchistan ranges with southeasterly exposure, brings little more than an odd shower or two upon further uplift in Iran. By the time this air descends from the Zagros and Eastern Taurus it is stable and dry. Over the Persian Gulf the dominance of northwesterly winds above 1000 m prevents any sizeable cloud formation or precipitation within the shallow sphere of the Southwest Monsoon (*Bauer* 1935).

However Southwest Arabia, Ethiopia and the Sudan enjoy their rainy season during these summer months from thunderstorms associated with the inflow of the moist Southwest Monsoon. The monsoon generally extends up to 2—3000 meters, but many on occasion reach 6000 meters, above which easterly or northeasterly winds dominate. 'Surges' of masses of damp air at below-average temperatures give rise to instability conditions, with resulting thunderstorms or even sandstorms further north (*El Fandy* 1953). *M. G. El Fandy* attributes these surges to widespread thunderstorms near the equator or over the Indian Ocean, or to troughs in the upper easterlies.

In conclusion we may restate the above briefly. Throughout the year the upper air circulation above 2—3 km shows a strong predominance of westerly components over the Near East. During the winter or rainy season from October or November to April or May there is a fair amount of precipitation increasing with elevation and decreasing with latitude. This rainfall is above all cyclonic, but as was seen, fronts are relatively weak and deteriorate rapidly within the interior, so that uplift is the trigger action necessary to release the moisture. Further the precipitation is subject to great mean annual variations—10—20% along the North African coast, and over 50% in the desert interiors (*E. R. Biel* 1944). Years with excessive rainfall show increases of 30—50% of the general rainfall mean, and up to 70% from one year to another (*H. de Terra* 1945). But above all, it is to be noted that, with few exceptions, most of the rainfall is associated with troughs in the upper westerlies. Such upper air minima are not entirely absent during the summer months, but the strong inversions existing at very low levels as well as the low vapour pressure over the continental interiors preclude any appreciable rainfall. During these months the surface winds show a strong predominance of northerly or northeasterly components in a circulation pattern characteristic of the horselatitudes. From the foregoing discussion it will be seen that the primary factor of the general atmospheric circulation regulating large-scale, long-term variations of rainfall is and can only be the relative strength and position of the local jet stream and the associated upper air westerly circulation.

Chapter III. Glacio-Eustatism and the Marine Quaternary of the Near East

1.—Introduction and General Remarks

An ever increasing amount of literature has, especially during the last two or three decades, been devoted to the problem of raised beaches, i. e. fossil shorelines lying above present mean sea level. The existence of raised beaches, usually attributed to uplift of the land, has long been recognized, but a more novel concept indeed was the existence of submerged beaches, something first shown by *R. A. Daly* (1910). Since then a new concept to account for these changes in relative sealevel has gradually achieved a dominant position, namely that of glacio-eustatism or glacial eustasy, which designates changes in world sea-level produced by changes of volume of water in the oceans according to the amount of water held in the solid state by the continental ice masses. Thus during phases of glaciation large amounts of water were withdrawn from the world oceans accompanying the accumulation of the continental ice-sheets, and during these periods mean sea-level lay many meters below that of the present, leading to the formation of beach conglomerates, abrasional and depositional terraces, marine platforms and benches as well as other phenomena now submerged. On the other hand during interglacials the world's ice masses were more extensively melted, which lent to a considerably higher sea-level. In fact, *A. Bauer* (1955) was able to show that if all the water bound in solid form to-day were returned to the oceans, the world sea-level would rise by about 54 m.

From the ensuing discussion it will be seen that many beach lines can be found at levels over +54 m to-day, indicating that glacial eustasy alone cannot account for all raised or submerged beaches, or at least not entirely. Tectonic uplift, whether it be isostatic, orogenic or epirogenic, has played its part in determining the present level of many coastlines. However it can usually be shown that tectonic activity has been largely absent on most of the unglaciated world sea-coasts since late Middle Pleistocene times, and in the Mediterranean Sea area we shall see that it has, in general, been absent since the formation of the 35 m Tyrrhenian beach. On the other hand, the successive terraces are progressively lower so that one is inclined to believe that the glacio-eustatic fluctuations are only a pattern superimposed upon a general lowering of sea-level since the Upper Pliocene. *F. E. Zeuner* (1952) and *Woldstedt* (1954, p. 292—93) have already discussed this point in greater detail.

The great amplitude which occurs within an accepted standard altimetric stage can be due to minor earth movements, local particularities, or to methodical differences of investigation. Fossil beach phenomena vary greatly and thus very often, determinations are several meters off due to faulty observations, as *Johnson* (1932) and *Zeuner* (1952) have emphasized. For instance, the former water level of a 'destructional terrace' cut into the sloping surface of a coastal plain will have been at a different relative point than on a 'constructional terrace' built forward into the sea. The range of the tide and a storm level must also be taken into consideration. In the outline below, it must therefore be borne in mind that the authors cited have seldom specified how the observed former sea-levels have been determined, or in referring generally to high beach terraces, just to exactly what part of the terrace they refer—the nip, the submarine platform, the cliff, etc.

Besides presenting us with evidence that the pluvials occurred during pronounced marine regressions, a study of these sea-level variations alone can make a dynamic understanding of fluviatile terraces and gravel deposition and their significance possible. Lastly, the glacio-eustatic fluctuations are even of direct climatic significance. They provide a fairly reliable guage of world mean temperature variation, at least since mid-Pleistocene times, and even more relevant is the effect of sizeable regressions on the coastal uplift of air masses, as well as on the amount of vapour provided to these air masses by shallow marine gulfs, such as the Persian Gulf, which was most probably laid dry during the marine regressions accompanying the three last glaciations.

2.—*Regional Outline of the Evidence*

a) The Aegean sea, Dardanelles and Bosporus.

The geological evolution of this area has been most satisfactorily worked out by *M. Pfannenstiel* (1944), and a short synthesis along these lines not only provides an index of glacio-eustatism for Western Anatolia, but gives a key to the history of the Black Sea as well as the Caspian.

Apart from beach lines at 135—140 m near Mürefte and at 150 m on the Armutlu Peninsula, five constant terraces can be traced almost continuously from Samothrake to the Princes Islands. An early Sicilian level varying between 90 and 110 m and a Milazzian level between 50 and 70 m most probably belong to the Günz/Mindel Interglacial. However this classification is altimetric and palaeontological evidence is lacking. A conglomerate deposited in 40—46 m elevation at Hora contains a molluscan fauna which is generally classified as 'Old Euxine' and ascribed to the brackish-limnic sediments of the Pontic-Caspian-Aral depression deposited during the Mindel Glaciation. The same 'Old Euxine' layers can be traced all along the Caucasus coast of the Black Sea at an elevation of 35—40 m. This stage was contemporary with the 'Roman' or Mindel Regression in the Mediterranean when the world sea-level was eustatically lowered by perhaps 90 m according to *Valentin* (1952), 115—120 m according to *Woldstedt* (1954).

The next or so-called 'Tyrrhenian' terrace lies at 30—35 m, and the subsequent Monastirian at 12—15 m. Both terraces contain a thermophile fauna characterized by *TAPES CALVERTI* and *CARDIUM TUBERCULATUM* (synchronous with the *STROMBUS BUBONIUS* of the Mediterranean), and are beyond doubt of climatic-eustatic origin. Whereas the 15 m 'Monastir' terrace was quite certainly formed during the Riss/Würm Interglacial, the earlier 35 m Tyrrhenian terrace is usually, but not always correlated with the Mindel/Riss. Significant is that whereas the Sicilian terraces were obviously uplifted, the Tyrrhenian and Monastirian are solely accounted for by climatic-eustatic arguments—the greater melting of the continental ice masses of Greenland and Antartica during intervals of climate warmer than that of the present.

At this point a brief account must be given of the development of the Black Sea—Mediterranean Sea isthmus according to *Pfannenstiel* (1944). The Dardanelles apparently only came into existence during the late Sicilian phase and at this time the Mediterranean penetrated into the Black Sea along a former channel through the Sea of Marmara, Gulf of Izmid and along the lower Sakaria River bed. The Bosporus is only of comparatively recent origin. Subsequently terraces at 30—35 m and 15 m in the Black Sea testify to a renewed penetration of the Mediterranean during the higher interglacial sea-levels.

Following upon the 15 m Monastirian, we find a withdrawal of an immense volume of water from the world oceans to build up the great ice sheets of the Würm Glaciation, Thus the mean sea-level during the 'Post-tyrrhenian' or Würm Regression was about 90—110 m lower than that of the present (*Blanc* 1942, *Valentin* 1952). As the Dardanelles are only 60—70 m deep, they were high and dry at 35—55 m above sea-level, while the islands of Thasos, Samothrake, Imbros, Lemnos, Lesbos, Chios and Samos were joined to the mainland. A good number of morphological forms as well as the present faunal distribution bear this out. Further the Sea of Marmara was a shallow fresh-water lake overflowing into the Aegean Sea via the Dardanelles River, while the Sakaria-Bosporus was gradually laid dry.

As the continental ice masses slowly and spasmodically wasted away after the Würm maximum, large quantities of water were returned to the oceans and the sea-level gradually rose in the so-called 'Flandrian Transgression'. *Pfannenstiel*'s unnecessary correlations of this latter transgression to a hypothetical three-maxima Würm need not be referred to here. Suffice it to say, that during the Flandrian Transgression the Mediterranean Sea eventually penetrated up the Dardanelles River, flooded the Sea of Marmara and only at this point brought the modern Straits of the Bosporus into existence.

And lastly, the lowest terrace at 3—7 m must be referred to. The fossil content of these terraces is identical with that of the present Mediterranean, while on Samothrake the 3—4 m terrace is overlain by white pumice washed ashore from an eruption of the volcano Santorin on Thera about 3000 B. C. This ubiquitous 'Nizza' terrace contains neolithic or even iron age artefacts at various places in the Mediterranean, neolithic and bronze age artefacts in the Black Sea (*Erinç* 1954), and can be safely assigned to the postglacial 'Climatic Optimum', at which time higher mean temperatures would probably imply a considerable shrinkage of the world ice masses in comparison to that of to-day[2]).

b) The Black Sea and the Caspian.

It is not proposed to go into any detailed consideration of the often disputed Black Sea stages of the Pleistocene, as these stadia are of interest here only as far as the Caspian Sea is concerned. The most convincing study, despite the presentation of *S. Erinç* (1954), remains that of *M. Pfannenstiel* (1944). Beginning with the late glacial period and going backwards, the following stages have been identified.

Old Black Sea. The Mediterranean penetrated up the new-born Bosporus in the Flandrian Transgression, leading to a gradual salinization and culminating in a Nizza terrace at 5 m on the Caucasus coast, where gravel terraces yielded artefacts dated at 3500 B. C. (Holocene).

New Euxine. The Mediterranean fell to —95 to —100 m leaving the Black Sea in the direct control of climatic elements alone. A regression down to at least —40 m is amply witnessed by morphological features on the north coast (liman erosion!). The water was only slightly brackish and characterized by a *DREISSENSIA ROSTRIFORMIS* fauna. As a comparison with the Caspian would require a transgression during this period of reduced evaporation and increased drainage basin, it must be postulated that the Black Sea overflowed over a threshold of at least —45 m somewhere in the Bosporus or Sakaria area throughout this stage corresponding to the Würm glaciation.

The Karangat is characterized by eustatic terraces at 15 m with *TAPES CALVERTI* and *CARDIUM EDULE,* salt-loving species. Obviously this is the Monastirian terrace characterizing the first half of the Riss/Würm Interglacial. A general 6—8 m terrace on the Turkish coast (*Erinç* 1954) probably represents the Late Monastir terrace, and lends strong support that the Karangat stage comprises the entire interglacial.

Postuzunlar. Lacustrine and fluviatile sedimentation on the northern shelf is evidence of a regression of unknown dimensions. Loess and gravel deposits are further a testimony of the Riss Glaciation, and the Black Sea apparently drained into the regressive Mediterranean at —110 to —120 m.

The Uzunlar and Old Euxine stages were characterized by terraces at 30—35 m and 35—36 m respectively, the former containing Mediterranean elements witnessing a Mediterranean ingression (Tyrrhenian = Mindel/Riss). On the other hand, the much longer Old Euxine stage evidently represented a united Caspian-Black Sea complex do-

2) From Table II below it becomes apparent that, excepting the Dardanelles area, the Nizza terrace invariably lies at 2—4 m and no higher in the Near East. Furthermore a Monastir II shoreline is strikingly absent here. It is quite likely, in view of a lack of palaeontological or prehistoric evidence, that only the 3 m terrace on Princes Island, and the 3—4 m terrace of Samothrake represent the Nizza stage. The terraces at 5—7 m near Dedeagatch, 7 m at Galipoli, 5' and 6 m on Samothrake and 7 m on Princes Island all could appear as convincing for the late Monastirian Transgression.

minated by a brackish and freshwater fauna of Caspian character, obviously equivalent to the Mindel Glaciation. Apparently the Old Euxine of the Mindel period represented a closed sea unable to drain freely into the Mediterranean, and thus fluctuating harmoniously with the Caspian.

After this stage definite information about the Black Sea ceases and it is of little profit to discuss the indefinite and hypothetical speculations that have been made. Suffice it to say that *O. Erol* (c. f. *Pinar* 1956) found high erraces at 60—90, 120—135, 160—170 and 210—280 m in the Trabzon area. Rather a brief consideration of the Pleistocene fluctuations of the Caspian Sea will be opportune here, following R. *Grahmann* (1937).

The quaternary history of the Caspian is characterized by alternating transgressions with a brackish-freshwater fauna and regressions with more salt-loving forms, stratigraphically connected with glacial and interglacial periods respectively.

At the beginning of the Pleistone the Caspian had been reduced to an inland lake and possibly in Günz times the first Pleistocene transgression[3]), the A s p h e r o n stage, left thick deposits of dark loams and sands behind as far as Stalingrad. The subsequent G u r o v Regression was followed by the great B a k u Transgression, which is assigned to the Mindel Glaciation. Dark blue and black loams containing a brackish-freshwater fauna *(CORBICULA FLUMINALIS)* were deposited up the Volga Basin to 51° N. This was apparently the maximum stage, and probably corresponded to the 80—90 m raised beach on the Persian coast (*Bobek* 1937). During the shrinkage of the waters, more shallow-water and terrestrial deposits remained behind, which contain *ELEPHAS, R. TICHORINUS, BOS PRIMIGENIUS, BOS LATIFRONS* and *CERVUS ELAPHUS*. The peculiar weathering of these last deposits during the Postbaku or Tiras Regression indicates a warm, dry climate, apparently the Mindel/Riss Interglacial.

During the C h o z a r Transgression (Riss) which did not exceed 25—28 m above the present level, crossbedded, dirty yellow and loamy sands with a brackish water fauna characterized by *PALUDINA DILUVIANA* were deposited. *E. TROGONTHERII, ELASMOTHERIUM SIBIRICUM, CERVUS MEGACEROS* and *BISON PRISCUS* fossils occur in the basal conglomerate and the more brackish, lower deposits. The relative insignificance of this transgression was probably a result of the continental ice sheet which overran a great part of the upper Volga drainage Basin during the Riss, thereby considerably reducing the flow of the Volga. This stands in contrast to the Würm, and probably the Mindel as well, when the Nordic ice-masses increased the drainage basin by reversing many rivers normally emptying into the Baltic and White Seas. Subsequently unstratified brownish sandy loams with frequent remains of grasses, *SALIX VIMINALIS,* and crystallizations of calcium and gypsum witness the shrinkage which took place during the A t e l stage (Riss/Würm).

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3) The earlier A k c h a g y l Transgression has recently been bound to contain a Villafranca fauna (*W. O. Dietrich* 1953) and is therefore younger than Pliocene as was originally assumed.

The last great transgression, the Chvalyn, is somewhat better known (*Leontyev & Fedorov* 1953) and we can speak with certainty of an earlier Chvalyn stage at 73—75 m (45—47 m above m. s. l.) followed by a regression during which alluvium and coarse gravels were deposited, and a later Chvalyn stage at 26—28 m (—2 to 0 m m. s. l.). The fauna is identical with that of the modern Caspian, except for the absence of *CARDIUM EDULE*, which only appears in the New Caspian stage (since c. 2000 B.C.?). *Leontyev & Fedorov* (1953) outline several stages in the shrinkage of the Postchvalyn Caspian without, however, being able to offer any precise means of dating. Three halts during the regression are marked by terraces at 16, 10—12 and —4 m relative to the present Caspian level, after which an absolute minimum of —20 to —22 m was reached during the Mangyshlak stage, which is suggested as contemporary to the Atlantic II and Subboreal I phases of Europe, c. 4000—2000 B. C. The subsequent history of the Caspian Sea in protohistorical and historical times will be considered in a later chapter.

Bearing these two chronologies in mind, what connections existed between the Mediterranean, Black, Caspian and Aral Seas after their separation at the close of the Pliocene epoch? The only proven connection between the Aral and Caspian Seas is indirect and relatively unimportant, being limited to a bifurcation of the Amudarya during the Middle and Upper Pleistocene, a branch of which flowed through the Sarykamish and Assaka-Andan Depressions and the Uzboi Channel into the Caspian until as late as bronze age times (*Tolstov, Kess & Shdanko* 1954). We have already seen that the Mediterranean transgressed into the Black Sea during the Old Black Sea, Karangat, Uzunlar and apparently during the latter half of the little known Postchauda stages, in other words during the interglacials as well as during the postglacial period. There remains only the question of the connection between the Caspian and Black Seas across the Manytch Depression, whose morphological features are well described by *Grahmann* (1937).

From the common fresh brackish Caspian fauna of the Old Euxine and Uzunlar Black Sea, we can assign the first proven Pleistocene intercommunication to the Mindel and Mindel/Riss periods. Most probably the highest 40—50 m terrace in the Manytch Valley, consisting of stratified brown loams upon clays, containing a freshwater fauna with occasional Caspian species, belongs to this stage. *Grahmann* ascribes the next connection to the Karangat stage, when loamy sands and sandy loams were deposited in a terrace at 15—20 m above the valley bottom. These deposits exclusively contain a Karangat fauna (the first *C. EDULE*!) in their lowermost layers, gradually going over to Caspian forms which dominate towards the top. The obvious interpretation is that the saline Black Sea overflowed into the Caspian (or at least came very close to doing so) during the Karangat-Atel stage, and that this condition was favoured and gradually reversed during the Early Chvalyn stage when the Caspian eventually overflowed with certainty into the Black Sea, once more giving dominance to a Caspian fauna there. *C. EDULE* only appears, or rather reappears, in the Caspian in very late times because it was nearly killed off by the freshening waters of the Chvalyn phase, and only survived in salty lagoons from where it spread out again with the rising salinity of Mangyshlak waters (*Grahmann* 1937). And finally, when did the Karangat or perhaps better, Early Chvalyn connection break off? Apparently this communication, the last, broke off during the Inter-chvalyn Regression. Thereafter the waters of neither the Caspian nor the Black Sea, which reached maxima of 0 and 5 m m. s. l. respectively, could ever have washed right over the 25 m m. s. l. watershed of the Manytch Depression. The 5 m terrace of *Grahmann* consisting of sandy loams containing both Black Sea and Caspian mollusca can only be fluviatile and not lacustrine.

In retrospect we have briefly touched upon the chief events of the Pleistocene history of those great inland seas, the Pontus and Caspian, and therewith their relation to the world-wide glacial-eustatic fluctuations of sea level. This history was seen to be quite complex, and often still controversial, an evolution which is but incompletely recorded in raised beaches at 6—8, 15—20 and 100—110 m m. s. l. on the north coast of Turkey (*Erinç* 1954), and at 25—30, 70—75, 80—90 m relative level on the Caspian shores of Iran (*Bobek* 1937).

c) The coast of Lebanon.

The Lebanese coast is a coastline of submergence, and the Lebanon Massif descends abruptly under the ocean, which has enabled the former high eustatic sea-levels to leave their mark all along the shores in the form of raised beaches and terraces. This profile of abandoned terraces is not the only complete one, but the best one at any rate, existing in the Mediterranean's eastern basin. The comprehensive accounts of *Wetzel & Haller* (1945), *E. de Vaumas* (1947) and *H. Fleisch* (1956) contain this profile in good detail.

A high terrace at 95—100 m was found to occur for almost 70 km along the 220 km extent of the coastline. This sea-level was followed by a regression to at least as low as 30 m, during which dunes formed along the coast, indicating the exposure of marine sediments to aeolian forces. There is a lack of palaeontological remains in situ necessary to assign the label of 'Sicilian' to the 95 m terrace with reliability. A subsequent terrace at 55—60 m, with Abbevillian implements, was followed by a major regression of at least 60 m to present sea-level during which there was a very widespread development of great coastal dunes. The next terrace lies at 45 m (with Middle Acheulian and Tayacian) and was followed by a regression to below +39 m. The Tayaco-levalloisian and Lower Levalloisian industries tend to confirm that this regression represents, as elsewhere, the Mindel and not the Riss Glaciation. The above terraces have all beenepirogenetically uplifted and belong to the Lower Pleistocene. Following upon the first, non-uplifted 35 m terrace was another regression to below 0m (probably Riss). The subsequent Monastirian terraces at 15 and 6 m, with *STROMBUS BUBONIUS* and with Levalloisian and earliest Levalloiso-Mousterian respectively, represent the Riss/Würm Interglacial with certainty. *Pfannenstiel* (1952) believes that the well-known prehistoric caves and grottos of the Lebanon were cut into the coastal cliffs by wave erosion during the Monastir I phase, and that these caves became habitable by man during the great regression to well below modern sea-level that followed the Monastir II stage. This is borne out by the occurence of the associated Levalloiso-Mousterian cultural horizons upon the Monastirian sediments of the caves, as well as within the 'ramleh inférieure' or 'dunes inférieures' (not to be confused with the first generation dunes of Palestine) which were built up during this regression according to *de Vaumas* (1947). Above the 'dunes inférieures' with their Levalloiso-Mousterian industry, *J. Bourcart* (1940) identifies bone-beds in a breccia containing 'Aurignacian' implements. Both of these industries in the terrestrial deposits of the 'Grande Régression' correspond well with the European industries of the Würm Glaciation.

At Jbail marine deposits of the Monastirian rest upon Cretaceous bedrock up to an elevation of 17 m and are overlain by stream gravels or by aeolian sandstones (*Wright* 1951). Locally the gravel and sandstone can be shown to be interbedded, the former deposited by aggrading mountain streams, the latter blown from the beaches widened by the post-Monastirian or Würm regression of the Mediterranean. Since the coastal streams are invariably dissecting their beds to-day, and since a lowering of the baselevel of erosion would normally produce vertical incision given a static climate, we must postulate an appreciable increase of local precipitation synchronous with the Würm Regression. At Chekka, *Wetzel & Haller* (1945) also identified deposits indicating greater stream activity and rainwash from the slopes during the Mousterian and Upper Palaeolithic. These slope silts, brown clays and gravels overlie Monastirian beach conglomerates.

d) The coastal plain of Palestine.

The flat coastal plain of Palestine has provided valuable material to correlate the Pleistocene glaciations and marine regressions with the Near Eastern pluvials by means of bore-hole profiles taken in this area. A number of geologists have already considered these profiles, but the latest study by *M. Pfannenstiel* (1952) is quite comprehensive and deserving of serious attention. Pfannenstiel has reconstructed a series of 6, or rather 5, profiles from the present coastline inland, based upon about 50 bore-hole profiles. The essential points of the profile may be outlined and discussed as follows.

Above the Lower Pliocene bedrock lie a series of marine, gravel and terrestrial horizons which have a fossil content corresponding closely with that of the modern Mediterranean and which therefore must be of post-Lower Pleistocene age. The stratigraphical gap was in all probability caused by a great lowering of the base level of erosion through epirogenic uplift, marine regressions and local climatic changes. As a first horizon, *Pfannenstiel* recognizes a marine horizon of shelly sandstones and breccias which are immediately overlain, and sometimes interwoven with an, on the average, 7—8 m thick gravel and fluviatile sand complex known as the 'lower gravel horizon'. Both of these horizons are almost ubiquitous and have been convincingly reconstructed in the idealized profile. The upper boundary of this first marine horizon ('D') occurs from —9 to —71 m within the borings, and is at a progressively lower level from east to west, probably lying at —90 m under the present coastline. The overlying base gravels have been reached at successively decreasing heights of 60 to —89 m from east to west, and lie at about —90 m under the present coastline. Above these two distinct lower horizons we have an alternating stratigraphical series of marine and terrestrial, chiefly aeolian, sediments.

Obviously the base gravel horizon was deposited immediately after the formation of the marine layer, a process that can only be logically explained if the Mediterranean sea-level was progressively receding and exposing new land which was subsequently aggraded by the streams from the Judean hills. In other words, the lower gravel horizon was deposited during a marine regressive phase and immediately thereafter, i. e. during the formation of the great continental ice sheets and contemporary to one of the major Pleistocene glaciations. To what cause can this abnormal aggrading of the Judean streams be assigned? Firstly a rejuvenation due to the continual lowering of their base level will have played a contrary part, favouring downcutting and not alluviation. But although erosion still takes place in the hills to-day, the streams are not able to transport the coarser material to the seacoast, and vertical incision is dominant in the lower courses of the streams, from which we must assume a considerable increase in precipitation during the period of deposition of the base gravels. In other words, we have again been provided by a good correlation of a higher latitude glaciation to an outspoken pluvial phase in the Near East.

Pfannenstiel rightly points out that this marine regression reached a depth of a least —90 m, but can it really be none other than the 'Post-tyrrhenian' or Würm Regression? The cultural evidence does not bear this out in the first place. *Löwengart* (1928) distinguishes four generations of coastal dunes lying from east to west in decreasing order of age and degree of weathering to terra rossa. The last two generations are not weathered, while the last is mobile and subrecent. Further there are generally two rows of sandstone ridges or "kurkars" running parallel to the coast (*Blake* 1935) which again represent fossil dunes. Weathering to red sand or terra rossa can take place when percolating rainwater dissolves any calcareous material and carries it away in solution, a process which requires a relatively low water table as well as a warm climate, favouring the formation of iron compounds. The kurkar crusts form when the dissolved calcite can evaporate at the surface, which requires a higher water table. The oldest dune generation, completely weathered to terra rossa to a depth of 50 m, and lying above the lower gravel horizon, must have been deposited by aeolian forces on the base gravels during the great regression while their weathering could only have taken place during a relatively warm and very extensive period such as an interglacial.

The calcification of the coastal dunes, on the other hand, would have taken place immediately after their deposition and during the more favourable moisture conditions of the accompanying pluvial. The next generation of dunes will have been blown up and kurkarized during a subsequent regression and superficially weathered to terra rossa during a warmer phase very much shorter than the previous, possibly an interstadial. The third generation was deposited and kurkarized during a third regression, but there has not been sufficient time nor a sufficiently favourable climate since to produce any weathering to terra rossa in other words, one could suppose this third regression corresponded to the last glacial maximum. The last recent, mobile dunes are strictly postglacial as they cover earlier historical sites in many places.

The point which led to this brief tangential discussion, is that the Mousterian sites never occur in the deeply weathered first generation dunes but always upon or above them. The red sand formation and lowest kurkars comprising the oldest dunes contain Chellean and Acheulian implements, the second dune generation Upper Acheulian and Mousterian, the third, Mousterian to Mesolithic (*Picard* 1943), which poses an almost insuperable objection to *Pfannenstiel*'s interpretation.

Secondly, *Pfannenstiel* postulates that the marine horizon 'D' lies at and below about —90 m immediately under the present coastline. However we can expect to find the former coastline not here, but very close to the —90 or —100 m isobath, which lies about 20 km offshore. Considering that the gradient of the marine shelf amounts to 4,7%, the gravel horizon which achieves a minimum of —89 m at 1,8 km inland will lie very many meters below that level 20 km away, and we can only logically suppose that this regressions was much greater than —90 to —92 m, and most probably amounted to at least the —115 to —120 m reached during the Riss, and probably during the Mindel Glaciation as well. Further it is to be expected that a lowering of the base level of erosion great enough to remove the Pliocene and Lower Pleistocene deposits would have been the greatest rather than the last regression. Also the associated fluviatile degradation and aggradation could only be convincingly associated with a pronounced pluvial such as the Mindel or Riss, and not with a relatively weak one which, as we shall see below, was associated with the Würm. Lastly the molluscan fauna of the 'D' horizon, *ARCA, BALANUS* and *PETUNCULUS* are not exclusively Würm, while the absence of the thermophile *STROMBUS BUBONIUS* is only to be expected during the glacial phases.

In other words, the great regression amply testified for on the Palestine coast is most unlikely to be related with the Würm Glaciation. The picture is much more complicated than the idealized profile and genial interpretation of *Pfannenstiel* would have us believe. Possibly it represents the Riss, or perhaps even the Mindel Glaciation. If the deep weathering of the first dunal generation took place during an interglacial, the superficial weathering of the second during an interstadial, then one might conceive of an association wit the Riss provided the first dunal generation of *Pfannenstiel* and *Löwengart* are identical. Or, if one suggested a correlation with the very long Mindel/Riss and shorter Riss/Würm interglacials respectively, a connection with the Mindel would not be impossible. The lack of evidence of a subsequent transgression of 15 m is not necessarily of importance, as the dunes and beach ridges may have accumulated sufficiently fast so that the rising sea was not able to overwhelm them. The abnormally great abundance of mobile aeolian material along the coastline to-day, even in areas of good rainfall, indicates local conditions almost as favourable as in the Bassa Versilia where *A. C. Blanc* (1936) illustrated a similar phenomenon. However no certain conclusions can be drawn at the present state of our knowledge, other than that at least one outspoken Mediterranean pluvial phase corresponded to the regressive phase associated with one of the major glaciations. It is hoped that this stimulating and important study of *Pfannenstiel* will be a continued object of future research, particularly in the way of a comprehensive field survey.

e) The north Egyptian coast.

Marine levels of 15, 46, 61—70, 80—98, 11—120 and 208—233 m were already recognized east and west of the Nile Delta by *K. S. Sandford & W. T. Arkell* (1939, p. 114—118). *F. E. Zeuner* (1950, 1952) believes that he has been able to identify a whole sequence of raised beaches along the coast of emergence west of Alexandria. Numerous morphological features of what appear to be fossil coastal bars and lagoon surfaces have provided this clue: the filling in of such a lagoon-floor with sand, silt and organic materials will provide a relatively plane surface at a level at, or slightly, above, the mean sea level at which the bar and lagoon came into being. Using detailed topographical maps and the personal acquaintance of *R. Summers* with the landscape, *Zeuner* has drawn up the following sequence on purely altimetric grounds.

Five Sicilian sea levels at 103, 90, 85, 80—100 and 80 m are first recognized. The Ruweisat bar at 58 m is assigned to the Milazzian, the Sanakra-Habbub bar at 35 m to the Tyrrhenian, the Gebel Maryut and Gebel Abusir bars at 15—20 and 5—10 m respectively to the Main and Late Monastirian stages. Lastly the fossil bar represented by the Harbour Island ridge of Alexandria, separated from present sea-level by low tide, is assigned to a sea-level approximating to that of the present which *Zeuner* suggests may belong to an interstadial of the Würm[4]).

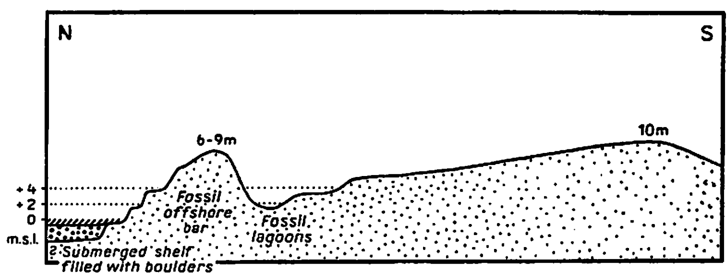
The 'Posttyrrhenian' or Würm Regression of 90—100 m has also left its mark on the Egyptian coast, namely in the submarine shelf in front of the Nile Delta. *Pfannenstiel* (1952, 1953) points out that this shelf

4) *Said, Philip & Shukri* (1956) have referred to 7 beds of gypsum alternating with 7 beds of fossiliferous limey marl from the old lagoon behind the 35 m Gebel Maryut bar near El Hammam, west of Alexandria. They have tried to assign climatic implications to these, drawing up a sequence which should carry down to the present. This is, however, impossible as it would require 6 further transgressions to about + 35 m since Tyrrhenian times! The entire lagoonal deposits must be of Tyrrhenian age, as the youngest deposits are also the highest.

stretches 120 km north of the present Delta and clearly shows the former Nile channels in its submarine topography down to the —90 m isobath (at least). When the base level of erosion of the Nile was lowered, the river began to incise itself deeply into the bedrock and carried the former deposits out to sea. Even some 25 km north of Cairo the bedrock under the river sole has been eroded to over 13 m below sealevel! However the question of the Upper Pleistocene undercutting of the Nile bed will be discussed in greater detail in Chap. 5.

The question next arises, is there any evidence of the Nizza terrace corresponding to the Postglacial Climatic Optimum? This question has been particularly investigated by the writer between Ras el Shaqiq and El Alamein, where numerous offshore bars and lagoon surfaces illustrate the recent history of this coastline.

Firstly (Profile 1) (Fig. 1—4.) a fossil offshore bar of oolithic limestone, in which an abbrasional terrace of 2 m height has been cut, is common on this coastal strip. The tidal amplitude is a mere 25 cm, but a storm level seldom exceeding 200 m above low water must be considered. A former submarine shelf extends 2—5 m landwards from this present 'cliff' to a second nip with a similar 'cliff' of 2 m altitude. The remains of a second fossil submarine bench extend another 10 m inland to a third nip of 2 m. Whereas the lower 2 m terrace is very distinct and occurs almost everywhere, the higher abbrasional terrace is considerably weathered and distinctly older. As the former sandbars seldom exceed 8 m, no further terraces could be recognized or expected here. Behind the former offshore bars lie dry lagoon beds of which the lowest floor is usually very little above sea-level, generally devoid of vegetation, and composed of a damp red sandy clay or terra rossa without any terrestrial shells. These base floors showed clear signs of holding rainwater pools and periodic watercourses during the rainy season, whose water drains off to the lowest situated lagoons following a torturous route immediately behind the bar. Within these former lagoons a 1.5—2 m terrace could be identified everywhere, upon which a fair steppe flora, innumerable shells and molluscs, and a terra rossa broken by numerous mudcracks could be found. Furthermore a similar 4 m terrace could also be observed differing only from the former in the absence of molluscs.



Profile 1: Profile of the fossil offshore bar and lagoon („E m e r g e d") Coast of Western Arab's Gulf (Egypt) with truncated +4 and +2 m. marine shelves (Flandrian Transgression)

In other words we are confronted by two distinct submarine benches at 2 and 4 m above the modern one, with corresponding lagoon surfaces behind the fossil bars which still performed their function during the formation of these abrasional terraces, presumably during the post-glacial Climatic Optimum. The sea-level fell from 4 to 2 m and then to the present or even a lower level, cutting off the majority of the lagoons as the threshholds of the tidal inlets (which are even now visible) were raised above sea-level. Subsequently the lagoons were filled with fluviatile deposits brought down by the minor torrents. This 4 m terrace between Ras el Shaqiq and El Alamein apparently represents the Nizza terrace.

However, several meters out from the present nip, the present submarine shelf goes over continuously into a level surface formed not by the bedrock, but by loosely accumulated boulders, giving the impression that this point marks another fossil nip lying below sea-level. A recent paper by *A. Shafei* (1952) appears to throw some more light on this feature. There are ruins at Abukir at 2,5 m below sea-level, and related phenomena can be shown to exist around the shores of the brackish Lake Maryut (the former Mareotis) which was a freshwater lake in classical times judging by the former fauna and flora. This would necessitate an overflow into the sea, at least during the rainy season, whereas today all the Graeco-Roman ruins, such as those of Taposiris, Toruga and Marea lie along the —0,5 m contour and would be inundated but for the pumping which keeps the lake level at —3 m. All in all, *Shafei* could present conclusive proof of a 'subsidence' of at least 2 m since the beginning of the Christian era. We would however suggest the possibility of replacing 'subsidence' by an eustatic rise in sea-level of 2 or 3 m during the last one or two millenia, in view of the fact that similar phenomena have been observed in England, Brittany, Flanders and along the Frisian coast (*Hafemann* 1954). The transgression here began somewhere between the 1st and 8th centuries, and this low sea-level may have persisted for about 2000 years if we may take the partially submerged megalithic monuments of Brittany as a guide.

There has also been a transgression on the Palestinian coast, where classical buildings are partially submerged in some areas. *McBurney & Hey* (1955, p. 98—99) note a similar feature in Libya with tombs and guarries submerged to —3 m. In conclusion, it is not mere idle speculation that the world sea-level may have stood at —2 to —3 m during the last one or two millenia B. C. This could explain the apparently paradoxical situation at El Alamein, where some lagoon surfaces remarkably similar to those found to be undoubtedly fossil, are at present submerged by the sea. They may have been flooded by a transgression during the historical period, locally favoured by the topography of the offshore bars. Bearing in mind that most of classical Alexandria lies below sea-level to-day, the fossil bar of Harbour Island may possibly only represent a similar flooded lagoon.

f) Cyrenaica and Tripolitania.

While *A. Desio* (1928) already refers to a raised beach at 100 m on the Libyan coast, *C. B. M. McBurney & R. W. Hey* (1955), and *Hey* (1956) have further identified marine shoreline at 6, 15—25, 35—40, 44—55, 70—90 and 140—190 m along the Cyrenaican coast, of which only the highest shows local signs of warping. The lowest beach was overlain by consolidated coastal dunes which occur around the whole Libyan littoral and form a low ridge (usually less than 10 m) adjacent to the modern shore. These dunes are clearly aeolian deposits judging by the cross-bedding, as well as the contained recent terrestrial snails. The 6 m shoreline never cut into the dunes which lay upon it or descended below sea-level on the their seaward, so that the exposed dunes form only the edge of a much wider submerged belt of equally recent dunes extending to at the very least —17 m *(McBurney & Hey* 1955, p. 98). These younger fossil dunes were blown up from the large expanse of loose exposed sediments during a post-Monastir II regression, obviously the Würm. They are intercalated with many meters of Levalloiso-Mousterian gravels issuing from the wadi mouths in the Derna area (ibid. p. 93), indicating the correspondence of pluvial and regression, and implicitly, of pluvial and glacial. The Riss/Würm age of the 6 m beach is substantiated by the fact that the earliest Middle Palaeolithic sites rest upon it (ibid. p. 162). Similarly the fossil wadi terraces of the great inactive drainage network of Tripolitania have a gradient in their lowermost courses which suggests that they dip well below the present coastline, so that *McBurney* (1947) believes that the last major phase of activity in the wadis (during the early Middle Palaeolithic) possibly coincided with a lower sealevel. The wadis are separated from the open sea by mobile dunes and consolidated sand bars suggesting an association with the Flandrian Transgression deposits noted near El Alamein, which in connection with the wadi terrace industries implies a Würmian age as well.

g) The Red Sea Littoral.

With respect to eustatic sea-level fluctuations in the Red Sea area we know little, with the exception of some brief notes given by *Sandford & Arkell* (1939, p. 60—68). Raised beaches at 2, 8 and 16 m are noted in the Suez area, and at 8, 15, 22 and 28 m between Safagah and Kosseir. Earlier workers had already noted a 55—60 m terrace between Kosseir and the Wadi Ranga. Fossil reef and other beach deposits occur at 200 m in the Gulf of Aqaba, at 230 m near El Tor, Sinai, and at 250 m near Suez (*E. Krenkel* 1925, p. 74—75). *J. Büdel* (1952) also lists a number of raised beaches and coral reefs near Kosseir at 1.5, 4, 6, 10—12, 30—40, 60 and 120 m above sea-level. Whereas the highest terrace appears to be Pliocene, he believes the two lowest are probably Holocene. At the mouth of the Wadi Feiran on the Sinai Peninsula, *Büdel* recognized terraces at 5, 10, and 20—30 m. Very interestingly, the 5 m terrace deposits overlie a fine grained, thin-layered and yellow marly sand deposit further up the wadi bed. *Büdel* assigns this terrace to a period of considerably greater rainfall.

Obviously the 5 m raised beach is older than this 'pluvial' deposit, but how old is the 5 m shoreline? Altimetrically it could fall within the Late Monastirian which ranges between 5 and 10 m, or it could represent the Nizza terrace which may lie between 4 and 7 m. In the former case the 'pluvial' deposit would be pre-Monastirian (Riss), in the latter, of Würm age. Apart from the contemporaneity of a pluvial and a marine regression, the question of the dating remains open.

h) The Persian Gulf Coasts.

N. L. Falcon (1947) has described some raised beaches on the coast of Makran, which he believes are due to uplift. However the photographic material, the descriptions and the classical altitudes of 80—90, 30 and 15 m suggest at least the participation of eustatic variations of sea-level. Furthermore the marine sandstones which in a number of cases rise from close to sea-level to 60 m several km inland are not an evidence of warping as *Falcon* maintains, but are merely normal inclined submarine shelves. As a consequence we may add a 60 m terrace, so completing the altimetric sequence from Sicilian to Monastirian. The same sequence of terraces occurs elsewhere in the Persian Gulf on Kharag Island, and the 30 and 15 m shorelines are found on Qishm Island and at Bushire.

In Oman subrecent marine shells occur at elevations of as much as 350 m, while extensive drowned valley systems imply regressions of "at least 1000 ft." according to *G. M. Lees* (1939, p. 38). The raised beaches must date as far back as the Pliocene, while either the regression has been exaggerated or likewise belongs to a later Tertiary regression.

The alluvial delta of the Tigris-Euphrates seems to have been deposited over a long period. Although only very fine sediments are transported so far to-day, gravels occur in greater depths suggesting a former pluvial or fluvio-glacial activity of the rivers. The Persian Gulf may have extended inland during the interglacial transgressions but no traces of shorelines or marine deposits have so far been reported. During the great regressions the entire Persian Gulf, maximum known depth 57 m, will have lain dry. Unfortunately the wealth of material studied by consulting geologists in resent years has not yet received publication, so that a discussion on Iraq would better be postponed at the time. *P. B. Cornwall* (1946) has given much evidence in favour of a 2—3 m marine regression on the Hasa coast, occuring somewhere since the Chalcolithic and at latest during the Mediaeval period.

3.— Conclusions

As outlined and discussed above, it was seen that the various raised beaches known as Sicilian, Milazzian, Tyrrhenian, Main as well as Late Monastirian, and lastly the postglacial Nizza or Tapes stage can generally be traced throughout most of the regions considered. With

Table II: *The Marine Quaternary of the Near East*

(based upon *M. Pfannenstiel* 1944, 1952, 1953; *S. Erinç* 1954; *N. Pinar* 1956; *H. Fleisch* 1956; *D. A. E. Garrod* 1956; *N. Falcon* 1947; *P. B. Cornwall* 1946; *C. Emiliani* 1955; *R. W. Hey* 1956; *F. E. Zeuner* 1950; *J. Büdel* 1952; *Sandford & Arkell* 1939, and others)

Regionally: Dardanelles Area	Black Sea	Levant	North Egypt	Cyrenaica	Red Sea	Persian Gulf
—	—	— 2—3 m	—2-3 m	— 3-4 m	—	—2-3 m
+ 3—5 m	+ 3-5 m	+ 3—4 m	+ 2-4 m	—	+1.5-4 m	—
Regression (below -70)	Regress. (below — 40 m)	Major Regress.	Regress. (below) —90 m)	Regress. (below — 17 m)	—	—
+ 5—10 + 12—15	+ 6—8 + 15	+ 6 + 15	+ 5-10 + 15-20	+ 6 + 15-25	+ 6-8 + 10-22	— + 15
Regression	Regress.	Major Regress.	—	—	—	—
+ 25—35	+ 30-35	+ 35	+ 35	+ 35-40	+ 28-40	+ 30
Regression	(+ 35-6)	Major Regress.	—	—	—	—
+ 50—70	+ 60-90	{ + 45-50 + 55-60	+ 58	+ 44-55	+ 55-60	+ 60
Regression		Major Regress.	—	—	—	—
+ 90—110	+ 120-35	+ 95	+ 80-120	+ 70-90	+120	+ 60-90
+ 135-150	+ 160-70 + 210-80		+218-233	+140-90	+200-50	

General: Average Level	Designation	Associated Industries in Lebanon	Associated Climate
— 2-4 m	—	Graeco-Roman	Similar to present
+ 2-4 m	Flandrian Trans.	Neolithic-Bronze	
Regression	Würm Regress.	Levalloiso-Mousterian	Cold-loving foraminifera (5° C colder); pluvial deposits, Cold & wet.
+5-10 m +15-20	Monastir II Transgression Monastir I	Levallois with Moustier influences; Microlevallois; Levalloisian.	Thermophile foraminifera; *STROMBUS BUBONIUS* fauna. Warm.
Regression	Riss Regress.	—	Cold-loving foraminifera; pluvial deposits. Cold and moist.
+30-35	Tyrrhenian Transgression	Lower Levalloisian.	Thermophile foraminifera; *STROMBUS BUBONIUS*. Warm.
Regression	Mindel Regression	Tayacian	Cold-loving foraminifera. Cold.
+45-50 +55-60	Milazzian Transgression	{ Tayacian; Middle Acheulian. Abbevillian.	Thermophile foraminifera and fauna. Warm.
Regression	Günz?	—	
+80-120	Sicilian Transgression	—	
+150-250	Calabrian?	—	

very few exceptions there have been no significant earth movements since the formation of the 35 m terrace, whereas the higher level stages have possibly all been subjected to considerable large-scale uplift during the Lower Pleistocene in particular.

Of greatest significance has been the study of submerged beaches, a field given its greatest impetus by *A. C. Blanc*'s work in Italy. Extending this technique to Palestine, *M. Pfannenstiel* was able to provide a direct association of the local pluvial gravels with a marine regression, possibly representing the Riss as we have seen, and similar indications have been convincingly demonstrated in Libya and Lebanon with respect to the Würm, and lastly a pluvial-glacial correspondence was also illustrated on the Sinai Peninsula. It will remain for a subsequent chapter to compare and study these results in relation to fluviatile terraces and gravel horizons, stream aggradation and degradation, as well as to other pluvial features of the Near East.

Also of interest is a world sea-level of —2 or —3 m during Hellenistic times. This is verified archaeologically by the partial flooding of Graeco-Roman buildings on the Cyrenaican, Egyptian and Palestinian coasts as well as in Hasa. The ancient harbours of Appolonia, Alexandria and Caesarea, to mention only a few, bear this out well. This is classically demonstrated in Lake Maryut, and geologically indicated near El Alamein and in Hasa. *D. Hafemann*'s recent investigations in the Western Mediterranean further support this, and the conditions of the coastlines of Northwest Europe are well known. There is too much evidence here to be discounted by 'local subsidence'. The world sea-level may have been lower by close to 3 m from perhaps 300 B. C. to 500 A. D. judging by the Near Eastern evidence, beginning even earlier from indications in Brittany and on the Frisian coast.

The marine deposits of the Near Eastern Quaternary are regionally summarized in Table II with associated industries (based upon *Fleisch*'s sequence for Lebanon) and designations. A last column is added which refers to the climatic character associated with the respective marine deposits. Firstly, the molluscan fauna forming the palaeontological Leitfossils of the raised beaches are also climatic indicators. *STROMBUS BUBONIUS, TAPES CALVERTI, CARDIUM TUBERCULATUM, CONUS MEDITERRANEUS,* etc. are warmth-loving molluscs whose presence signifies a considerably warmer climate in the Mediterranean Basin. Pluvial conditions were contemporary with at least the last two great regressions, judging by unequivocal pluvial deposits intercalated with the marine sediments in Lebanon, Palestine, Cyrenaica and Sinai. Lastly, the deep sea core samples from the Eastern Mediterranean analyzed by *C. Emiliani* (1955) are of great value. The relative percentage of cold or warmth-loving foraminifera reflects a good part of the sequence of Pleistocene glaciations quite reliably, and a radiocarbon date gave an approximation of the rate of sedimentation. The average water temperature of the Eastern Mediterranean appears to have been some 5° C colder than to-day during the Würm Glaciation. The new deep sea core samples taken by the *Vema* Expedition in 1956 should add some more important results to this topic.

Chapter IV. Pleistocene Glaciation and Periglacial Activity in the Near East.

1.— *Glaciation to-day and during the Pleistocene.*

a) Preliminary remarks.

Glaciation is of relatively little importance in the Near East to-day, and has in fact never been of particular significance there. Even at the climax of the Würm Ice-Age there was no real extensive glaciation, permanent ice being limited to cirque glaciers and a few isolated valley glaciers of several kilometers in length. Only on the Kesis Dag, Ala Dag, possibly the Bulgar Dag and in Iraqi Kurdistan is there evidence of more than one glaciation, so that it is often claimed that considerable uplift must have taken place until the Last Glaciation, due to which a larger number of peaks were only then able to rise sufficiently above the climatic snowline. It cannot be disproven that such uplift has taken place, but a great part of the deficiency will also be due to a lack of intensive field studies such as have been made in Europe, as well as the more intensive weathering undergone by such morphological features in a subtropical climate. The reason for the insignificant areal extent of permanent ice masses can be ascribed to the comparative aridity and higher temperatures accompanied by a much greater insolation than is known in our latitudes. Thus the present snowline which varies between roughly 3000 and 4500 m in Turkey and Iran only lay some 7—800 m lower during the Würm maximum.

However, although the small cirque and valley glaciers of the Near East are of so little areal importance, they are nevertheless of inestimable value as an indicator of climate, specifically, temperature variations in the area. Furthermore, even quite outside their zone of occurence, their relation to the present and glacial lower limit of frost pattern soils can permit at least an analogous extension of these principles to fossil soil structures elsewhere, a factor of weighty morphological moment throughout the drainage systems of streams and rivers originating in such higher elevations.

A regional description of the relatively well-known glacial forms of the Near East is given below and will subsequently be compared with our rather scetchy knowledge of the far more important related phenomena of solifluction and soil patterns.

b) Present and Würm Glaciation in Anatolia.

Probably few studies of glacial forms in Asia can compare with that of *H. Louis* (1944) in comprehensiveness. There is little doubt that the overall picture, drawn up from a wealth of personal observations and an application of the existing literature, will only require modification in smaller details as a result of newer investigations. Consequently it shall be merely necessary to give a brief outline of the results.

In the western and central parts of North Anatolia (Ulu Dag, 2500 m; Koroglu Tepe, 2378 m; Ilgaz Dag, 2500 m) there were a few isolated cirque glaciers, of which the lowest reached down to 1900 m. As the cirque floors lay at 2200—2300 m, a climatic snowline of c. 2300 m was estimated. The glacial forms retained in northeastern Anatolia are more widespread and extensive. On the southern side of the Tiryal Dag (2700 m) there are cirques and glacial troughs with moraines down to 2250 m, while on the north side there is a trough-lake at 1800 m, for which features an overall climatic snowline of 2300—2400 m is given. A large cirque glacier upon the Cakirgol (3063 m) was able to leave behind a trough-lake at 1900 m and the snowline was probably around 2500 m here. Similar results were obtained for the Kordevan Dag (3050 m) and Yalnizçam Dag (2900 m). *S. Erinç* (1949) has supplemented or corrected the data for Lazistan. The Karagol Mountains merely extended some 400—500 m above the 2600 m Pleistocene snowline and harboured a number of cirque glaciers. However the higher Kaçhar (3987 m) and Salaçor Dag were able to send 8—10 km long glacier tongues with a thickness of 300—500 m down to an elevation of 2150 m. From the present cirque glaciers of this region the contemporary snowline varies from 3200—3500 m depending on a northerly or southerly exposure, giving a Pleistocene depression of 600 or so meters. This snowline depression seems somewhat small, and both *Louis* and *Erinç* harbour the idea of possible postglacial uplift.

In Central Anatolia the Kesis Dag (3537 m) near Erzincan has u-shaped glacial valleys and endmoraines down to 2250 m on its southern flank, while on the northern flank we have the only case of what we might call an embryonal piedmont glaciation in Turkey, extending down to 1750 m. The Würm snowline is estimated at 2700 m, but very interestingly a stream ravine has exposed an older moraine with solidly cemented, distinctly striated material underlying the younger, Würm moraine. The nearby Monzur Chain was extensively glaciated but the lower elevated piedmont prevented an greater extension of the glaciers into the lowlands. The Erciyas Dag (3916 m) which still harbours a tiny glacier at 3900 m to-day, apparently had a Pleistocene snowline of 2900 m, judging by two cirque glaciers and moraines down to 2100 m. This once more gives a snowline depression of 700—800 m. Little definite is known about the extent of the former glaciers on the Ararat Plateau. At present the glaciation of Mt. Ararat (5160 m), the Supan Dag (4430 m) and the Alagoz Dag (4100 m) suggests a snowline of 4000—4100 m. Apparently the glacial snowline was 700—800 m lower on the Supan Dag.

In Turkish Kurdistan, where *Bobek* (1940) estimates a contemporary snowline of 3500 m from the persistance of perhaps 20 small glaciers up to 2.5 km long, the Cilo Dag (4170 m) and Sat Dag (3810 m) were extensively glaciated, one tongue being about 10 km long. *Bobek* estimates a lowering of the snowline by 700 m, and has interestingly connected glacial outwash terraces in the upper river valleys with these extended glaciers.

The only large glaciers in the central Taurus area were to be found on the Bulgar Dag (3585 m) and Ala Dag (3910 m). On the former, moraines were deposited down to 1700 m eroding deep u-shaped valleys with large moraines, suggesting a Würm snowline of about 2600—2700 m. Interestingly, *Louis* again found a very well silicified conglomerate which may represent an older moraine. On the Ala Dag, there are still two very small glaciers from which a snowline of 3700 m is deduced, with a Pleistocene depression of 800—900 m. *H. Spreitzer* (1939) refers to impressive glacial traces, as well as the certainty of two glaciations, but gives no further details[5]).

In the Lycian Taurus of southwestern Anatolia the Ak Dag (3000 m), Bosburun Dag (2500 m) and Dedgol Dag (2980 m) have a number of large cirques, while the Barla Dag and Bey Mountains (3086 m) had glaciers which deposited moraines at 2050 and 1800 m respectively. An overall snowline of about 2400—2500 m is suggested.

I. Yalçinlar (1955) has attempted to show that the Honaz Dag (2571 m), the Akbaba-Akdag (2308 m) and the Bozdag (2157 m) of western Anatolia were extensively glaciated. A total of 42 cirques, mostly over a kilometer broad, are given for these three mountain groups. Although most of the so-called cirques have a northerly exposure, little else appears to support their existence. The photographic material does not show a single morphological form even closely resembling a cirque, and no cirque threshold whatever is visible at the necks of the broad flat alluvial-like valleys harbouring so-called tarns (at 1050—1100 m!). In short there is no ground to accept the existence of anything but a few small nivational niches and what appear to be large solifluctoidal sheets, if we can go by the illustrations provided. This point of view has been confirmed by *S. Erinç* (1955) who attributes the glacial-like profile of the Hogaz-Dag to former periglacial frostshattering and cryoplanation above 2000 m, below which level, an extensive fossil congeliturbate mantel is identified. *Erinç* assesses the Pleistocene snowline at not below 2400 m.

However the glacial traces which *Philippson* hinted at on the Sandras Dag (2294 m) have recently been confirmed, and *de Planhol* (1953 a, b) gives a remarkably low snowline of 2050—2100 m. Apparently the marine location and high precipitation are responsible.

This retrospect shows that during the last glaciation or Würm, to which these features are unhesitatingly ascribed because of their youthfulness, an overall lowering of the climatic snowline of about 700—800 m took place, permitting numerous cirque glaciers and even a few larger valley glaciers to a extend to a minimum altitude of 1700 m, and to achieve a maximum length of perhaps 10 km. In other words, the glaciation itself was not considerable, a conclusion, as we shall see, that also holds for Iran. *Louis* was able to conclude that the relative distribution of

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5) At the INQUA Congress, Madrid 1957, *Spreitzer* discussed the Ala Dag glacial morphology in impressive detail.

rainfall was very similar to that of to-day, glacier growth being favoured on the moister flanks of the mountains and in areas bordering paths of cyclonic disturbances to-day. The present snowline of the Taurus has a positive mean annual temperature of 4—5° C, and to account for a 700—800 m depression of the snowline, a lowering of the temperature as well as a more or less greater rainfall are necessary.

c) Present and Würm Glaciation on the Iranian Plateau.

The only wider study of glacial forms in the highlands of Iran was made by *H. Bobek* (1937) and is of particular value in that it pays attention to many related phenomena such as retreat stadia, periglacial activity, and a wide range of pluvial characteristics.

In Azerbaijan the Seidandag (3615 m) had a number of cirque glaciers extending down to 2700 m or so, with a glacial snowline of 3200—3300 m. The Savelan Mountains (4500 m) obviously had a considerable glacial cover with a snowline of 3300—3400 m, but preciser information is lacking. Curiously the Sahend Mountains (3700 m) show no glacial traces, and the snowline must have lain above 3500 m. There is a possibility of post-glacial uplift in the case of the Savelan and Sahend Mountains, just as this also appears to be possible in Lazistan.

In the Elburz Range, more definite information is available. The Tacht e Suleiman group (4823 m) still has two large cirque glaciers to-day extending to 3600 and 3850 m with cirque floors at 4200—4300 m from which *Bobek* estimates a contemporary snowline of 4100—4150 m. During the Pleistocene there was an extensive glaciation on the north flank of these mountains. The 13 km long Dahir glacier extended down to 2100 m, the Sardabrud, 22 km long, down to below 1800 m, and the Barur, 11 km long, to about 2000 m. There is nothing available from the Kulumbeste group which is apparently glaciated to-day, and was appreciably more so during the Würm.

Elsewhere there are cirques at 3600—3700 m on the Talaghan Mountains (4068 m) indicating a former snowline at that height. A glacier tongue 8 km long extended down to 2600 m from the northern flank of the Tocal group (3970 m), indicating a snowline at 3300—3400 m.

Mt. Demavend (5670 m) has two small glaciers on its north flank to-day with a snowline at 4500 m, or quite possibly somewhat lower, if we consider that the nearby Tere Mumedsch (3035 m) still carried firn in a fully unsheltered and exposed position in September, 1936 (*Heybrock* 1940). Little definite can be said about Pleistocene glacial traces, so that *Bobek* only hesitatingly suggests a former snowline of perhaps 3700 m. To sum up in the Elburz there were no developed glaciers with a southern exposure necessitating that the snowline was 300 or even 400 m higher than on the northern side. Otherwise the 700—800 m depression of the Würm climatic snowline is in direct correspondence with that of Anatolia. There is no direct evidence of any earlier glaciations, although possible indications are suggested in the Tacht e Suleiman. The parallelism of the present and past snowline isochines is remarkably close which proves that there was essentially a similar climatic zonation during the Würm Glacial-Pluvial, with identical pressure gradients. The glacial-pluvial climate was apparently only altered in a relative sense, in other words modified but not strictly changed.

Farther east in Afghanistan, where the present snowline lies between 4000 and 4500 m, *R. Furon* (1926) refers to a fairly extensive cirque glaciation witnessed by extensive glacial forms, and, polished and striated rocks occur down to a lower limit of 1970 m in Kabulistan. *E. Trinkler* (1928) found moraines down to 2600 m in the Hindukush, but could find no typical trough valleys.

H. E. Wright (in *Braidwood* 1954) mentions at least two phases of glaciation in Iraqi Kurdistan. In this preliminary report he notes an earlier stage with large cirque glaciers extending down to 1100—1400 m. The cirques of the more recent and less significant glaciation are all located above 2400 m and the end-moraines only reach down to about 2000 m. A more detailed account is awaited.

In the Zardeh Kuh (4286 m) of southwestern Iran, *A. Desio* (1934 a, b) was able to show the existence of four small glaciers with a northerly exposure, from which he calculates a contemporary snowline of 4000—4100 m. These glaciers enjoyed a considerable expansion during the Pleistocene, extending to a maximum length of 6 km down to an elevation of 2650 m. Employing the method of *Kurowsky, Desio* suggests a glacial snowline of 3350— 3400 m, implying a snowline depression of 600—650 m. *N. L. Falcon* (1946) has minimized the present glaciation by calling *Desio*'s glaciers 'snow drift ice' and 'niche glaciers', and has disclaimed any sizeable Pleistocene expansion of the Zardeh Kuh glaciers. However Prof. *Desio* has kindly communicated a lengthy report to me in which he refutes *Falcon*'s contentions, convincingly confirming the validity of his own earlier conclusions.

d) The Problem of Mt. Lebanon and Mt. Sinai.

The question of a possible glaciation in Syria has almost become a classical problem. Earlier observers believed that Mt. Lebanon (3076 m) as well as the Hermon (2814 m) and Anti-Lebanon (2659 m) were at one time glaciated. *C. Diener* (1886) clearly disproved the case with respect to the latter two, but left the first as an open possibility. From perennial firn patches he theoretically estimated the present snowline for Syria at 3100—3200 m which however appears rather too low for the true climatic snowline. On the humid western slope near the Cedars there is a cirque-like valley at whose mouth there is a horsehoe-shaped belt of moraine-like material at 2000 m which *Fraas* described as tufaceous limestone bearing plant imprints mixed within a gravel breccia. *Diener* was unable to find any grooved or striated rocks, and *L. Dubertret* (cited by *Neuville* 1934) has subsequently accounted for this bizarre cirque as a result of differential permeability and subsequent erosion of the cretaceous and jurassic rocks. The travertine interspersed in the gravel beds makes a glacial origin rather unlikely. In other words, there are no unequivocal traces of glaciation in Syria, suggesting a Pleistocene snowline not under 2800 m, although the possible interpretation of the Cedars 'moraine' as a periglacial feature remains open and requires further investigation. The recent reinvestigation of *W. Klaer* (1957) is of considerable interest to the subject.

A similar problem was raised by *H. Schamp* (1951) who drew attention to a cirque-like form with northeastern exposure at 2500—2600 m on Mt. Sinai (2641 m), which he thought may well have harboured a firn cap or even an icefield during the Pleistocene. *Büdel* (1954) examined this curious valley or gully but found no grooved or striated rocks, no steep headwall or cirque threshold, no nivational niche and no traces of any moraines. Even the possibility of a stagnant firn mass in this sheltered canyon seems excluded by the absence of a nivational niche. Consequently, the principles whereby the present and glacial theoretical snowline achieves its highest altitudes above the subtropical horselatitudes rather than above the equatorial convergence belt (c. f. *Troll* 1944 a) seem to be substantiated.

2.—*Contemporary Periglacial Activity.*

The morphological significance of present and past 'periglacial' activity, in the sense of *C. Troll* (1944 b), cannot be overestimated, and this topic well deserves a separate treatment, although our scetchy knowledge of the present occurence of frost pattern soils and cryoturbation (not even that of the Pleistocene!) make such a treatment appear almost presumptious. The strong mechanical weathering above the lower limit of structure soils provides large quantities of rock detritus, and when during the glacial phase(s) this boundary was lowered by an amount perhaps corresponding to the snowline depression, vast areas of the eastern Anatolian Plateau were able to deliver immense quantities of angular gravels to the strongly overloaded rivers which deposited great terraces of such material, such as we find in the middle Euphrates Valley.

A most important contribution to the study of frost pattern soils and solifluction was made by *C. Troll* (1944 b, 1947, 1948), who not only collected all of the material cited below and illuminated it in the pattern of a world-wide scheme, but has provided great individual impetus for further research in the field. The periglacial cycle of denudation, according to *Troll* (1948) occurs not only in areas with permafrost, but also in all climatic zones with morphologically active soil frost. To the latter belong the temperate zone mountains with an annual tjaele as well as the temperate, subtropical and tropical mountains with a diurnal tjaele, i. e. very frequent or regular nightly frosts and ice-formation in the uppermost soil layers.

In the temperate and subtropical highlands of our latitudes, which show a very strong diurnal as well as a pronounced seasonal variation of temperature (*Troll* 1943), two specific types of frost pattern soils occur (*Troll* 1944). The effect of an extended annual tjaele is usually similar to that permafrost, and leads to the formation of large soil structures (one meter or more in diameter) with relatively poorly assorted material. On the other hand, the 'tropical pattern' of structure soils is characterized by miniature forms of small inner diameter (10 to 25 cm), an especially pronounced sorting of the materials, a complete lack of vegetation and a marked preference for soils with a great water-capacity. The distinctive character of the tropical, as opposed to the polar type-pattern, is due to the repeated diurnal freezing and thawing of the upper soil layers which produces smaller but distincter forms. Intermediate types, or both tropical and polar patterns, possibly in a modified form and often side by side can often be found in the transitional zones.

Most noteworthy, indeed, is that the lower limit of soil structures and the present snowline run more or less parallel, although the vertical distance between them is not necessarily constant (*Troll* 1944 b). This lower limit of frost pattern soils is usually but not always above the present tree line and above the Pleistocene snowline.

The alternating freezing and thawing leads to considerable movements within the soil, and the gentlest slope suffices to set the water-permeated soil in motion, so directing huge quantities of soil and detritus down the hillsides and slopes. When the snow within the higher elevations melts, this material is transported by the overloaded mountain streams, leading to aggradation further downstream. Aeolian forces are not idle while the water is held in solid form, and a special form of wind-deflation, 'gelide-flation' as *Troll* has called it, is not without it morphological significance (loess!). In other words, frost shattering and frost weathering, solifluction and cryoturbation, lateral erosion and aggradation, wind-deflation and deposition — all within their own periodical and regional mode of occurrence — assure a very energetic areal erosion within the 'subnival' climatic zone, i. e. between the climatic snowline and the lower limit of soil structures. This erosional or denudational process is known as 'cryo-planation' (*Troll* 1948).

After this necessary review of these fundamental concepts, the present distribution of frost pattern soils will be briefly described below.

In the Pontic Mountains of northern Anatolia, stone polygons and soil stripes occur as low as 2600 m to-day, while in the central Taurus area, they occur even lower. The lower limit of frost pattern soils on the Ala Dag lies at 2500 m and there are fine examples of stone nets, stone stripes and stone rings, especially on the gentler slopes between 3000 and 3200 m. Although most of these Anatolian forms are of the miniature 'tropical' pattern, with a diameter of 15 to 30 cm, the polar type occurs as well. The reason for the occurence of both comes from the cold winter temperatures accompanied by a thick snow cover which lasts until June, wher-after the dry summer climate permits strong insolation and nocturnal reradiation leading to strong diurnal temperature variations with nightly soil frosts. Consequently nice specimens of earth garlands such as can be found in the Alps still occur at 2600 m. The fossil cryoplanation terrace at about 2000 m in the Honaz Dag has already been mentioned. Further *Pfannenstiel* (1956) notes frost pattern soils at and above 2400 m on the Uludag.

The structure soils of the Caucasus are predominantly of the miniature variety and occur from 2800—2900 m upwards. Earth stripes and earth garlands, stone polygons and vegetation polygons are particularly characteristic. In Kurdistan, soil structures occur only above the present climatic snowline, and *Bobek* (1940) found miniature earth stripes and stone nets at 3500 m on the Cilo Dag and at 3800—3900 m on Geliasin. In the Elburz Mountains of Iran, solifluction may be observed in elevations above 3000 m to-day, and miniature stone stripes and stone garlands occur at 4100—4200 m on Mt. Demavend, Lesherek and the Alamkuh. H. *Bobek* (1954) has further made a contribution to fossil periglacial forms in the Near East. He considers the breccias occuring on the slopes down to 2300 m, which are at present all being eroded, as cemented remnants of ice-age congeliturbate sheets. In other words, the limit of periglacial activity was lowered by 700 meters during the Würm Glaciation. This agrees with observations of similar fossil slope breccias occurring between 2300 and 1500 m at the foot of the Ala Dag, also associated with a period of greater periglacial activity, soil and rock creep (*M. Blumenthal* 1952).

And lastly, *W. Klaer* (1957) sets the lower limit of frost pattern soils at 1900 m on Mt. Lebanon to-day, while on Mt. Sinai there are vegetation structures above 2400 m (*Schamp* 1951, *Büdel* 1954), and *Schamp* was able to observe needle ice, a typical sign of ground frost, at 2000 m. However typical frost pattern soils were absent.

From the above somewhat scetchy outline of the distribution of frost pattern soils and cryoturbation, the necessity for further and more specific attention to periglacial phenomena by future field-workers in the Near East becomes apparent. At the present state of our knowledge, any too far-reaching conclusions would be hazardous, and merely to illustrate the importance of Pleistocene cryoturbation, some assessments will be made by analogy. As mentioned already, *Bobek* estimated the glacial depression of the lower limit of cryoturbation at 700 m in Iran, a figure corresponding to that of the climatic snowline depression in the High Atlas of Morocco. *H. Mensching* (1953) was able to establish a depression of the Würm snowline as well as of the lower limit of cryoturbation by 800—900 m in both cases, basing himself, however on a greater number of more homogeneous observations. On the other hand, *K. Wiche* (1953) notes a depression of the lower limit of cryoturbation by at least 600 m compared to 600—800 m for the snowline depression in the M'Goun Range of Morocco. If we could assume, by analogy, that the lower limit of cryoturbation was lowered by 700—800 m everywhere in the Near Eastern highlands, then using those scanty observations available and employing their relative distance to the isochiones for interpolation, a very tentative map of the areal extent (c. f. Map 4) of the periglacial zone could be reconstructed.

Considering the large periglacial areas so described, one should except to find the deposition of river terraces similar to that found in the periglacial zone of Europe. And this is precisely the case. The Euphrates, which originates deep within this area of cryoplanation, reveals the classical altitudes of 100, 60, 30 and 15 m in the neighbourhood of Deir ez Zor, and an 'Upper Chellean' implement was found in the gravels at the base of a 27 m terrace (*Passemard* 1927). While the short streams of the Elburz did not build up any regular system of terraces, they nevertheless deposited immense quantities of 'fluvioglacial' material (from the zone of cryoplanation) which remain in the form of gravel beds and conglomerates (*Bobek* 1937). So, the assumption that cryoplanation was of indisputable importance in the highlands of Anatolia and Iran during the Würm Glaciation seems to be amply justified.

3.—*Conclusions.*

Although both the present and Pleistocene glaciation of the Anatolian and Iranian Highlands is areally of no great importance, the present and past snowline provides a valuable indicator of the temperature climate of the Near East. A general snowline depression varying between 600 and 800 locally can be compared with a similar depression for the lower limit of cryoturbation. Presuming no change in precipitation, this would suggest a mean temperature decrease of about 4° C from the observed upper air lapse rate (0,55° C/100 m on average) for Near Eastern stations. This result is identical with that already obtained by *Louis* and *Bobek,* and *Flohn* (1953) assumes a similar lowering of temperature for the tropics in general.*)

The new technique of deep sea core samples has yielded even further substantiation in that a sediment section dated at 10 000 to 28 000 B.C. by radiocarbon suggests an average water temperature some 5° C colder than the present for the Eastern Mediterranean (*Emiliani* 1955). It must be remembered however, that the cold glacial meltwaters of the northern rivers will have made this decrease slightly greater than was actually the case on the neighbouring mainland.

The scanty details available suggest the Riss snowline depression was appreciably greater.

*) The results from Zardeh Kuh further confirm the same trend in the heart of the horselatitudes.

Chapter V. The Middle and Upper Pleistocene pluvial Chronology

1.—*Introductory Remarks.*

The existence of a 'pluvial' period, i. e. a period of widespread, long-term rainfall increase of sufficient duration and intensity to be of morphological importance, has long been suspected in the Near East, and the evidence of such a phenomenon led *E. Hull* to adopt the word 'pluvial' with reference to Palestine in 1884. A direct association of the Mediterranean pluvials with the higher latitude glaciations was already explicitly stated by *M. Blanckenhorn* (1896) and this concept has been harboured by many Quaternary geologists and meteorologists since. The direction of much attention to the tropics, in particular East Africa, largely as a result of the work of *E. J. Wayland* since 1921, set a tendency to regard pluvial periods as characteristical of the lower latitude Pleistocene in general. In more recent years, however, distinct trends have been established whereby the role of pluvial periods has been greatly minimized, their association with higher latitude glaciations doubted, or their very existence often outrightly disclaimed.

Firstly a distinction must be drawn between the subtropical pluvials, i. e. those occurring along the poleward margins of the great continental trade-wind desert belts, and the tropical pluvials characterizing the equatorial margins of the same deserts. Five great desert belts come into question in such a discussion: the great American Desert of the Great Basin and northern Mexico, the Atacama Desert, the great deserts of Australia, the Namib-Kalahari desert complex of southwestern Africa, and lastly, the great Sahara-Arabia-Turkestan desert belt of northern Africa, southwestern and central Asia. In the latter area two, or rather three types of pluvial are commonly mentioned in the current literature. 'Mediterranean pluvial' are ascribed to the Mediterranean coastline of Africa, southwestern Asia, and implicitly central Asia, while the pluvials of the southern margins of the Sahara are often designated as 'Sudanese', those of East Africa and the Indian Peninsula as 'Equatorial' pluvials. However the adoption of the terms 'subtropical' and 'tropical' to describe the pluvials of the poleward and equatorial margins of the great desert belts respectively, as defined above, is of greater general applicability and is more acceptable in a meteorologic sense. For, the great desert belts are but an expression of the trade-wind zones or 'horselatitudes' as they are often called. Any climatic shifts on the equatorial margins of the horselatitudes are a result of circulation changes within the circumplanetary equatorial easterly and westerly currents, while climatic shifts on the poleward margins reflect similar phenomena within the westerly drift of higher latitudes. That these climatic shifts are contemporary, i. e.

that the desert margins converge or diverge synchronously rather than that the desert belt itself shifts, has been postulated and accepted by a number of leading authorities, but apart from the fine pioneer study of *S. A. Huzayyin* (1941), no effective systematic treatment has ever been made to prove or disprove this assumption. The ideal area in which to consider these problems and very likely to prove the contemporaneity of subtropical and tropical pluvials as expressions of an identical primary cause, is of course the Saharo-Arabian Belt. Here the amount of evidence available from the Near East, Northwest Africa, the western and central Sudan, Ethiopia and Southwest Arabia is sufficiently large to make even a tentative attempt seem quite promising. However this study is more limited in plan and we have chosen a select section of the subtropical pluvial zone in which, as an inevitable preliminary to a large-scale correlation, we shall aim to demonstrate three points with respect to the Near East:

1) the existence of subtropical pluvials,
2) the association of such pluvials with the world-wide glaciations, and
3) the character, distribution, intensity and chronology of such pluvial episodes.

Only with this prerequisite can a palaeometeorologic reconstruction be attempted and a more extensive correlation made.

Two distinct morphologic problems reoccur continually in the physical evidence of pluvials, namely the question of fluviatile terraces and the significance of cave sediments. Since neither of the two is sufficiently familiar or insufficiently controversial to pass over without comment, a few words of discussion with references to more detailed and authoritative publications will be presented.

Symmetrical, alluvial river terraces represent a cessation of vertical incision accompanied by lateral erosion leading to the formation of more extensive valley floors. Such terraces can be ascribed to alternating degradation and aggradation in response to climatic changes, intermittent uplift or eustatically-controlled variations in the base level of erosion. Since, unless otherwise specified, tectonic uplift is of secondary importance during the Upper Pleistocene in most of the specific areas considered, the climatic-eustatic and the climatic types of terrace are of primary importance here. A eustatic lowering of sea-level will cause 'rejuvenation' of a stream in its lower course leading to a regrading activity to this lower base level, namely vertical incision, which will progress upstream (*W. D. Thornbury* 1954, p. 142—60). Similarly a rising sea-level will lead to river aggradation and lateral erosion which likewise proceeds upstream. On the other hand, during a local glaciation, valley filling with glacial outwash will proceed downstream, while the gradients required to transport this outwash will no longer be necessary during interglacials and valley trenching will ensue (*Thornbury* 1954). In other words, diametrically opposed processes are at operation in such areas either aggradation uptream and degradation downstream or vice versa. The complexity of this process was ably illustrated by *P. Woldstedt* (1952) and *C. Troll* (1957) and has been interestingly discussed by *L. Tre-*

visan (1946, 1949). The same complexity appears to exist in semi-arid regions affected by the pluvial epochs and having streams capable of carrying their waters into the world oceans. *E. Huntington* (1914, p. 33—4) believed that aggradation characterized a relatively arid climate because the runoff was insufficient to transport the load of the streams. However *K. Bryan* (1941) and *E. Antevs* (1952) have more convincingly argued that the reduction of the plant cover on hill slopes and floodplains during more arid phases would permit the intense rains to run off rapidly, resulting in soil erosion and extensive gullying, with deposition only far downstream on the major rivers. During moister phases, the more complete vegetational mat would slow down the rate of runoff and induce streams to deposit their loads sooner. *C. A. Cotton* (1945) further points out that where the vegetation is anyway too little modified by climatic changes to affect its function of preventing soil erosion, which is actually the case in the semi-arid and arid Near East as opposed to the areas with a sclerophyll vegetation, increased precipitation above a certain threshhold value will produce flood erosion and accelerate mass movement, swelling the load of detritus out of proportion to the accompanying increase in water volume. This leads to aggradation in valleys receiving no fluvioglacial gravels, and here the pluvials will be accompanied by an accumulation of alluvium which is left as terraces after the rivers revert to vertical incision (*Cotton* 1945).

The second morphologic process of particular importance in this investigation is the significance of the various sediments found is the stratigraphical profile of cave deposits. *R. Lais* (1941) has made the first systematic study of such cave sediments, and valuable guidelines have also been provided by the work of *G. A. Blanc* (1921) and *G. Freund* (1955).

The separation of limestone fragments from the ceiling and walls of a cave can be ascribed to two causes according to *Lais*. Firstly, the percolating water coming down from the surface dissolves the limestone along the clefts and splits, leading to precipitation of calcareous, clayey or loamy materials as well as to the loosening and disaggregation of corroded, superficially dissolved and somewhat rounded limestone blocks. This process requires the percolation of considerable quantities of water and indicates a humid climate. Secondly, the freezing of water in the limestone clefts leads to expansion and disintegration, a process favoured by frequent freezing and thawing (thermoclastic weathering) through which angular, friable and uncorroded limestone fragments are loosened from the ceiling. Whereas the first are usually deposited in tufaceous or clayey beds, the latter are loosely aggregated and not cemented into calcareous breccias. Stalagmitic and stalactitic formations are well known in the literature, and result from the evaporation of percolated water on the ceiling or floor of the cave, as the dissolved limestone compounds held in solution are precipitated. This process likewise requires a good amount of seepage water, and since stalagmites in general are not forming under present climatic conditions, at least not in appreciable amounts, stalagmitic horizons can be taken as an indication of a more humid climate in the Near East.

Clayey and loamy deposits are mostly either washed in near the entrance of caves, or carried in through the ceiling by percolating water from the soil above (*Lais* 1941). Since the mean temperatures of cave interiors are generally quite low and subject to small temperature variations, little or no weathering takes place inside them, so that such materials indicate the form of weathering then dominant outside. Consequently brown soils suggest a slightly cooler climate than terra rossa, which is the typical product of subtropical Mediterranean weathering.

Lastly, humic components are relatively insignificant as they represent the vegetable and animal matters brought into the cave by man or beast (*Lais* 1941).

The invaluable stratigraphical profiles of the Near Eastern caves have usually taken a secondary place in most commentaries on the local Pleistocene, and we shall attempt to evaluate them as well as possible, for their integration into the morphological evidence shall prove to be of surprising significance to the Pleistocene chronology and climatic sequence established below on a regional basis.

2.—*Libya during the Middle and Upper Pleistocene.*

Although our overall knowledge of the Libyan Pleistocene is still a little scetchy, a few select observations do throw considerable light upon the Middle and Upper Pleistocene pluvial sequence so that the inclusion of Libya is of good profit in the reconstruction of an overall picture. Although the Cambridge archaeological expeditions have focussed wide attention upon the important finds in the Haua Fteah Cave of Cyrenaica, an earlier investigation of a similar nature must first be referred to.

C. Petrocchi (1935, 1940) already gives a stratigraphic sequence for the Hagfet Et Tera Cave near Bengazi, which can be outlined briefly as follows[6]:

A—. 20—50 cm.

A_i - recent material with beduin remains.

A_{ii} - clayey terra rossa with *BOS PRIMIGENIUS*, *BOS* sp., *EQUUS CABALLUS* (?) as well as *CERVUS* sp. This horizon which contains an Upper Palaeolithic blade industry of evolved Capsian character is taken as indicating damper conditions than now prevail.

A_{iii} - sterile layer of stalagmite.

B—. 20—50 cm. Loamy terra rossa containing *RHINOCEROS (MERCKII?) BOS PRIMIGENIUS, EQUUS CABALLUS (?) E. ASINUS HYDRUNTINUS (?), CAPRA sp (?), HYAENA* and an antilope. The rich industrial remains represent a trend from Middle Palaeolithic (Mousterian) to Upper Palaeolithic (Capsian). An abundance of large limestone blocks characterizes the upper part of the horizon (B^i).

6) *D. M. A. Bate* (1955) believes the *E. CABALLUS* is only a zebra. The ass could more probably be the wild African ass, while the *CAPRA* suggests a Barbary sheep.

C—. Stratum of stalagmites 6 cm thick.

D—. Sterile horizon of coloured soils containing calcareous nodules, largely decalcified. 30—90 cm.

E—. 10—20 cm. Brown clayey earth with *EQUUS CABALLUS (?), CAPRA, HYSTRIX CRISTATA,* and Mousterian-type flakes.

From the previous comments on the nature of cave sediments in general we can suggest the following. The two stalagmitic horizons A_{iii} and C clearly imply a fairly humid climate as no stalagmites form here under present moisture conditions. Similarly the decalcified material of D suggests a moister phase. Lastly the large limestone blocks occuring in the upper half of the B horizon suggest the possibility of thermoclastic weathering, although the overall decrease in temperature cannot have been too great as terra rossa still indicates a warm climate. In short one may conclude a cooler phase during the Upper Palaeolithic ushered in by a very moist interval during the early upper Mousterian, with indifferent climatic conditions in between. Prior to this the climate resembled that of the present, while subsequently there was apparently a renewed moist interval in Capsian times before the return to modern climatic conditions. This would imply a generally drier climate during the Riss/Würm, a very moist phase at the onset of Early Würm followed by a more temperate cool climate during later Early Würm and Main Würm, with a renewed, short wet interval probably during the Atlantic phase.

The sequence of the Haua Fteah Cave, west of Derna, is as follows (after *McBurney* 1953; *McBurney, Trevor & Wells* 1953, described by *R. W. Hey):*

0— 95 cm	Loose, powdery earth with occasional limestone fragments. Greek, Roman and Arab remains.
95—210 cm	Reddish earth, darkened locally by charcoal. Neolithic.
210—260 cm	Similar with localised concentrations of limestone fragments. Microlithic.
260—470 cm	A consistent zone of angular limestone fragments (especially below 300 cm) and large, uncorroded limestone blocks, indicating a prolonged period of extreme thermoclastic weathering. Density of limestone debris decreases below 450 cm and is negligable below 480 cm. Large Upper Palaeolithic blade industry.
480—840 cm	Fine grained, uniform, reddish soil with very frequent stalagmitic concretions and zones of cementation below 510 cm. The highest traces of stalagmites are at 440 cm, in the form of a very thin, localized sheet. Levalloiso-Mousterian.

Fortunately several of the cultural layers have been dated more closely by C_{14} (*H. E. Suess* 1954), and we can give the following radiocarbon dates:

195—220 cm	primitive Neolithic	4 850 B. C. ± 350
220—240 cm	Microlithic	5 350 B. C. ± 300
280—300 cm	Upper Palaeolithic	8 650 B. C. ± 400
335—360 cm	Upper Palaeolithic	10 350 B. C. ± 350
465—480 cm		26 550 B. C. ± 800
570—590 cm	Levalloiso-Mousterian	32 000 B. C. ± 2800 or older

This enables us to delimit the period of intensive frost weathering, under a much more continental climate, between roughly 25,000 and 8000 B. C., coinciding chronologically and climatically with the Main and Late Würm phases of Europe. And with the exception of the onset of Main Würm (stalagmites up to 440 cm) this whole period was not any moister than the present. On the other hand, there was a very moist phase—a pluvial, if we may call it so—of many thousand years duration preceding the Main Würm phase. One may justly consider the zone from 450 to 510 cm as a phase of transition which must correspond to the inter-Würm oscillation, while the pluvial phase is certainly chronologically equivalent to the Early Würm period. In other words, the Haua Fteah stratigraphy distinctly points to local pluvial during the Early Würm, after which there was a transition to different climatic conditions, accompanied by a cultural discontinuity between a Middle Palaeolithic flake-industry and an Upper Palaeolithic blade industry. This intervening stage occured some 30,000 years ago, i. e. simultaneous with the 'Göttweiger' zone of weathering. Thereafter during the Main and Late Würm stages the climate was quite cold, and improved moisture conditions were limited to the initial phases of the Main Würm period. However the Early Würm pluvial was not appreciably colder than to-day judging by the reddish colour of the deposit and the lack of angular limestone fragments. After 8000 B. C. modern climatic conditions gradually set in.

The coastal wadis around Derna generally show traces of two terraces, the older only incompletely preserved and without archaeological associations. Of greater interest are the 'Younger gravels' which have been examined by *McBurney & Hey* (1955). These gravels are cemented, generally well-rounded (ibid. p. 74—75) and frequently cross-bedded. These appear to be regular accumulation deposits of semi-arid regions under conditions of alluviation resulting from greater rainfall (or relative subsidence), not a result of increased mechanical weathering as these authors suggest[7]). Well-rolled gravels indicate greater discharge here (as they are contemporary to a regression or 'uplift'), the source of material being greater erosion and transporting ability. The 'younger gravels' often rest directly on the 6 m Monastir II beach and never carry traces of it, and must therefore be post-Riss/Würm Interglacial. They are often interdigited with the dunes blown up during the post-Monastir or Würm Regression (ibid. p. 93, Fig. 7), and in a number of wadis overly tufaceous deposits, apparently conformably. The latter contain a warm flora, and imply a greatly increased activity of the perennial springs feeding some of these wadis, i. e. a warm, wet climate. These tufas and marls overly the bedrock, and as the 'younger gravels', contain an evolved Levalloiso-Mousterian industry. The geological outline of the gravels and tufa deposits (ibid. p. 74—138) does not imply a phase of vertical incision separating the tufas and gravels as *McBurney* (1953) has suggested. In brief, the wadi and beach sediments permit the following sequence in the Wadi Derna region:

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7) At least as far as one can judge from the text. The present writer has not been in Libya.

1) 6 m beach conglomerates and abrasional platforms, upon which the earliest Middle Palaeolithic sites are situated. At this time or earlier, vertical incision of wadis to bedrock.

2) Greater activity of perennial springs leads to deposition of tufas and marls containing a warm flora. Levalloiso-Mousterian.

3) Deposits go over into well-rounded gravels conformably. Intercalated with fossil dunes at coast, indicating gravels contemporary to Würm Regression. Levalloiso-Mousterian.

4) Vertical incision to the present.

The phase 2) indicates a warm and wet climate at the transition to the Würm, a feature which will be seen to reoccur frequently in the Mediterranean. A fairly general continuation of somewhat moister conditions during the Upper Palaeolithic is indicated by decalcification in situ in the deposits of the Hagfet et Dabba Cave between Barca and Cyrene (*McBurney & Hey* p. 191—98).

G. Knetsch (1950) recognizes at least 8 stages in the recent morphological evolution of the Djebel es Soda area in Central Libya:

1—. Two periods of formation of crustal surfaces separated by a phase of downcutting. (400 mm precipitation).

2—. Erosional cycle characterized by angular wadi gravels. (400 mm).

3—. Formation of a light-coloured calcareous crust upon the wadi gravels of stage 2. (200 mm).

4—. A cycle of erosion characterized by well-rounded gravels and travertine. (over 400 mm).

5—. Angular wadi gravels and cementation of the previous sediments by a red crust. (200 mm).

6—. Erosional cycle with angular gravels followed by local formation of calcareous crusts. (300 mm then less than 200 mm).

7—. Erosion with angular gravels and local formation of red earths in the Central Sahara. (Capsian) (300 mm).

8—. Modern conditions (150 mm).

On the grounds that calcareous crusts form chiefly in areas with an annual precipitation of 150—250 mm in the Sahara to-day, that red earths rarely develop with less than 300 mm rainfall, and from other morphological considerations, *Knetsch* has drawn up an accompanying rainfall curve the essential points of which are added to the physiographic stages above in parentheses. However *Knetsch* is careful to point out that these pluvials are not to be taken as proven, but still require further investigation. Unfortunately no means whatever of dating these stages, with the exception of 7, has been provided, and it is hoped that some archaeological evidence will be found to supplement these important results. Four or five pluvial phases or subphases are indicated and as such only serve to emphasize that there have been quite a number of pluvial phases during the Pleistocene, only that their traces have been but poorly preserved or are difficult to recognize.

C. B. M. McBurney (1947) has also given attention to the great fossil drainage system extending for several hundreds of kilometers through now virtually waterless eastern Libya. The fossil wadi terraces of the Wadi Merdum and Wadi Soffegin, for example, are composed of coarse, rounded gravel and boulders which contrast strongly to the fine-grained deposits on the modern wadi sole. The last phase of activity of the wadis is connected with an early Middle Palaeolithic hand-axe industry whose implements are all strongly and deeply chemically corroded by carbonic acid given off by decaying organic matter and humus in connection with calcareous materials. Some of the specimens of this industry, which are infinitely more plentiful than any of the subsequent cultures, are also clearly water-worn, while the few late Middle Palaeolithic implements (bearing a definite resemblance to the Egyptian Lower Sebilian) are all very fresh and uncorroded in appearance. Consequently *McBurney* (p. 57—8) concludes that the last activity of the ancient wadis took place 'subsequent to a part of the Acheulian' and that all major activity had ceased before the end of the Middle Palaeolithic. As mentioned already in Chapter III, the gradient of these wadi terraces near their outlets strongly suggests that they dip well below the present coastline to a considerably lower sea-level than the present, which implies their correlation, and that of the pluvial phases, with glacial-eustatic regressions of the Mediterranean Sea.

The implications of the evidence of *Knetsch* are that phase 6, as the last period of major pluvial activity, is contemporary with the last phase of wadi activity identified by *McBurney* elsewhere during the early Middle Palaeolithic, and with the very moist interval indicated by the stalagmite stratum C of the Hagfet et Tera Cave, which also preceded the greater part of the Middle Palaeolithic. Both the Hagfet Et Tera and Haua Fteah Caves indicate a persistance of moister conditions to the close of the Middle Palaeolithic but this closing phase was apparently no longer noticeable in the desert interior. Previously phase 5 of *Knetsch* seemingly implies the Riss/Würm Interpluvial. The Libyan succession and our suggested correlation to the European chronology can best be presented in a tabular form headed by a numerical code index which shall also be adopted for the other regions to facilitate an overall comparison further below.

Another feature deserving mention with regard to Libya are the great loess deposits of the Tripolitanian area pointed out by *Rathjens* (1928). The underlying marine beds near the coast contain a number of modern mollusca, and in general the loess further overlies pluvial gravels to a great depth. As no further deposition occurs to-day, rather wind-deflation and erosion, *Rathjens* is forced to ascribe the loess to an arid period with more frequent and stronger southerly winds than are known to-day, somewhere between pluvial and historic times. From similar evidence of a climate more arid than the present in the Fayum, the Jordan Valley and Iran we shall see later that the main period of Libyan loess deposition can probably be assigned to the closing stages of the Upper Palaeolithic some 12,000 years ago.

In the southern Fezzan, *M. Dalloni* (1945, p. 48) saw a number of terraces with rolled gravels along wadis debouching from the northwestern

Table III. *The Libyan Chronology*
(after *Petrocchi* 1935, 1940; *McBurney* 1947, 1953; *McBurney & Hey* 1955; and *Knetsch* 1950)

Libya Index	Hagfet et Tera / Haua Fteah		Djebel es Soda / Wadi Derna /		Suggested Correlation	
1	Ai	0—260 cm	8	(150 mm)	4	Holocene
2	Aii - Aiii	260—440 (2–3)	7	(300 mm)	3 (7–6/7, with 450—510)	Early Holocene
3	Bi		6/7	(200 mm)		Late & Main Würm
		450—510				Interstadial(?)
4	Bii	510—840 (4–5)			2	Early Würm
5	C, D		6	(300 mm)		
6	E?		5	(200 mm)	1	Riss/Würm
7			4	(over 400 mm)		Riss?
8			3	(200 mm)		Mindel/Riss?

Tibesti foothills. The Wadi Wur is accompanied by an 8—10 m alluvial terrace, for example, but unfortunately the prehistorians of this expedition merely collected surface finds. Similarly large alluvial terraces are known to occur at some 10 and 30 m in wadis of the Tibesti Massif (*Dalloni* 1934, p. 135—6) (The great fluvio-lacustrine phase of this area is associated with a Mousterian industry, and probably represents the Early Würm.) It is regrettable that the prehistorians and geologists of the French missions to Tibesti and the southern Fezzan did not attack their problem as thoroughly and systematically as elsewhere in the French Sahara, as there is no doubt still a wealth of material awaiting future investigators in Tibesti.

3.—*Egypt and the Nile Valley.*

a) Introductory remarks.

Although no area within the Near East has been subject to more detailed and methodical investigation than the Nile Valley in Egypt, no physiographic features present a more difficult and complicated problem than the oft-studied Nile terraces. Fluviatile terraces can result from a good number of usually interconnected causes—subsidence or uplift of the land, eustatic changes of sea-level, changes in volume or load accompanying local climatic changes, or morphological changes within the drainage basin, just to mention a few. *K. S. Sandford* (1929, 1934) and *Sandford & W. J. Arkell* (1929, 1933, 1939) upon whose systematic work all subsequent comments and conclusions have perforce been based, unfortunately wrote at the time when many of the now-held concepts of climatic aggradation and degradation were not yet clearly developed. These authors assume an uninterrupted pluvial epoch throughout the Pleistocene, lasting indeed from Lower Pliocene times or even earlier. While the pluvial supposedly stopped in Middle Palaeolithic times in Nubia, it lasted into the Upper

Palaeolithic further north in Egypt. The entire succession of terraces of both Nile and its tributaries is simply tied in with eustatic changes of sea-level in the Mediterranean and no need is felt to identify any climatic variation within Egypt itself. In this way an otherwise masterly field-study is of limited practical value and while we shall attempt to draw what we can from the field work described, the whole problem can only be ultimately solved and this most important link within the Quaternary fully evalued after a renewed field investigation of the Nile Valley.

In no part of the Near East, excepting the Nile Valley, do we know anything about the Lowest Pleistocene or about the Plio-Pleistocene limit. The geological examination of *Sandford* (1934, 1939) at least provides a framework for the delimination of the youngest Pliocene and earliest Pleistocene. The maximum Pliocene transgression took place during the Astian, leaving deposits to 180—200 m in Egypt, where an arm of the sea extended 500 miles southwards to Aswan. These waters were fresh to brackish in Upper Egypt, and the freshwater or estuarine zones progressed north during the course of the Upper Pliocene. With the beginning of a new regressive phase, erosion took place on the adjoining land, depositing sands subacqueously and then coarse river gravels and boulder beds until the whole valley was filled. This phase was described as 'Plio-Pleistocene' by *K. S. Sandford,* and is probably partly of Villafranchian age. The lowermost Pleistocene ('Plio-Pleistocene' of *Sandford*) was characterized by a fluviatile phase with enormous gravel deposits and eventually incision of the Nile into the sediments of the Upper Pliocene Gulf. Rock-cut terraces with gravels occur intermittently at 46, 76 and 100 m (gravels to 180 m) as far as Wadi Halfa, and suggest at least a connection with the Sicilian and Milazzian stages. The earliest Pleistocene deposits, probably of Calabrian age, indicate great pluvial activity to account for the erosion and subsequent transport and deposition of the massive conglomerates filling the old Pliocene Gulf.

Before going on to the specific climatic evaluation of the younger physiographic features of the Nile Valley, a number of basic problems will be reviewed here. Firstly the evolution of the southerly Nile drainage basin is of paramount importance, although this region lies quite outside the area under consideration.

The Nile Valley in Nubia is post-Pliocene as no deposits of that date occur south of Aswan. The highest ('Plio-Pleistocene') terraces at 46, 76 and 100 m show no signs of material from the ancient metamorphic massif of the northern Sudan, and apparently the river had a higher course or an independent one different from to-day (*Sandford & Arkell,* 1933, p. 82—3). *Huzayyin* (1941, p. 117, 151) even goes so far as to suggest that the Blue Nile and Atbara, which to-day contribute 75% of the Nile volume (*W. Pietsch 1910, E. Nilsson* 1953), only drained into the Nile since very late Middle Palaeolithic times, prior to which they had to build up a flood plain and a levée system across the Sudan plain. However the laboratory analysis of the Nilotic sediments in Egypt as carried out by *N. M. Shukri* (1951) and *Shukri & N. Azer* (1952) has yielded some highly useful and somewhat surprising results. Just as augite is the characteristic mineral in Atbaran and Blue Nile sediments, hornblende distinguishes the Sobat, and sillimanite the Bahr al-Ghazal. Augite is entirely absent from the Pliocene and 'Plio-Pleistocene' sediments. The occurence of augite in appreciable amounts and in varieties similar to those of to-day on the 30 and 15 m terraces shows that the Atbara and Blue Nile (or at least one of the two!) were connected with the Nile during Lower Palaeolithic times. However its presence then in quantities less than those of more recent and modern Nile sediments shows that the Abyssinian influx was not as great as in more recent and modern times. Only in Middle Palaeolithic and later times was the mineral composition of the Nilotic sediments similar in all respects to that of to-day. The explanation for this can best be sought in Ethiopia itself, where *Nilsson* (1940, 1949, 1953) points out that hydrographic conditions only took on their modern aspects shortly before the onset of the last tropical (Gamblian) pluvial, which *Nilsson* correlates with the Würm Glaciation. We do not intend to go into detail on this point, other than to mention that all of the ancient lake sediments around Lake Tana belong to the Gamblian, and *Nilsson* believes that the Tana Basin did not exist during the earlier Kamasian (Riss?) Pluvial. During the first pluvial, the Kageran, (or at latest during the early Kamasian), another, now non-existant Lake Yaya left 80 m thick lacustrine deposits in Central Ethiopia, but the direction of drainage of this monstrous body of water is not yet known with certainty, although it most probably drained into the Sudan. In other words, the sources of water of the Nile before the onset of the Upper Pleistocene must still be determined.

The second point on our agenda is the applicability of the common principles of aggradation and degradation in the case of the Nile. The terraces of the Nile and its Egyptian tributaries are symmetrical or cyclic, and disregarding the possibility of intermittent uplift, these alternations of vertical erosion and lateral planation can only be ascribed to eustatic sea-level variations and climatic changes within the drainage basin. The Nile tributaries in the Eastern Desert hardly ever carry water into the floodplain to-day and their activity is confined to local torrents which on the whole contribute very little to the deposition of wadi fill. Yet most of the larger wadis display Palaeolithic terraces at 30, 15, 8—9 and 3—4 m, immense accumulations of debris often transported over a 100 km stretch and carried further right into the Nile (Fig. 11). Such feats of transport and aggradation could only be made possible by a very appreciable increase in the local rainfall, regardless of the base level of erosion. Similarly the large amounts of coarse gravels and other materials carried down and deposited by the Nile during various phases of the Pleistocene points to indisputable climatic changes within the greater part of the drainage basin, also irrespective of the base level of erosion.

Now to the question of a changing base level of erosion corresponding to the glacio-eustatic variations of sea-level described above. Firstly we must give a summary of the Nile terraces as identified by *Sandford & Arkell* in their various publications, particularly 1934, p. 126, along with the associated human industries.

Middle & Lower Pleis	80—98 m	Locally pre-human
	60—76 m	ditto
	45—50 m	ditto
	30 m	Primitive Chellean, Chellean, Chelleo-Acheulian.
	15 m	Developed Acheulian
Upper Pleistocene	8— 9 m	Early Mousterian
	Suballuvial. —3 m in Upper Egypt, —30 m in Lower Egypt.	
	3— 4 m terrace in Upper Egypt	Late Mousterian
	8 m gravels in Middle Egypt Base silts of Upper Egypt	In part contemporary to 3—4 m, but with later forms identical with those at base of Upper Egypt silts
	Aggradation silts in Upper Egypt	Lower Sebilian
	Degradation gravels in Upper and Middle Egypt Suballuvial in Lower Egypt to below —30 m.	Middle and Upper Sebilian
	Accumulation	Post-Palaeolithic.

It is not here intended to minimize the role of glacio-eustatism in the formation of the Nile terraces, and we readily admit the tempting relation of the 3—4, 8—9, 15, 30, 45—50, 60—76 and 80—98 m terraces to the classical sequence of Mediterranean raised beaches. But as we see on closer observation, while the 3—4 m terrace has nothing to do with the Nizza terrace, the upper three terraces are far more often represented by bare rock benches than by alluvial terraces, the 8—9 m terrace is confined to the stretch between Mallawi and Esna, and the 3—4 m terrace is missing in Nubia. The effect of a different base level of erosion is transmitted upstream quite slowly, and before the Nile in Upper Egypt or Nubia had conformed to an eustatic rise or fall of the Mediterranean, the process may have long been interrupted or reversed in the lower course of the river. This contradiction exists even at the present time, where the Nile south of Aswan is continually degrading, while north of Aswan it has been aggrading for possibly as much as 10,000 years (*S. & A.* 1933, p. 52—3, 84—5). The possibility that the equal altimetric terraces in the lower, middle and upper reaches of the Nile as well as in the various wadis are genetically not quite identical is not to be summarily dismissed. In short, we insist that *Stanford & Arkell* have oversimplified a far more complicated picture, so much so that we can only employ their fieldwork with reservations and we feel that it is not possible to accept their conclusions with regard to the local climatic chronology. Similarly we do not hold it possible to reinterpret their results as do *J. Ball* (1939), *Huzayyin* (1941, p. 156—9), *Caton-Thompson* (1946), and arrive at any more satisfactory results in this way. With respect to the latter, *Huzayyin*'s rigid two-pluvial system (c. f. also 1949 a) is, in the long run, just as untenable as the uninterrupted pluviation of *Sandford & Arkell*. The boulders, gravels and sands transported such long distances and deposited in such quantities in the 30 and 15 m terraces of the Nile and the tributary wadis (c. f. *Sandford* 1929) are in themselves indicators of the existence of two distinct pluvials within the Lower and Middle Pleistocene. Lastly the relatively well-rolled wadi gravels of these two stages recall the waterworn pebbles associated with the maximum pluvial episode of *Knetsch* in Libya. There have, according to all indications, been a number of pluvials during the Lower and Middle Pleistocene, only that the evidence is yet too fragmentary, incertain and insufficient for any systematic delineation.

b) The Upper Pleistocene of the Nile Valley.

In our consideration of the Nile Valley we shall arbitrarily regard the Upper Pleistocene as comprising the post8 m terrace stages[8]). Degradation followed upon the 8-9 m terrace stage and the Nile was cut down to its present floodplain in Nubia, to perhaps - 3 m in Upper Egypt *(Sandford* 1934, p. 69, 76-7) and to about - 30 m in Lower Egypt *(S. & A.* 1939, p. 76). In the latter case *Sandford* has applied the work of *R. Fourtau* (1915) and has thereby earned great merit for the possibility of correlating the Nile sequence to the eustatic regressions of the Mediterranean. *Fourtau* has identified (at least) three buried channels of the Nile, testimony of vertical incision to depths well below the present Nile bed, something that can only be understood as a response to marine regressions below modern sea-level. The 'lower buried channel' is filled with sand and gravel in which pebbles of igneous and metamorphic rocks and waterworn feldspar crystals are dominant. These gravels, which have already been tapped at more than —100 m by bores, cannot be older than the Plio-Pleistocene (*S.* & *A.* 1939, p. 75—6) on account of their Eastern Desert or Nubian origin. The next buried channel, known to a depth of —30 m m. s. l. in the Delta, rests unevenly upon the 'lower buried channel' and is filled with hornblende sands and silts of igneous and metamorphic provenance, undoubtedly of Pleistocene age. Lastly, the 'upper buried channel' is filled

8) Miss *G. Caton-Thompson's* valuable reclassification of the Egyptian Levalloisian industries (1946) gives the following designations to the Nile Valley industries (Sandford & Arkell classification in brackets):

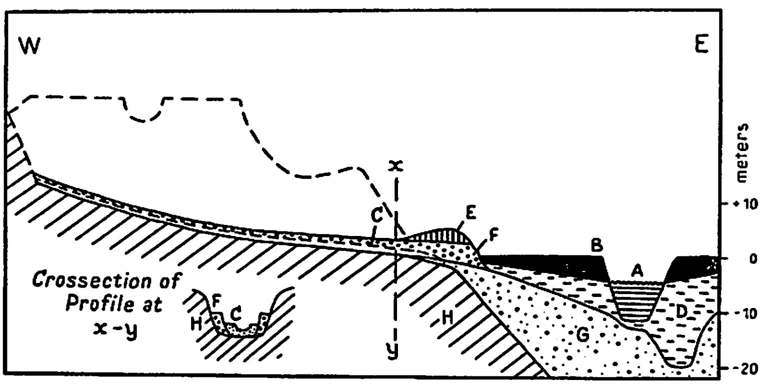
9 m Acheulio-Levallois	(Early Moustier)
3—4 m Late Lower Levallois	(Middle Moustier)
8 m Upper Levallois	(later Middle Moustier)
Silts etc. Epi-Levallois I	(Lower Sebilian)
Epi-Levallois II	(Middle Sebilian)
Epi-Levallois III	(Upper Sebilian)

In Kenya the Acheulio-Levallois industries belong to the later Kanjeran pluvial, while in the Horn of Africa they precede the 12 m (Monastir) shoreline (c. f. *S. Cole* 1954, p. 43, 158—60, 193). For this reason we are simply assuming that the 8—9 m stage, limited to Upper Egypt, probably represents a local moist interval in Middle Pleistocene times.

with sands and silts very rich in Abyssinian mica flakes and hornblende crystals, and is known to a depth of - 30 m in the southern Delta and is probably considerably deeper further north. This 'upper buried channel' has been tapped at 16-21 and 18-20 m below the Nile alluvium at El-Matanah, 16—19 and 13—20 m at Luxor, 6—18 m at Qena, 28—34 m at Balyana, 36,5—39 m at Tahta, 35,5—46 m at Asyut, and 29 m at Abu Ghalib where it is 13 m below present sea-level. This last buried channel will be referred to again shortly, where we shall identify it with the main Würm Regression of —90 to —100 m in the Mediterranean, accompanying the Main Würm.

The degradation phase, suggesting a marine regression of over 30 m, was not of too long duration before a new phase of aggradation set in during which the wadi gravels at first thickened at their Nileward ends, while their upper courses remained unaffected. This process continued till these gravels, containing Late Mousterian implements, conformed to a general level of 3—4 m above modern alluvium from Asyut to Aswan (*Sandford* ibid.). North of El Fashn these aggradation gravels reach 8 m but curiously contain later types of Moustier than appear in the 3—4 m gravels of Upper Egypt, while older forms are missing, so that *Sandford* (1934, p. 124) believes they may exist in the lower part of the gravel below the alluvium. However being so, the 8 m aggradation gravels of Middle Egypt, contrary to *Sandford*'s interpretation, cannot be due to an adjustment to a rise in sea-level, which adjustment was 'far less complete in the south'. The stimulus to aggradation would rather seem to have come downstream and not the reverse. At any rate it is wrong to assign the 8 m gravels to an eustatic sea-level of 8 m as does *Sandford*. During this interval some, and as yet, unclarified tremendous hydrographic or climatic changes appear to have been going on in Abyssinia, for at the very end of the Late Mousterian and during the Lower Sebilian Nubia and Upper Egypt were overwhelmed by vast quantities of silt entering Egypt through the Second Cataract. This thick blanket covered the base of the 3—4 m gravels and made itself felt as far north as Nag Hammadi, reaching a depth of 5.5 m in Luxor and 30 m in Wadi Halfa. In this case *Sandford* (1934, p. 124) is careful to stress that the transport of this superabundant material was due to changes in the far south and not to a change in sea-level. But curiously he states simultaneously that the Late Mousterian found in the silt is identical with that found in the 8 m gravels of Middle Egypt. In other words the 8 m gravels were surely not a reponse to a changing sea-level either. In Nubia the silt has choked almost every wadi, except the largest, at their mouths. This silt is undisturbed, not redeposited and an insignificant watercourse cuts it, so that one may conclude that the amount of water erosion since the Lower Sebilian has been insignificant here (*S. & A.* 1933, p. 40). Of possible value as a climatic criterion of a contemporary local arid climate is given by a 4 ft thick lenticle or dune of false-bedded aeolian sand found intercalated in the Lower Sebilian silts south of Armant (*S. & A.* 1933, p. 47).

The Nile gradient was very steep during Middle Sebilian times, as is indicated by water levels of 22 m at Wadi Halfa, 12 m at Kom Ombo, 6 m at Edfu, —3.5 m at Abu Kurkas, and —5.5 m at El Fashn (*Sandford* 1934, p. 125). Obviously the Nile was undercutting in its lower stretches to conform with a new lowering of sea-level. This renewed degradation affected the whole river in Egypt by Upper Sebilian times, and the 'upper buried channel' of *Fourtau* came into existence, achieving at least —30 m below modern alluvium in the Delta, and judging by the —46 m depth of this buried river bed at Asyut, considerably more[9]). That this period of degradation was of long endurance can be seen that even at Edfu the Nile lowered its bed an unknown amount below the present alluvium, an amount which still exceeded 20 m at Luxor. That this phase corresponded to the maximum Würm Regression is very probable, and it is all the more interesting that there was no pluviation in Nubia at the time. Further north there appears to have been another period of greater rainfall after the 3—4 m stage as the wadis are generally cut down to below this level. Similarly the writer has noted a 1.5 to 2 m gravel terrace within the Wadiyein (opposite Luxor) (Profile 2, Fig. 6—10), which however did not quite extend to the mouth of the 4 m gravels



Profile 2: Idealized profile of the Wadiyein and Nile Valley at Qurna, illustrating Upper Pleistocene deposits.

A = Present Nile at low water
B = Holocene Alluvium
C = 1.5-2 m Wadi gravels
D = 'Upper buried channel' (Upper Sebilian) & Suballuvial, reeroded Nilotic sediments
E = Isolated caps of lower Sebilian silt
F = 4 m Mousterian gravels
G = Lower buried Channel
H = Pliocene bedrock

(based largely upon K. S. Sandford 1934)

9) On theoretical grounds, by plotting the gradients of *Sandford's* terraces, *J. Ball* (1939) has arrived at somewhat different results for the different Nile levels at Beni Suef and the associated Mediterranean sea-levels. However *F. E. Zeuner* (1950, p. 232) has undertaken a rigorous theoretical revision of the Nile terraces and their gradients between El Fashn and Cairo according to the different authors and has been able to confirm the results of *Sandford & Arkell* on this point.

estuary. Apparently the water volume was comparatively much smaller and the load had to be deposited w i t h i n the former wadi bed. This terrace reappears frequently in the wadi, reaching into its uppermost reaches. The 2 m gravels in the lower wadi course, which reach to within 400 m of the 4 m gravels estuary, are composed of relatively water-worn gravels and medium boulders and suggest a post—4 m gravels moist period possibly synchronous with the onset of the Main Würm.

In post-Palaeolithic times the Nile began to aggrade its bed again north of Aswan, and every summer a new load of alluvium is added to the fields, so that the ancient buildings and cities are eventually being buried, especially in the Delta where the rise amounts to some 4 or 4.5 inches per century according to the archaeologists (*S.* & *A.* 1933, p. 53, 1939, p. 96). From this rate of accumulation *Sandford* & *Arkell* suggest that c. 8000 B. C. the Nile was still 10 m below its present-day level. *Huzayyin* (1941, p. 153, 158—9; 1952 a) however points out that the true picture is far more complicated according to the findings of the Ma'adi Excavations Staff since 1939. Abyssinian silt supposedly was found to a level of 20 m above present alluvium at Turah, south of Ma'adi, overlying a bed of small gravel containing mesolithic-type implements. On these grounds, *Huzayyin* suggests aggradation to 20 m in Lower Egypt during late pre- and proto-Neolithic times, followed by degradation to an unknown level and lastly a renewed phase of aggradation in late prehistoric and historic time, which latter process is still going on. The Blue Nile flood-level was 4 m higher than to-day during Mesolithic times in the Sudan (*A. T. Arkell* 1949, p. 109), a point that agrees with *Huzayyin's* suggestion of a greater Nile discharge. Further more we have already seen that the Mediterranean rose to 4 m or even more during the Climatic Optimum (in 'Neolithic times'). Still, however, 20 m does seem incredibly large.

A general aggradation to +20 m so recently as the Neolithic would certainly be visible on a much widescale than fully isolated in one, still unsatisfactorily published prehistoric site. Neither is it geomorphologically seasible that 'renewed climatic or hydrographic changes in Abyssinia' should lead to aggradation only on the Lower Nile, rather in Upper Egypt as was the case in Lower Sebilian times. With relative frequencies of some 24% iron ores, 37% amphiboles, 24% pyroxenes, 9% epidotes etc. among the heavy minerals it would be reasonable to draw attention to the Sebilian silts examined by *Shukri* (1951) from Aswan and Kom Ombo: the composition is identical! It appears conceivable that the Turah silts are redeposited Sebilian material, or belong to the so-calles middle palaeolithic silts of *Sandford* and *Arkell* (1939, p. 54 ff.) that occur widely at similar altitudes in Lower Egypt. *Sandford* (1934, p. 107—08) has also drawn attention to the often secondary nature of neolithic pottery sherds under Nile alluvium.

Lastly a word or two to the faunal assemblages found so far, as presented by *L. Joleaud* (1933). Apart from the derived animal bones in the cemeteries at Qau, *HIPPOPOTAMUS, FELIS LEO, BUBALUS, EQUUS SIVALENSIS* have been found in Sebilian beds at Kom Ombo, while *EQUUS SIVALENSIS, CERVUS sp.* and *BOS SIV.* occur in, as yet, not certainly dated formations at Wadi Halfa. The *HIPPOPOTAMUS AMPHIBIUS, ELEPHAS AFRICANUS, BUBALUS LELWEL* and *ORYCTOLAGUS CUNICULUS* found in the Fayum are probably Neolithic according to *Caton-Thompson* and *Gardner* (1934, p. 84 ff). Scanty as this assemblage is, even more limited are its climatic implications due to the relatively unchanged microclimatic environment provided by the exotic Nile river.

Before attempting to summarize the Nile Valley Upper Pleistocene chronology in tabular form, the evidence of the Fayum and Kharga Oases will be outlined and discussed below.

c) The Fayum pluvial lakes.

The Fayum Depression, achieving some 53 m below sea level, has been subject to more speculation and controversy that the riddle of the Sphinx. However there has been a definite trend in recent years which promises to solve the many geomorphologic problems associated with its Quaternary history. Already *H. J. Beadnell* and *Caton-Thompson & Gardner* (1929 ff.) attributed the origin of the depression to aeolian forces, working partly in the Pleistocene but that the depression already existed at the beginning of the Quaternary although implicitly not in its present form and depth. *Sandford & Arkell* (1929) attribute its excavation to hydrographic forces working within the Pleistocene, but *Huzayyin* (1949 b) and particularly *M. Pfannenstiel* (1953) have seemingly decided the controversy in favour of the aeolian hypothesis, wind excavation working predominantly during the Lower and Middle Pleistocene. During the course of the blowing-out and enlargement of the basin, the watershed between Nile and Fayum was progressively narrowed and lowered, so that by the time of the 15 m (developed Acheulian) Nile level, most probably during the Riss/Würm Interglacial, the watershed was sufficiently low for the Nile to overflow across what has subsequently become the Hawara Canal and formed the first Nile-controlled Upper Pleistocene Fayum lake (*Pfannenstiel* 1953).

The highest Fayum lake at 42—44 m (or rather 40 m with a storm-beach at 42—44 m according to *Caton-Thompson, Gardner & Huzayyin*, 1937) was first identified by the Survey of Egypt (*O. H. Little* 1936). The depression was again subjected to a thorough field survey in 1946 by *Huzayyin* (1949 b) and the 42 m beach is quite definitely the oldest and highest Pleistocene lake level of the Fayum. The complete succession including the lower Palaeolithic beaches according to *Sandford & Arkell* (1929), *Caton-Thompson & Gardner* (1929, 1934) and *Caton-Thompson* (1946) are as follows (Map 2):

40 m	with storm beach at 42—44 m (m. s. l.)	Upper Acheulian ?? (not in situ)
34 m	Late Mousterian	(Upper Levalloisian)
28 m	Lower Sebilian	(Epi Levallois I)
22.5 m	Middle Sebilian	(Epi Levallois II)

Lake completely or almost dried up, Epi-Levallois III

To this sequence one should possibly add the controversial 22—25 m Gisr beach of the western Fayum, identified by *Little* (1936) as Dynastic, which *Shukri* & *Azer* (1952) have finally dated as Upper Pleistocene on account of the mineral content which is quite different from the historic Nile sediments. However the presence of abundant frosted, rounded grains in the formation illustrates the indisputable importance of aeolian agents according to the latter authors.

The purpose of treating the Fayum pluvial lakes is not to arrive at any direct knowledge of the local climate with which these lakes have no connection, but to supplement the observations made in the Nile Valley proper. In order to connect the Fayum lakes with Nile levels and cultural sequence, the following table has been drawn up employing *Caton-Thompson* (1946) for the cultural sequence—merely for the sake of an identical basis of comparison, *Sandford* (1934, p. 92—3) for the Nile and lake levels, the uppermost row being interpolated by the writer. The purpose of the table is to show the feasibility of the gradient Nile-Fayum and the convincing correspondence of the Palaeolithic industries, from which we may conclude the overall acceptability of the correlation.

Nile levels at Beni Suef	Fayum lake levels m.s.l.
50 ft = 142 ft m. s. l.	137 ft (42 m)
25 ft = 117 ft Upper Levalloisian	112 ft (34 m) Upper Levalloisian
9 ft = 101 ft Epi Levalloisian I	92 ft (28 m) Epi Levalloisian I
-18, -15 = 77, 74 Epi Levallois II	74 ft (22.5 m) Epi Levalloisian II

The only factor absent from this scheme is the Mousterian phase of degradation to perhaps c. —30 m in Lower Egypt, which should fall between the 42 m and 34 m lakes. Little enough is known about the highest beach and so far nothing has been found to substantiate the theoretical hypothesis of *J. Ball* (1939) that there were two stands at the 34 m level separated by a drop of lake level to perhaps 10 m. However *Caton-Thompson* (1946) seems inclined to accept the possibility of an Early and a Late Mousterian stand at 34 m, separated from each other by a low-level fluctuation of unagreed extent, provided there was a free connection with the Nile throughout. Similarly the virtual disappearance of the Fayum lake in Upper Sebilian times until its resurrection in post-Palaeolithic times, can be easily explained. Ten bores to the bedrock taken across the Hawara Canal reached a minimum depth of —17 or —18 m m. s. l. (*Little* 1936), so that after the Nile was degraded at the very most to a similar level, as it actually was in Upper Sebilian times, we can expect the Fayum lake to be cut off and left to the mercy of an arid climate, so that it rapidly shrank and aeolian agents were able to attack the exposed lacustrine sediments severely. But on account of the peculiarities of the molluscan fauna and the great precipitations of lime in the shoal waters of the Edwa bank, *Caton-Thompson* & *Gardner* (1934, p. 14) believe the communication was possibly already interrupted when the lake stood somewhere between 18 m and sea-level. *Pfannenstiel* (1953) sets the threshhold level at 20 m, believing that the Hawara Canal was only eroded to its present depth subsequent to this.

Admitting the genial correspondence as originally conceived by *Sandford,* a few words may be said about the local climate in the Fayum Depression. Stratigraphically, the earliest deposits of the Pleistocene Fayum lake were white diatomaceous clays which occupy the floors of nearly all the depressions, ranging in level from —3.5 to +14 m (*Caton-Thompson & Gardner* 1934, p. 13). Even immediately at the shore these clays are pure and wholly unmixed with sands and other coarse detritus, so that *Caton-Thompson & Gardner* conclude that very little runoff can have entered the lake (from the north side) at the time of their deposition. Even *Sandford* (1934, p. 70—2) is forced to admit that these clays point to a lack of running water, something that can not be said about the later deposits in which sands and clays predominate. From this we must assume that the local climate at the time of the 42 m lake was arid, and this is logical in view of its chronological position in the Riss/Würm Interglacial. Unfortunately local evidence for the subsequent stages lacks the same clarity. From a prominent gravel fan of local origin entering the former 34 m lake at Shakluf Bridge (*S. & A.* 1929, p. 42) one could suggest that the Late Moustier period was not at all very dry. Similarly from the explanation to Plate 5 of the same work we note that the downwash-covered plain below the 28 m beach has been very little dissected since the waters of the Lower Sebilian lake retreated from it. Greater local rainfall during the period of formation is suggested by the numerous fan-like gullies of streams running to this level. In contradiction to this, *Caton-Thompson & Gardner* (1934, p. 16—7) remark that the beds of the 22.5 m lake on the north shore suggest an increased rainfall. This means that beyond the overall greater rainfall during the Late Moustier to Middle Sebilian stages nothing specific can be said about local conditions at the time. Lastly a return to arid conditions at the close of the Palaeolithic can be shown with greater certainty. After the Nile connection was severed while the lake stood somewhere under 20 m, the greater part of the waters must have disappeared, otherwise an extraordinarily severe subaerial erosion would not have scoured away so many of the morphological traces of the Upper Pleistocene, in particular the sandrock deposits of the 23 m lake (Fig. 5). That this shrinkage implies a rainfall no greater than that of to-day can be deduced from the protracted halts and impressive beaches of the shrinking Neolithic lake under identical circumstances. Since wind denudation of the Neolithic and Dynastic beach formations of the Fayum has been negligable, it appears that such aeolian deflation was particularly pronounced in Upper Palaeolithic times, as is also indicated by the Tripolitanian loess. Finally, the occurence of such decidedly northern elements as *P.PLANORBIS, LYMNAEA LAGOTIS* and *PISIDIA* among the predominantly Nilotic molluscan fauna of the Upper Pleistocene lake (*C.-T. & G.* 1934, p. 17), does point to more temperate temperature conditions than to-day.

In summary, the Fayum evidence has not only complemented our treatment of the Nile Valley Upper Pleistocene, but has lent considerable support to our conclusions. The Nile apparently stood at 15 m in Lower Egypt during the Riss/Würm Interglacial, and the lack of local run-off during the time of this earliest Nile-fed lake at 40 m suggests that this was a period of interpluvial climate, not very different if not more arid than to-day. After the degradation to —30 m, the Late Mousterian culture bearers witnessed a gradual reversal to aggradation and the wadis which had cut their rock platforms down to conform to a suballuvial Nile now deposited up to 3—4 m of coarse, torrential gravels at their mouths. Great climatic, hydrographic or tectonic activities appear to have occured in Ethiopia a little later, i. e. most probably during the Würm Interstadial, and during the Lower Sebilian Nubia and Upper Egypt were overwhelmed with large quantities of silt which choked the mouths of the Nubian wadis more or less permanently. Aeolian sand intercalated in the silts could indicate local arid conditions which would be suggestive of a Würm intrapluvial. Further downstream aggradation gravels were deposited to 8 m north of Asyut, but this cycle of aggradation was cut short by a rapid lowering of Mediterranean sea-level, particularly during Middle and Upper Sebilian times, so that by the late Upper Palaeolithic the Nile was degrading along its whole length north of the Second Cataract. A certain degree of pluviation can be ascribed to this second Upper Pleistocene phase of degradation, as the Egyptian wadis were able to cut through the Late Mousterian gravels down to about the present Nile level, although particularly the western wadis are quite extinct, as far as morphological agency goes, to-day. A local 2 m gravel terrace built up within the wadi floor of the Wadiyein at Thebes possibly belongs somewhere in the last half of the Würm, but it remains to be seen whether this feature is general. From the Fayum we can conclude that the greater part of the last degradation phase, which we assign to the Main and Late Würm phases, to below —30 m was at least as dry as the present day.

d) The Kharga Scarp, Sinai and the Red Sea Coast.

The eastern boundary of the Kharga Depression against the limestone plateau is formed by a steep scarp descending some 250 m in two major steps. This eastern scarp, although fully uninhabitable to-day, enjoyed a high but quite local rainfall at various times during the Pleistocene, and has attracted the interest of geologists for some eighty years already. However only the investigations of Miss *Caton-Thompson* and Miss *Gardner* (1932) were able to provide the systematic study necessary for any palaeoclimatological evaluation. In the neighbourhood of the Bulaq Pass these two noted workers were able to identify a remarkably detailed succession of physiographic cycles, which we ścetch below according to their 1932 joint-paper and *Caton-Thompson* (1952, p. 3—11).

1—. 'Plateau Tufa'. Aggradation of thick, massive deposits of lime as tufa or travertine, resulting from the evaporation of the floodwaters of torrential rains. No implements, fauna or flora found except reed impressions.

2—. 'Pre-Upper Sheet Gravels'. Great erosion due to increased rainfall led to the formation of deep, broad V-shaped valleys cutting through the plateau edge.

3—. Arid conditions are witnessed by the filling in of the upper reaches of the early wadis by great accumulations of limestone and marl, set in a fine angular matrix showing no signs of water action—breccia formation. No industries in situ.

4—. Upper Acheulian and Acheulio-Levallois Tufas. Runoff was highly lime-charged and tufa was deposited on the breccia filling the old wadis together with gravels and silts washed down by heavy, intermittent rains. The rainfall was sufficient to permit growth of trees and ferns on plateau and scarp as shown by the plant impressions in the tufa.

5—. Intense erosion marked the reexcavation of the breccia and tufa fill of the old stage 2 wadis. During stage 4 and 5 the so-called 'upper sheet gravels', consisting of well-rounded pebbles, were deposited in alluvial fans at the foot of the scarp. Supposedly this was the phase of maximal Upper Pleistocene moisture conditions.

6—. Lower und Upper Levalloisian Tufa. A second phase of gravel, silt and tufa aggradation comparable to stage 4 supposedly represents a decreased rainfall as the waters were unable to carry their load downstream.

7—. Erosion followed during which the previous tufas and gravels were intrenched by steep-sided wadis following quite modern drainage lines during a secondary rainfall maximum. Throughout stages 5,6 and 7 the less rolled 'lower sheet gravels' were deposited.

8—. Levalloiso-Khargan Tufa. A declining rainfall enabled the last phase of gravel, silt and tufa after the pattern of stages 4 and 6. No more sheet gravels were deposited, gravels accumulated only within the wadi courses themselves leading to blockages, ponding and the formation of a cellular tufa.

9—. Upper Palaeolithic Wadi Terraces. Terraces at 9—10, 7—8 and 3—5 m are frequently found cut into the sheet gravels redeposited in the lower wadi reaches. During these last phases, man gradually abandoned the scarp for the more hospitable plateau edge where he favoured the localities around the rainfall accumulation 'pans'.

The climatic evaluation of the periods of tufa formation (*C.-T.* 1952, p. 14—21) ist not too controversial and quite useful. Impressions of *FICUS INGENS*, *F. SILICIFOLIA* and *F. SYCOMORUS* found in the tufas would suggest a rainfall of 500—1000 mm, although these fig trees can exist outside of these limits. Of the aquatic mollusca only one species is typical of the desert, the landshells also favouring damp or marshy spots as well. The most plentiful species of the last was *ZOOTECUS INSULARIS* which is considered to require a minimum annual precipitation of 400—600 mm. Finally comparing the modern distribution of *FICUS*, *CELTIS INTEGRIFOLIA* and *ZOOTECUS* in the Sudan, Miss *Caton-Thompson* believes the periods of wadi tufa formation corresponded to an annual precipitation of at least 500 mm. However this refers only to local conditions on the scarp, and to a smaller degree, perhaps to the plateau regions with moderate relief, but there is no pluvial evidence in the depression proper.

The identification of intense rainfall with erosional phases appears to be quite at odds with the concepts of most geomorphologists, and this has in fact been seriously challenged by *Huzayyin* (1941, p. 91—94) so that we feel it is essential to restate his opinions on this aspect of arid land morphological evolution. Firstly the English co-workers attribute both downcutting (erosion) and deposition (gravel-silt-tufa) by similar agencies of pluviation. Secondly, and this is decisive, there are two distinct types of valley in question here: a) V-shaped, primeval valleys cut into solid rock, and b) steep-sided valleys cut (emboitées) in the gravels and drift choking the primeval valleys. The erosion of the primeval valleys (a) must correspond to a heavy rainfall associated with lateral erosion in order to produce the sloping sides of the valleys, and the detritus was largely deposited as fan-deltas by a good water supply in the lowermost courses of the rivers. Cutting of the emboitées valleys (b) into the gravels and soft materials, on the other hand, suggests less rain and even aridity (intermittant storms leading to irregular torrential activity), and to-day new emboitées valleys are still being cut or deepened in arid regions — as also in the Kharga. In such valleys the small amount of running water was limited to that part of the valley floor which it cut down, while in the primeval valleys the waters apparently spread over a wider bed, with lower velocity and, according to *Huzayyin*, permitting the deposition of gravels within the wadi, slowing down the waters and thus permitting silt and tufa deposition. The latter also agrees well with the concepts of *Bryan* (1941) and *Antevs* (1952) where the increased vegetational cover during moister periods also slows down the drainage, leading to deposition as opposed to gullying during drier periods. All in all we feel inclined to favour the latter point of view, which would ascribe pluvials to the tufa stages 6 and 8, and two subphases of pluviation to the stage 4, The periods of erosion designated by 5 and 7 may not have been much, if at all, moister than the present.

The chronological position of the pluvial-tufa stages is a matter of taste as the interpretation of the morphological data. Miss G. *Caton-Thompson* (1946) regards the Acheulio-Levallois of Kharga typologically equivalent to *Sandford*'s Early Moustier of the 8—9 m terrace, and her Khargan Late Lower Levallois to the Mousterian of the 3—4 m terrace, and following the world chronology, the two tufa stages in Upper Acheulian and Acheulio-Levallois times would not appear particularly absurd as subphases of the Riss Pluvial, the major Lower and Upper Levallois tufa phase in the Early Würm, the minor Levalloiso-Khargan (early Upper Palaeolithic) tufa stage 8 in the Main Würm. This would place the emboitée valley cutting of stages 5 and 7 in the Riss/Würm Interpluvial and Würm Intrapluvial respectively, nothing very extraordinary as no breccia formation is taking place under present arid conditions, only the deepening of the emboitée valleys which is a very slow process. Extrapolating, the breccia stage 3 could imply the great interglacial of the Mindel/Riss, the pluvial stages 1 and 2 the Mindel. The waterworn upper sheet gravels, deeply patinated as they are, are culturally mainly connected with the stage 4 (*Caton-Thompson* 1946, Dia. 1), the lower sheet gravels with Lower and Upper Levalloisian. This recalls the well-worn, rounded gravels mentioned by *Sandford* (1934, p. 70—2, 124) as characterizing the 30 and 15 m terraces, as opposed to the angular, torrential-type gravels of the younger terraces. It also recalls the stage 4 of the Djebel es Soda with similar well-rounded gravels of pre-Würmian age. Lastly it may be recalled that the 'pluvial curve' of *Caton-Thompson* and *Gardner* is not as rigid as one would believe, as can be seen from *Caton-Thompson's* four alternatively suggested correlations (1946, p. 90—2), the most extreme of which would ascribe stage 4 to the Tyrrhenian (Mindel/Riss) and only stage 9 to the Würm!

To round off the regional treatment of the Upper Pleistocene in Egypt, a few words may still be said about the Sinai Peninsula and the Red Sea area. *J. Büdel* (1952) mentions the existence of at least two fossil calcareous crusts in northern Sinai which he would like to correlate to two pluvial periods in the Lower or Middle Pleistocene[9]). In Chapter 3 we already referred to the fine grained, highly calcareous and thin-layered, yellow marly sands reaching up the Wadi Feiran, and intruding immediately below the 5 m marine deposits at the coast (*Büdel* 1952). This fluviatile terrace, which suggests a steppe climate to the latter author, stretches 100 km upstream at relative levels of 2—30 m as it levels the steep rock platform of the present wadi floor. Although *H. Schamp* (1951) among others have preferred to call these deposits lacustrine, the strong similarity with an identical case in the Sus Valley of southern Marocco, would favour the fluviatile hypothesis. In our earlier discussion we suggested that the pluvial implied by these deposits was probably the Würm, and it is unlikely that it is older, otherwise it could not have been so well preserved as it is, considering the general effect of denudation on other Middle and Lower Pleistocene features in Egypt and Libya.

Sandford & *Arkell* (1939, p. 60—68) identified wadi terraces at 22, 18 9, 5, 3 and 2 m in the Suez area and at 28—30, 21, 16, 8—9 and 3—4 m in the Safagah-Kosseir coastal strip. However no attempt to separate local and eustatic factors was made, as *Mensching* did in the Sus Valley, and the terraces have been invariably ascribed to eustatic causes. The only exception to this otherwise valueless detail is the discovery of a few primitive Middle Palaeolithic implements in a 3 m terrace of the Wadi Hamrawain, which at least suggests the possibility of Upper Pleistocene aggradation as there are no unquestioned marine beaches at this level in the vicinity, nor is such an Upper Pleistocene shoreline of any duration known.

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9) *S. A. Huzayyin* (1952a) describes 2 terraces on the Wadi Arish, the younger of which contains finer materials and a Levalloisian industry. The older was probably preceded by a third pluvial phase during which the wadi valley took on its present configuration.

In retrospect the results of the regional investigation for Egypt can be tentatively set up in tabular form below.

Table IV: The Egyptian Chronology.
(based upon *Sandford* 1929, 1934; *Sandford & Arkell* 1929, 1933, 1939; *Caton-Thompson & Gardner* 1929, 1934, 1932; *Caton-Thompson* 1952.)

Egypt Index	The Nile Valley Aswan-Asyut	Asyut-Cairo	Fayum	Kharga	Suggested correlation.
1	Aggradation	Aggradation	historical and Neolithic lakes	9	Holocene
2	Degradation to at least -20 m	Degradation to well below -30 m	Subaerial erosion (arid)		Late Würm
3	Degrading	Degrading	Lake cut off and drying up	8	Main Würm
4	Degrading, wadis still cut down to alluvium.	Degrading to -6 m at Beni Suef.	22-23 m lake (cool, ? moist)		
5	Abys. aggradation silts. Desert sand dune at Armant.	8 m aggradation gravels	28 m lake 34 m lake (cool, moist ?)	7	Interstadial
6	3-4 m wadi gravels			6	Early Würm
7		15 m Nile gravels	42 m lake (arid)	5	Riss/Würm
8	Degradation to below alluvium				
9	8-9 m wadi gravels			4b	Riss II
10	15 m gravels?			4a	Riss I
11		30 m Nile gravels		3	Mindel/Riss
12	30 m gravels?			1&2?	Mindel

4.—The Levant: Palestine and Syria.

The Holy Land has always been the classical land of investigation for Pleistocene geologists in the Near East, and it was the first land in this area to possess anything like a Pleistocene climatic chronology, almost exclusively due to the work of *M. Blanckenhorn* (1896, 1910, 1921), whose basic concepts still hold, in a general way, to the present day. *Blanckenhorn*'s work, cut off by the First World War, was taken up some years later by *L. Picard,* who likewise contributed valuably to the geological exploration of Palestine, while simultaneously, palaeontological and archaeological investigations in many areas contributed to the establishment of a fairly satisfactory amount of individual, although often unintegrated contributions.

a) The Jordan—Dead Sea Valley.

An integration, comparison and evaluation of the Palestinian and Syrian evidence into a coherent and applicable chronology can best be begun by reviewing the geological evidence from the Jordan Valley. Following *Picard* (1932, 1933, 1937) we can outline the stratigraphical sequence as follows.

Interpluvial a. Terra rossa loams lying unconformably upon Pliocene deposits and unconformably covered by Lower Pleistocene gravels suggest a semi-arid Mediterranean-type climate at the beginning of the Pleistocene. Tectonically this was a phase of orogenic uplift and blockrifting.

Pluvial A. Real pluvial gravels of the 'Naharaim' beds overlie the base loams of (a). Boulders and sandy loams alternate in regular layers in the Jordan trough, and coarse, fresh-looking gravels suggest severe, winter rainstorms and rapid torrential streams. At first the streams aggraded at the rim of the rift-valley after a short stream-course, but vertical incision proceeded backwards quite rapidly, and the peneplain was given a very youthful relief due to the great amount of degradation during this longest and most pronounced of the Pleistocene erosive phases. This genuine pluvial phase is equated to the Riss or both Riss and Mindel Glaciations, and presumably was accompanied by further uplifting.

Interpluvial b. The great Pluvial A was succeeded by a phase of pronounced vulcanism associated with extensive areal spreads of basic lavas and the Naharaim gravels are overlain by 30 m of basalt in the Jarmuk Valley and by 20 m of basalt tuffs in Galilee. The great areal spreads of lava in the Hauran and Djolan cut off the waters of the Damascus Plain from flowing into the Jordan Basin any longer, and likewise a basalt bar isolated Lake Hule. Red earth loams were again formed and indicate a return to semi-arid conditions persisting over a long period.

Pluvial B. A renewed phase of degradation and erosion set in upstream leading to an extensive deposition of gravels and sands by the Jordan tributaries, particularly the Samakh gravel beds of the great Jarmuk delta. The materials are surprisingly well water-worn and fine-grained. The strong rainfall, whose intensity can be estimated from the deep incision of the resistant Rukkad lava of the Jarmuk, lead to a revival of the Jordan inland sea, but stagnation gradually set in and fine, suspended clays and marls were precipitated in the form of the Lisan marls during the summer season.

Interpluvial c. An increasingly arid climate caused the Jordan inland sea to shrink in stages leaving widespread terraces behind, of which the Jericho terrace stands out in particular (Fig. 12—13). At the close of the phase only two highly saline, relict lakes—the Dead Sea and Lake Tiberias—were left in the deepest hollows of the rift valley. Terra rossa formation indicates a return to dry, warm conditions.

Pluvial C. At the close of the Pleistocene a last, weak phase of erosion set in in the upper courses of the rivers, leading to the deposition as delta-fans of large, well-rounded limestone and basalt blocks ('upper terrace') by the principal Jordan tributaries in front of the mountain edges and on top of the main Jericho terrace. The water of the Hule Basin broke through the intervening basalt bar and entered Lake Tiberias which subsequently freshened and found an outlet in the Jordan River. During the subsequent return to semi-arid conditions the rivers cut into the Lisan layers and led to the isolation of the 'upper terrace'.

Blanckenhorn (1931, 1939) places the Lisan stage into the Middle Pleistocene and correlates it to his 'Great (Riss) Pluvial', assigning to this stage the finds of *TICHORINUS ANTIQUITATIS,* the woolly Liberian rhinoceros, *ELEPHAS TROGONTHERII* and *BISON PRISCUS,* the European forest bison. However *Picard* (1937) points out that the *E. TROGONTHERII* found near Lake Hule can be stratigraphically connected with the Pluvial A, and not the Pluvial B. This extinct proboscidian is also a characteristic element of the Lower and Middle Pleistocene fauna. The *T. ANTIQUITATIS* (which is doubted by *Bate* and *Picard*) was indentified by *Zumoffen* (c. f. *Blanckenhorn*) near the Nahr Beirut, was connected with a Lower Mousterian industry and also fits better into an Upper Pleistocene faunal association, being most frequent in the European Würm but only rare during the Riss. In short there are no objections possible on faunal grounds to a correlation of Pluvial A to Riss or Riss and Mindel, Pluvial B (and C) to Würm, as *Picard* (1932) also preferred to do, despite his somewhat provincial usage of the terms 'Lower', 'Middle' and 'Upper' Pleistocene.

It appears that *Picard* inclines to minimize the intensity of Pluvial B as compared to A. This is not at all so obvious, although Pluvial A was of *incomparably longer duration.* In his 1937 article, *Picard* begins the deposition of the Lisan marls during the Pluvial A, something which appears acceptable on the grounds that there is no reason why the Pluvial A should not have favoured the existence of a Jordan inland sea as well. Possibly he does this on grounds of the sandy and gypsum-bearing marls with little gravel found at the Jarmuk mouth directly overlying the Naharaim gravels and underlying the normal coarse clastic deposits of the Lower Lisan facies (*Picard* 1932). However the resurrection of the Jordan Sea to its maximum extent during Pluvial B, despite the apparent loss of the Damascus Plain and Hule Basin drainage before this time, demands a fairly considerable increase in precipitation At this time the sea had a volume 5 times that of the modern Dead Sea, and a length of 300 km compared to 70 km to-day (*G. S. Blake* 1930), reaching from the Tiberias Sea to far inside the Wadi al-Araba, and standing at approximately some 200 m above the present level (*Blanckenhorn* 1931). However *Picard* (1932) does not agree on the identical age of deposits at 195 m of the Dead Sea on its south shore and at 230—244 m at Jericho, something that would require an impossible amount of tilting during the tectonically quiet phase since the Interpluvial b. In short, we believe that Pluvial B differed only from the preceding pluvial in duration and not so much in intensity. The long duration of the latter which must follow from the above suggests that a renewed investigation may possibly find field proof of the inclusion of two separate pluvials under the heading of Pluvial A, something that can already be suspected from two stages implicit in *Picard's* discussion: an earlier aggradation at the rim of the rift from short, inconsequential streams, and a second stage of rapid, regressive erosion upstream of V-shaped, primeval valleys.

G. S. Blake (1928, p. 24—5; 1930, p. 7) has analyzed the sediments of the old Jordan lake more closely. Although the lake at its maximum extent was considerably less saline than to-day, soon after it began to shrink it was already so strongly charged with salts that the enormous summer evaporation over its vast expansion caused the precipitation of gypsum and calcium carbonate, which was followed by silts carried down by the streams during winter (Fig. 15). As a result some 50,000 alternating annual layers of some 2.5 mm thickness were deposited to a depth of some 120 m or more, giving an approximate date for the duration of the desiccation period. Below this lie another 30,000 alternating bands of blue clays which may extend the sequence even further back into the Pleistocene. However we fail to see why and how these seasonally-banded Lisan sediments should be associable with the Jordan lake terraces of the (interpluvial c) retreat stages, as *Blake* seems to imply. Of the latter, *Blake* recognizes three steps at the northwestern end of the Dead Sea, consisting of a gentle slope from 200 m (2 : 140 m, 3 : 75 m) to 170 m (2 : 120 m, 3 : 45 m) with steep slope to 140 m (2 : 75 m, 3 : sea-level) above the Dead Sea. He does not specify whether these terraces are constructional or abrasional, yet in neither case can we correlate these deposits to a particular beach: if the gentle slope is regarded as a constructional beach, no marls would have been able to precipitate on it; if the steep slope is regarded as an abrasional feature (and the gentle slope as a submarine shelf), a great part of the sediment series will have been destroyed by wave-erosion and the sequence would be inapplicable anyway. The present writer examined this same area in March 1956 and, unimformed of the almost inacessible work of *Blake,* likewise noted the similarity of the seasonal banding to varves. However the distinct abrasional character of the fresh, erosional shorelines up to 50 m (Fig. 16) precluded the possibility of any connection between the varve-like bands and the age of the terraces cut into them. The only direct application would be to the relative fluctuations of the annual silt-and-marl-complex layers on the basis of an absolute scale, without however being able to fix either the upper or lower end with a known event or date, unless perchance something susceptible to isotopic dating could be found in the series. As such the 50,000 (or 80,000) years assigned to the 'desiccation period' of the Jordan Sea are no hindrance to a correlation of Pluvial B to the Würm, on the grounds that the 100—120 m thick deposits in the lowest part of the Ghor need not be continuous deposits but can represent the 'desiccation' of a Riss as well as a Würm Pluvial lake, just as *Picard* (1937) seems to imply.

The Jordan Valley evidence then, to sum up, gives the possibility of assigning the Pluvial A to Riss or to both Riss and Mindel, considering the lack of detail. The Pluvial B would correspond to the Early Würm during which phase the Jordan Sea achieved some 200 m, falling rapidly during the dry intrapluvial phase 'c'. During the Main Würm, the renewed phase of aggradation known as Pluvial C took place, at a time when the Dead Sea may possibly have stood some 80—100 m above the present. This is suggested on the grounds that *R. Köppel* (1932 a) recognizes Dead Sea shorelines at 40, 80—100, 120—130 and 200 m above the present in the Tell el Ghassul quadrant, of which the second and last alone show impressive delta fans of large conglomeratic blocks. The 200 m shoreline is obviously the Jericho terrace corresponding to the late Early Würm phase, while the renewed aggradation at the 80—100 m level is suggestive of the Pluvial C. However it must be pointed out that whereas there are no objections possible to the correlation suggested above at present, there would also be no objections whatever possible to the alternative correlation Pluvial A = Mindel, Pluvial B = Riss and Pluvial C = Würm. The chronology as such can be shifted within this range, and although we prefer the first alternative on the grounds that C would appear too weak a pluvial to correspond to the whole Würm, the possibility of the second correlation cannot be excluded.

Towards the close of the Upper Pleistocene a quite arid climate seems to have prevailed in this area. The Jordan and its tributaries cut deeply into the Pleistocene sediments, leading to the isolation of the 'upper terrace' deposits of Pluvial C. The vertical incision proceeded well below the present alluvial plain by at least 9 m (*Picard* 1929) and after the subsequent aggradation of the 'lower terrace' or modern floodplain, degradation has only been able to excavate a shallow channel since Neolithic times (Fig. 14). In Lake Tiberias, *R. Köppel* (1932 b) found innumerable silex implements at 1—2 m below the present level, often at a distance of 20—30 m at sea, which implied a submerged strandline of —2 m or lower. On typological grounds he suggests a Mesolithic date for this lower level. Lastly *M. Avnimelech* (1937) identifies a warmer and drier climate of similar date on the basis of the occurence of miniature varieties of the mollusca *LEVANTINA CAESAREANA* and *L. HIEROSOLYMA* in two Palestinian grottos.

b) The coastal strip: Palestine and Lebanon.

The coastal strip of Palestine and Lebanon has already been considered in Chap. 3 and it will only be necessary to restate the conclusions arrived at there. It was firstly noted that there was a great pluvial phase associated with the great marine regression on the Palestinian coast which with good probability corresponds to the Riss. The tremendous amount of gravels also recalls the Pluvial A of the Jordan Valley. Next, the existence of a post-Monastir pluvial phase connected with an evolved Levalloiso-Mousterian industry on the Lebanese littoral was shown, and unequivocally associated with the Early Würm. *M. Avnimelech* (1936, p. 102—11) and *Picard* (1928) describe two fluviatile wadi terraces reoccurring repeatedly in the Judaean foothills and the Vale of Jezreel, but although artifacts were found in situ they were always corroded beyond recognition.

The last particular site remaining to be considered in this section is that of Ksar Akil, some 6 km east of Beirut, standing under a 50 m cliff near the Wadi Antelias. The site and neighbouring areas have been closely examined by *H. E. Wright* (1951). 6 m of alluvial gravel, sand and clay, with Upper Levalloiso-Mousterian artifacts, bones and stones fallen from the cliff rest upon the bedrock, which shows potholes and fluting due to stream erosion. The continual accumulation of cultural deposits during the Aurignacian up to 75 m, excluded the stream from the site and 4 m of further alluvium were deposited on the opposite side of the valley. Subsequently the tiny stream has begun dissecting again, and the vertical erosion in the alluvium has amounted to some 7 m. In the neighbourhood there are extensive areas of rock debris due to landslides occuring before and during the early stages of alluviation. These landslides have since been dissected by gullies and modified by a thin surface crust. *Wright* interprets the original dissection of the wadi to the rock floor by a more arid climate, obviously Riss/Würm according to the cultural implements. The landslides (due to lubrication of shale and weak limestone by water) and alluviation are suggestive of a somewhat moister climate during the Würm[10]), and the subsequent dissection and formation of a thin crust are the product of a drier climate in post-pluvial times. Furthermore there are thick surface crusts on older deposits, stream alluvium and older landslides in the area, which deposits *Wright* assigns to a pluvial, probably the Riss, and the crust to a longer interpluvial phase.

c) The cave deposits and faunal assemblage.

The oldest faunal assemblage known is that of the bone beds at Bethlehem (*Gardner & Bate* 1937) which contained *HIPPARION, ELEPHAS, STEGODON, HIPPOPOTAMUS, R. ETRUSCUS, BOS. sp.*, etc., principally Asiatic in origin. They are considered to indicate a warmer and moister climate in the Upper Pliocene or early Lower Pleistocene. No unequivocal human implements were found associated with them (*D. A. E. Garrod* 1937).

Apart from the faunal assemblages of the four Syrian Palaeolithic caves to be discussed in detail below, we can summarize the occurence of the more important faunal elements found elsewhere. We have already referred to *E. TROGONTHERII,* of no particular climatic significance here occuring in Pluvial A deposits at Lake Hule. Similarly the *T. ANTI-*

10) *v. Wissmann* (1956) has suggested that the alluviation of Ksar Akil was probably merely due to periglacial waste and debris transported down the slopes of Mt. Lebanon. However since frost pattern soils only occur above 1900 m, we can be certain that the maximum depression of the lower limit of cryoturbation during the Würm never went below 1000 m so that the highest parts of the Wadi Antelias drainage basin remained below that limit. In fact only a few areas of the Lebanon were above the Würm treeline, as even the Cedars 'moraine' at 2000 m contains numerous tree imprints of Würm age (c. f. Chap. 4).

QUITATIS of the Nahr Beirut and the more questionable find at Ras el Kelb belong to the Pluvial B and the Mousterian—strongly suggestive of more temperate conditions than are prevalent at present. Similarly the seven finds of *BISON PRISCUS*, an animal preferring a temperate forest habitat suggests a somewhat cooler climate. The brown bear, *URSUS ARCTOS* is found in Mousterian and Aurignacian horizons corresponding to the Würm at Ksar Akil, Erq el Ahmar and Mugharet el-Zuttiyah and also suggests a temperate climate according to *R. Neuville* (1934), otherwise we can hardly account for its local disappearance during the early Holocene while the warmth-loving Syrian bear has been endemic since Lower Acheulian times at least. Lastly, the non-migrant, cold-loving alpine birds such as *MONTIFRINGILLA NIVALIS, OCTOCORIS PENICILLATA* and *PYRRHOCORAX ALPINUS* still found in the higher Lebanon to-day must have advanced southwards during a Pleistocene cold phase (c. f. *Huzayyin* 1941, p. 95).

As noted in Chapter 1, there is little possibility for a palaeobotanical reconstruction of the Pleistocene flora of the Near East. One of the very few exceptions to the general rule of no palaeobotanical evidence is once again provided by tufas, just as was seen in the Kharga. *F. Fraas* (c. f. *Blanckenhorn* 1921) recognized plant imprints of *QUERCUS, FAGUS, ULMUS* and *CORYLUS* in the tufa fragments associated with the so-called Cedars 'moraine' in the Lebanon. *Picard* (1937) remarks that this is nothing special as each of these species still occur somewhere in isolated spots of Syria to-day. The fact remains, that as only imprints of these now locally very rare, temperate species were found, and none at all of the now predominant Mediterranean genera, leaves little doubt that these species must have been very much more important and bountiful, and as such are an indication of a somewhat more temperate climate. The chief phase of travertine development in Syria seems universally attributed to the Upper Pleistocene (*Blanckenhorn* 1939, *Picard* 1932) and one can fairly safely assign this more temperate climate to the Würm.

After this brief discussion of the fossil faunal, and as far as that goes, floral assemblages, the remainder of this section shall be devoted to the highly profitable cave stratigraphy of four outstanding profiles that shall be treated in order of age. Reaching farthest back into the Pleistocene is the Umm Qatafa cave some 15 km southeast of Jerusalem on the Wadi Khareitun. *R. Neuville* (1931, 1934, 1951) has given a good analysis of the geological profile which is summarized here.

A_1. Black earth with occasional pebbles and charged with animal matter. Recent. 45 cm.

A_2. Powdery black earth charged with humus in lower parts. Bronze Age. 37 cm.

B. Calcereous loam with numerous small, quite angular limestone blocks due to thermoclastic weathering of the roof at a temperature lower than to-day. Innumerable rodent bones. Sterile. 40 cm.

C. Dark brown loam charged with small rock fragments at edge of walls where it replaces B locally. Great number of rodent bones. Archaeologically sterile. 30 cm.

D_1. Light brown, very fine clay charged with small pebbles and forming a breccia along the walls where it replaces C locally. Contains brown phosphatic concretions and a Micoque industry. 1 m.

D_2. Light brown, marly soil. Upper Acheulian.

E_1. Compact clayey earth alternating with thick stalagmitic horizons. *RHINO. MERCKII* and a temperate fauna. Abundant Middle Acheulian hand axe industry. 1 m.

E_2. Large angular, fallen blocks cemented by stalagmites. Temperate fauna. Middle Acheulian. 3 m.

E_3. Clayey soil with some stalagmites. Abundant Tayacain. 1 cm.

F. Dark brown loam derived from terra rossa. Tayacian.

G. Siliceous, tufaceous soil. Tayacian. 2.1 m.

H. Brown breccia. Sterile. 2.5 m.

I. Brown-grey tufaceous soil. Quite porous. Sterile. 30 cm.

J. Marly limestone, finely stratified. Light grey. Sterile. 75 cm.

K. Bedrock.

The powdery black earth of the A_2 horizon suggests conditions more arid than today during the Bronze Age. Horizons B and C strongly recall the Haua Fteah sequence of Cyrenaica, and we can ascribe them to Main and Early Würm respectively in view of the chronological position of the lower horizons. Again we meet a cold, dry glacial maximum ushered in by a moister interval. The light-coloured materials of the D horizons show no pluvial characteristics, and with their Micoque and Upper Acheulian industry suggest the Last Interpluvial. The E horizons with their abundance of stalagmites indicate a major pluvial phase, and the E_2 horizon possibly thermoclastic weathering as well. This is the temperate and very moist Riss, judging by the industries. A subdivision into two subphases appears possible, the first being colder than the second. E_3 is probably a transition from the great interpluvial to the Riss. The F horizon is derived from terra rossa and suggests a mediterranean type climate (moist as *Neuville* suggests). The Tayacian level G appears drier as well. The lowest layers are sterile. The breccia of H seems to hint at a moister phase, the light porous soil of I a drier one.

The stratigraphy of the last glacial phase, the Würm, is shown more satisfactorily in the Djebel Kafzeh Grotto of Judaea. *Neuville* (1951, p. 179—80, 258) draws up the following sequence with climatic evaluations:

A. Middle Age deposits.

B. Red-brown calcareous soil with abundant pebbles. Bronze Age I—III. 10—100 cm. Warming up.

C. Red-brown calc. soil with abundant rock fragments, large blocks at surface. Upper Palaeolithic. 1.5—2.0 m. Cold.

D. Red-brown calc. soil with blocks and very abundant small limestone fragments. Abundant fauna. Upper Palaeolithic II. 60—85 cm. Maximum of cold.

E. Fine, dark-brown calcareous soil without rock fragments. Upper Palaeolithic I. 75 cm. Dry and temperate.

F. Thin red-brown clay layer. 10 cm. Mousterian. Temperate, moist.

G. Brown clay with little rubble. *RHINO. MERCKII.* Upper Levalloisian. 1.1 m. Moist and temperate.

H. Same. Abundant fauna. Upper Levalloisian. 40—90 cm. Warming up.

I. Light brown clay with large blocks. Abundant fauna. Middle Levalloisian. 25—60 cm. Moist and becoming warmer.

J. Light brown clay with very abundant rock fragments and blocks. Lower Levalloisian. 0.3—1.0 m. Maximum moisture and cold.

K. Brown clay with few limestone pebbles, increasing towards top of horizon. *R. MERKII.* Lower Levalloisian. 40 cm. Moist and becoming cooler.

L. Loose dark-brown clay with small fragments, and stalagmites at base. Abundant fauna. Lower Levalloisian. 50—80 cm. Moist and becoming coller.

M. Light brown travertine. Sterile. 70 cm. Dry and temperate.

R. Neuville divided the deposits into an oceanic phase M—F and a continental interval represented in levels E to B. More precisely, we suggest M appears to be the Riss/Würm while L and K are transitional periods. Levels J to F would qualify well for Early Würm, E for the Interstadial and horizons C to D for the Main Würm. The stratigraphy of the Djebel Kafzeh grotto is one of the most brilliantly examined, and also the most instructive of all the Near Eastern cave deposits published so far.

The Jabrud Cave, situated at 1400 m elevation in Syria, has been excavated by *A. Rust* (1950) yielding a stratigraphic sequence including the whole Upper Pleistocene in good detail. According to Rust (c. f. p. 138—40) the deposits can be summed up as follows.

A. 0 to −2 m (Acheulio-Mousterian) (Würm). Fine grey, loose calcareous debris with breccia remnants divided into two horizons (A_1 and A_2) by an intervening breccia-free layer. Pluvial conditions possibly interrupted by a drier snap.

B. −2 to −5 m (Acheulian) (Transition R/W to Würm). Hard breccia layers alternating with loose calcareous materials or thin layers of loose, black crumbling material (possibly humus). Large fallen blocks from the ceiling occur throughout the level. Indicates a predominantly quite moist period, representing transition to the Last Pluvial.

C. −5 to −9 m (Acheulio-Jabrudian) (Riss/Würm). No traces of breccia and very loose, almost fine gravelly layers suggest a dry climate with strong diurnal variations of temperature. At −7.5 m a layer of reddish, aeolian desert sand probably represents the climax of a genuine interpluvial.

D. −9 to −11 m (Acheulia-Jabrudian) (Early Riss/Würm). Loose, relatively coarse calcareous gravel becoming increasingly fine towards the bottom. At −10.5 m a bed of waterworn pebbles was deposited by running water, which suggests moderately moist conditions at the transition from the Riss to the Last Interpluvial.

Contrary to breccia formation in open air, the cementing of the fine materials of cave detritus into a matrix of angular materials requires considerable moisture in an interior location, and we can follow *Rust's* suggestion that the breccia-free layer at -1 m may possibly represent a drier period. Similarly the increasing amount of uncemented and loose calcareous material of B and eventually the typically arid deposits of horizon C represent an increasingly drier climate. Further, although the cave was well inhabited during the deposition of A, B and D, there are very few traces of human habitation in the C horizon, which fairly certainly represents the Riss/Würm Interpluvial par excellence. The surprisingly moist conditions exhibited during the transitions to the interpluvial are not so astounding if we bear in mind that the Jabrud Cave still enjoys a fairly pronounced seasonal Mediterranean rainfall to-day. Only one thing is a little puzzling: the large fallen blocks of the B level appear to have been dissolved by seepage water and the overall character of the layer suggests a climate, admittedly subject to great variations, often much moister than the A horizon, so much so that we believe it may be synchronous with the initial stalagmitic layer ushering in the Early Würm in many Near Eastern and almost generally in the Italian and Riviera caves and grottos.

Further south the Wady el-Mughara excavations of Miss *Garrod* and Miss *D. M. A. Bate* (1937) at Mt. Carmel have long attracted widespread attention and their results have led to far-reaching speculations on the Upper Pleistocene climatic sequence so that the chronological position of the cultural phases has been often violently shifted, without any adequate reasons, merely to fit a very doubtful rainfall curve. For *Bate* has constructed what has been interpreted as a climatic curve according to the relative frequency of fallow deer (*DAMA MESOPOTAMICA*) and gazelle, the first supposedly indicative of moist conditions, the latter of steppe conditions. According to this, *DAMA* reached a maximum during early Micoquian and Upper Levalloiso-Mousterian times, a submaximum in Middle Aurignacian times, and minima during Lower Levalloiso-Mousterian, Lower Aurignacian and post-Upper Palaeolithic times. Already *Picard* (1937) had serious misgivings about such a curve, emphasizing the role of chance played in the hunting booty uncovered in only two caves (Tabun and Wad). *Rust* (1950) likewise inclines to disclaim the climatic implication of such hunting booty, emphasizing that the various peoples and cultural groups succeeding one another would possibly have quite different tastes and hunting methods, giving a striking example from Jabrud. Further, *Stekelis* & *Haas* (1952) have also emphasized that the true picture of relative frequency of *DAMA* or *GAZELLA* may have been blurred by a deliberate choice on the part of the hunters.

A second salient point, also somewhat overemphasized, is that of the warm, moist tropical fauna supposedly suggesting such a climate in the Tabun layers F to C, Upper Acheul to Lower Levallois-Moustier. On typological grounds, *Rust* (1950, p. 140) equates the Tabun F with the Jabrud C horizon, and its outspokenly arid climate, insisting that an elevated continental site like Jabrud should be a better recorder of climatic conditions than a location next to the sea. More decisive is that the few isolated finds of *HIPPOPOTAMUS, CROCODILUS, R. HEMITOECHUS* and *TRIONYX* sp., a large water tortoise, can be easily accounted for by a more favourable microclimate: local swampy coastal lagoons or springs at the foot of the mountains. The Hippo endured until 1500 B. C. at Ras Shamra in Lebanon and into the 17th century A. D. in the Nile Delta, while the crocodile still is to be found in the swamps at Kabra, and as such the extinction of these species seems to be more the result of human agency than climatic variation.

Nevertheless a few profitable points can be drawn from the faunal assemblage at Mt. Carmel. Firstly the faunal break (*Garrod & Bate* 1937, p. 149—55) at Wad G and Tabun B witnessed above the Upper Levalloiso-Moustier horizon could be accounted for by the onset of the cool, continental climate of the Main Würm as opposed to the more temperate (e. g. Haua Fteah), moister climate of Early Würm, as do the majority of authors working on the Mediterranean Palaeolithic (e. g. *R. Vaufrey* 1939; *Neuville & Ruhlmann* 1941, p. 137). Secondly the appearance of such forest species as wolf, badger, hare and marten with the Lower Aurignacian does in fact suggest more temperate conditions. However the overall value of the faunal evidence has proved to be rather disappointing, and its applicability limited to a supplementary role to the stratigraphical sequence. However Miss *Garrod* (1937, p. 122—3) does draw attention to some stratigraphic evidence of a pluvial maximum during the Upper Levalloiso-Mousterian and Lower Aurignacian stages. During the former period the limestone roof of the Tabun cave collapsed probably due to increased rainfall working on an already existing hole; and a period of severe erosion, due to rainwater entering through holes in the vault, followed in Upper Palaeolithic times upon the deposition and hardening of the late Middle Palaeolithic breccia. However the great number of limestone blocks and boulders fallen from the roof may also have been connected with thermoclastic weathering.

The last series of cave deposits of value as climatic criteria are provided by the grotto at Ksar Akil described by *J. F. Ewing* (1947, 1951) Here a number of interesting stratigraphic horizons reoccur repeatedly in the Würm levels of the cave. The first consists of a layer of tightly packed or cemented, small, flat, angular limestone pebbles derived from the roof and walls, whose deposition requires greater humidity and temperature changes (more frequent and prolonged frosts). Secondly red clay layers, the product of decalcification in situ, also testify to a very humid climate. At —15 m two such stone beds were found to be separated by a layer of red clay, and resting upon an irregular band of the same material, achieving a depth of 2 m. This level was associated with an Upper Levalloiso-Mousterian industry and a faunal break as well, a parallel to the contemporary level at Mt. Carmel. At —10 m a very distinct complex of stone layer resting upon red clay (75 cm) was found again, and at —1.5 m a well-defined stone bed (50—75 cm) without a red clay layer beneath it. *Ewing* considers the —15 m level as representing Würm I, and it does indeed suggest Early Würm, while the —10 m level with its Upper Palaeolithic industry is correlated to Würm II, our Main Würm. However the —1.5 m level (Final Palaeolithic) is too close to the surface to be anything but the last glacial relapse of the Upper Dryas already noted at Hagfet Et Tera. All in all Ksar Akil provides a valuable link in the Upper Pleistocene of the Near East, clearly designating as it does the two, cooler, moist phases of the Würm Pluvial-Glacial phase.

In retrospect the stratigraphical profiles of the Syrian caves appear to present some of the best evidence upon which to build up an Upper Pleistocene chronology. Table V below attempts to visualize, compare and correlate a few of the more complete successions outlined above.

Table V: The Syrian Chronology.
(after *Picard* 1932, 1937; *Neuville* 1931, 1951; *Rust* 1950; *Wright* 1951; *Ewing* 1947, 1951, and others.)

Syrian Index	Jordan Valley	Umm Qatafa	Djebel Kafzeh	Jabrud	Ksar Akil	Suggested Coorelations
1	Recent	A_1	A	—	Vertical erosion	Subatlantic
2	Renewed erosion	A_2	B?	—	Vertical erosion	Subboreal
3	Lower terrace	—	—	—	(Last stony layer -1.5 m)	Atlantic to Upper Dryas
4	Erosion to -9 m	—	C	—	Indifferent	Late Würm
5	Pluvial C. Upper terr.	B	D	A_1	Alluviation of 4 m; (stone layer-red clay complex at -10 m)	Main Würm
6	Interpluvial c.	—	E	A_1/A_2	Indifferent	Interstadial
7	Pluvial B	C	J-F	A_2	Alluviation to 6 m; (stone-red clay complex at -15 m)	Early Würm
8	Pluvial B	—	L, K	B		
9	Interpluvial b	$D_{1,2}$	M	C	Vertical erosion; crustal formation	Riss/Würm
10				D		
11	Pluvial A	E_1			Older alluvation and landslips	Riss
12	Pluvial A	E_2				
13	Pluvial A	E_3				
14	?	F, G?			Older crusts	Riss/Mindel
15	Pluvial A	H?				Mindel

In the Middle Orontos, *C. Voute* (1955) has been able to show the existence of at least one pluvial phase. The present Orontes is cutting a bed into alluvial deposits filling an old valley excavated to at least 10 m below the present bed. The newer vertical incision of perhaps 20 m has proceeded in at least 3 cycles judging by terraces in the old alluvial fill. The cutting of the Orontes Valley took place in at least two major stages, separated by a period of accumulation. The older valley is four times as broad as the present one, and can only be accounted for by a much greater discharge.

Most recently, *F. E. Zeuner* (1956 a) has drawn up the geomorphological evolution of the Jafr Depression in Jordan:

1. Sandy gravels of the reg desert platform (moist) Abbeville
2. Sandy desert pavement of the reg platform (arid) —

3.	Unconformity	Clacton
4.	Erosion to 10 m Castle Terrace (moist)	—
5.	Settlement of lake shore, dune sands (drier?)	Upper Palaeo. VI
6.	Erosion to 5 m Police Post Terrace (moist)	—
7.	(Climate drier)	—
8.	Erosion of depression to present level (moist)	—
9.	(Climate drier)	Mesolithic and Neolithic.

This sequence proves to be of considerable interest, and it is hoped that a more detailed account will be forthcoming oon. At present it seems that the stages 4 and 6 represent phases of the Würm Pluvial, while the stage 8 may be contemporary to the brief moist interval during the Upper Dryas.

Before closing this regional study of the Levantine Pleistocene, a word may be said about the Quaternary geology of northern and eastern Arabia, an area which is almost terra incognita archaeologically. Frequent references have been made to the great fossil drainage sytem running west to east across the breadth of the peninsula, particularly the Wadis Hauran, Batin, Rumma and Dawasir along which large igneous and metamorphic cobbles were transported many hundreds of kilometers across the breadth of the peninsula. *P. B. Cornwall* (1946) refers to the fossil dunes of the Hasa which he assigns to an arid period probably corresponding to the Last Interglacial. The dunes are oriented northwest-southeast and *Cornwall* believes the prevalent wind direction at the time of formation was somewhat different than the NNW winds of to-day, although it is not clear from the context whether longitudinal or transverse dunes are in question. Beyond these few indications, however, little else is known about this key area.

5. *The Anatolian Interior.*

Strictly speaking no Pleistocene chronology has ever been worked out for the semiarid interior of Anatolia, although a fair amount of reliable but undated material on raised beaches of the various non-outlet lakes has accumulated during the last twenty years or so. Perhaps the greatest stumbling block, besides the diversion of interests to glacial forms, has been the almost painful scantiness of Palaeolithic finds in this vast region. The Pleistocene glacial morphology and periglacial features of the Anatolian highlands have already been treated in Chapter 4 and we shall reserve our attention to the pluvials and their imprint in this section.

The only systematic attempt to establish a succession of fluviatile terraces and correlate them with the European chronology has been that of *M. Pfannenstiel* (1940) in the Ankara Ova (Valley). *Pfannenstiel* indentifies four terraces at 20—23, 65, 80 and 100—110 m above the present river sole, composed of coarse, angular and relatively little rolled gravels, which apparently have been little transported by water[11]). *Pfannenstiel* believes this

11) At the INQUA Congress, Madrid 1957, Dr. *v. d. Brelie* informed the writer of 2 river terraces of of well-rolled rocks on the middle Sakaria.

feature is due to frost weathering and greatly increased mechanical weathering during the glacial-pluvial periods. However we must bear in mind that the drainage basin of the Cubuk scarcely shows any elevations of above 1500 m, so that employing the results of Chapter 4, very little of the basin actually lay within the periglacial zone, and was thereby not subjected to the subnival cycle of erosion as described by *C. Troll* (1948). Neither has anyone yet described fossil or active soil or rock creep in the Ankara Ova, so that it is misleading to implicitly refer to fluvioglacial or periglacial type gravel terraces in the area. Of course no one can deny that the increased continentality of the climate could have favoured accelerated mechanical weathering, but one must bear in mind that particularly during these pluvial phases the climate was considerably moister, to which effect evidence will be presented below, and will have produced a more complete mat of vegetation and even decreased the amount of arid-zone mechanical weathering. The terraces of the Ankara Ova are asymmetrical, only two terraces occur in the Etimessut Ova, and they are lacking entirely in the Cubuk Ova. *Pfannenstiel* ascribes this to a south-north tilting between the formation of the 65 and 85 m terraces, by which the terraces on the northern flanks were more or less completely removed by subsequent dissection and erosion. The established erosional gullies would have continued to operate after the cessation of the tilting, tending to the complete or partial removal of the two lowest terraces as well. According to *Pfannenstiel* the terraces are due to climatic causes, and bear no relation to tectonic (and implicitly eustatic) factors: the excess of detritus due to increased mechanical weathering during the pluvial-glacials caused the streams to be overloaded and aggrade, while during the interpluvials the load was decreased and erosion took place. We have given reason above for doubting the validity of this mechanism here, and we would draw attention to the concepts of *H. L. Richardson* (1945) who believes that a greatly increased rainfall, particularly of the irregular torrential type, leads to increased erosion of the type associated with landslips and periodically flooded streams and rivers in semiared regions. This process leads to the relatively quick deposition of relatively little rolled materials downstream, due to the sheer overloading of the stream. Such an explanation also renders the absence of any terraces upstream in the Cubuk Ova more acceptable than *Pfannenstiel's* hypothesis, by which the amount of detritus should be increasingly abundant upstream and in the higher source regions. In short, we believe that the terraces of the Ankara Ova are in all probability climatic, but that they are due to a considerable increase of rainfall of a violent, seasonal type such as is common in a dry Mediterranean-type climate.

The lowest terrace at 20—23 m contains Upper Levalloiso-Mousterian artifacts at a depth of 1.5 to 5.0 m. Although *Pfannenstiel* would accordingly like to correlate this terrace to the Würm II, not only the European chronology but also our own observations throughout the Near East: Cyrenaica, Egypt, the Lebanese marine terraces and the Ksar Akil stratigraphy unaminously correlate this lowest terrace with the Early Würm and possibly both Early and Main Würm, i. e., with the Würm Pluvial proper. However the formation of the floodplain before returning to present-day vertical erosion may possibly represent renewed aggradation during the Main Würm, but it may also represent a later subpluvial as does the similar floodplain or ‚lower terrace' of the Jordan. The phase of erosion previous to the 20—23 m terrace would fit into the Last Interpluvial, while the upper terraces at 65, 80 and 100—110 m wuld correspond to three earlier pluvial episodes — possibly Günz, Mindel and Riss. What has not been preserved further south due to the incredible denudational forces operating in the desert, has been clearly shown here: the existence of three, distinct pluvial phases in the Middle and Lower Pleistocene. What is suggestive of the G-M-R correlation is the long period of erosion and undercutting to 20 m below the present valley sole between the formation of the 65 and 80 m terraces, accompanied by important tectonic activity. Such a long interpluvial may possibly have been the Mindel/Riss Interglacial. However all our references to the Middle and Lower Pleistocene are only theoretical, as no industries or characteristic faunal remains have been found in situ in the three upper terraces. Significant is however, that the 100 m terrace rests on Pliocene clays with *MASTADON*.

E. Chaput (1931) has described two lakes in the Ince Su Valley of the Ankara area which strikingly show the intrenched meanders of a formerly large river which was eventually choked by the excessive amounts of alluvium it was forced to transport during some period of the Quarternary. *Chaput* believes the river could eventually no longer cut through the deposits, and the water was held back behind natural barrages to form two lakes which show the winding curves of submerged meanders. It may just as well be possible that the river could no longer cut through its own deposits after its volume was progressively decreasing in postpluvial times, for the Ince Su of to-day is an insignificant little watercourse. This would place the large meandering river into the Würm, otherwise the intrenched meander lakes could not have been so well preserved.

The 15.5, 30.5, 56 and 95 m terraces at Deir-ez-Zor on the middle Euphrates *(E. Passemard* 1926) have already been referred to in Chapter 4. These alluvial terraces, of which the second lowest contained an Upper Chellian implement in situ, are not only partly fluvioglacial and periglacial in origin, but have been complicated by eustatic sea-level variations as has the River Nile. Both the altitude of the 27—30 m terrace and that Upper Chellian (i. e. Lower Acheul) implement speak for a correlation to the Mindel/Riss Interglacial and the Tyrrhenian Transgression.

Further evidence from the pluvial epoch is more or less limited to strandlines above the present level of most of the non-outlet lakes of the interior. Lake Burdur, 180 km², over 50 m deep and with a water level at 855 m, has strandlines at 900, 935 and 945—50 m *(H. Louis* 1938, *A. Ardel* 1954a). There is an overflow threshhold at 947 m so that the lake did not exceed 948 m, which level is also the upper limit of the mollusc *DREISSENSIA BURDURENSIS*. Due to the freshness of the morphologic forms, *Louis* considers the maximum level as belonging to the Würm, and microliths found in the dune sands whipped up from the floor of the retreating lake suggest the lake only began its (last) retreat in late glacial times. Likewise Lake Iznik, 304 km^2 and over 60 m deep has raised beach conglomerates and cliffs at 100—105, 130—35 and 140—45 meters above the present level, although it is not clear whether the two upper beaches are Pleistocene (*Ardel* 1954 b). At its maximum it probably overflowed westwards through the Garsak gorge. The shallow lake of Aksehir, some 100 km^2, 2—4 m deep and with a water level at 960—65 m, has a flood season expansion of 160 km^2 and is liable to strong variations, drying out entirely at times (*H. Wenzel* 1932, p. 27—9). The latter lake once stood higher and overflowed over the threshhold at Cay, c. 1000 m. The ancient shoreline has been strongly tilted and falls from 1000 m in the northwest to 975 m elevation in the southeast. After the tilting a period of aggradation of the mountain streams followed, during which fan deltas were built out into the plain, without however being accompanied by any more recent beach formations (*Wenzel* 1932).

The great Konya-Eregli basin (150 by 50 km) with its almost absolutely plane alluvium floor at 990 m was at one time filled by a large, relatively shallow lake which was more recent than the most recent vulcanism of the area (*Louis* 1938). There is only one shoreline at 1015 m and since there was apparently no surface outlet, the watershed being at 1035 m, *Louis* believes there must have been a subterranean exit. The great fan deltas at Konya were contemporary to the Konya lake. The highly saline Tuz Gölu, at 900 m and with an area of some 1250 km^2, has a depth of 0—2 m according to the season (*Louis* 1938). Originally this playa lake was thought to have raised beaches at 40 and 75 m, but *Louis* has discounted this, maintaining the highest level was at a mere 905 m with an areal expansion of close to 2000 km^2, an average depth of over 5 m but without an outlet. During this period the Ince stream, which to-day does not even reach the lake, built up a delta at 5 m.

Farther eastwards, the Hazar Gölü in the Elazig area has raised beaches at 30 and 100 m (*E. Lahn* 1951), and Lake Van, 3730 km^2 with a level at 1720 m, apparently achieved a distinct maximum of 60 m according to *H. Lembke* (c. f. *Louis* 1938). *A. Ardel* (1938) has also determined several lower shorelines at 12, 25—30 and 45 m, but negates the existence of any fluvio-lacustrine deposits higher than the last level. Since the watershed at Kotum is 1820 m, the lake cannot have had an outlet. Lake Urmia or Rezaieh, according to season 4500—6000 km^2, with a maximum depth of 16 m and a water level at c. 1300 m, has two raised beaches at 45 and 55 m (*Bobek* 1937). Even at its maximum extent, with a depth of 60—70 m and an area of 10 500 km^2, the lake had no outlet and *Bobek* believes this expansion could be accounted for by a mere 5° colder annual temperature. However the numerous deltas at this level suggest an appreciably greater drainage.

This overall picture of higher water-levels, for the greater part, no doubt, during the Upper Pleistocene, has led *Louis* to postulate a lower temperature and less evaporation but no increase in precipitation on the grounds that areas with double the present precipitation would most certainly have developed outlets to the sea, under present temperature conditions, *H.*

Wenzel (1935, p. 40—42) is, however, of a different opinion, maintaining that the dissolution of the formerly closed drainage network of Central Anatolia into innumerable small hydrographic units can only be accounted for by a recent reduction of the precipitation. Tectonic processes are only of local importance; karstic phenomena have affected some localities but cannot be held responsible for the drying out of rivers and lakes in general. Underground exits drain the Beysehir, Sogla and Akgöl but are impossible in the Aksehir, Tuz and Konya basins on account of the geologic substructure. In short the erosion of great valleys, the deposition of large gravel fans, as already noted by *W. Penck* (1918, p. 53, 76) in the Kutahia and Sandykly Ovas, and the former expansion of the now non-outlet lakes with volumes often over 10 times those of the present, can only be explained by a temperature decrease of 4° C. accompanied by a not inconsiderable increase in precipitation[12]). And if our previous observations are applicable here, the lakes reached their maximum expansions during the Early Würm, at a time when the temperature decrease was as yet nowhere close to 4° and which point is even more suggestive of greater humidity.

In conclusion then, the Upper Levalloiso-Mousterian apparently corresponded to a pluvial phase in Anatolia, that can be correlated to the Würm Glaciation. Evidence to this effect is forthcoming from most parts of Central Anatolia, although few details are known about this pluvial as yet. Prior to this there were perhaps three further pluvials during the Middle and Lower Pleistocene, as well as an interpluvial during the Riss/Würm and quite likely during the Mindel/Riss Interglacial as well. Unfortunately the considerable amount of knowledge we have about higher lake levels is almost inapplicable due to a lack of dating possibilities.

Table VI: The Anatolian Chronology.
(based upon *Pfannenstiel* 1940, *Louis* 1938, *Ardel* 1938, 1954, *Bobek* 1937).

Anatolian Index	Ankara Ova	Lake levels	Suggested correlation
1	Erosion	Modern levels	Holocene
2	Formation of the floodplain?	Intermediate strandlines?	Main Würm
3	Erosion?	Regressions?	Interstadial
4	20-23 m terrace	Maximum lake levels?	Early Würm
5	Erosion		Riss / Würm
6	65 m terrace		Riss
7	Erosion to -20 m		Riss / Mindel
8	80 m terrace		Mindel
9	Erosion		Günz / Mindel?
10	100-110 m terrace		Günz??

12) *X. de Planhol* (1956) notes massive tufa deposits in the Antakya area, containing a cold flora and dated indirectly by archaeological associations as Würm. This presupposes a great activity of the local springs.

6. The Iranian Plateau and its Borderlands.

The last area to be considered in this regional survey, that of Persia and the peripheries of the Iranian Plateau, is to a large extent virgin soil for the geologist and little known for palaeoclimatological purposes, at least if one considers its great expanse. Perhaps no region in the countries under consideration offers greater possibilities than a thorough morphological survey devoting particular attention to the Quaternary evolution of the Iranian landscape. A systematic examination of some of the better suited larger wadis or river valleys for climatic terraces and associated cultural implements would be of great benefit to the problem of Pleistocene climatic variations.

Beginnignd in Iraqi Kurdistan, the general geologic study of *H. E. Wright* (1952) in the Chemchemal Plain provides an outstanding sequence for the Pleistocene chronology:

1. Erosion of the gently folded redbeds in front of the outside limestone ridge to a smoothly graded surface (Chemchemal-A surface) wih a coating of local chert and limestone gravels. Long phase of crustal and climatic stability permitted the entire stream system to lower the intervening watersheds to a nearly common level.

2. Deposition of silt-cover (Chemchemal-B surface) during a phase of more humid climate.

3. Renewed downcutting of the major streams, leaving long fingers of the Chemchemal surface extending as residuals from the bordering ridges into the basin, and producing the Jarmo-A surface. Presumably uplift associated with an increasingly arid climate.

4. Renewed deposition (to make Jarmo-B surface) during a more humid interval, at the very beginning of which the Acheulio-Mousterian site of Barda-Balka was occupied. The first gravels were buried by a thick cover of silts which reach a maximum depth of some 60 m. Lacustrine deposits occur locally.

5. Renewed dissection of the Jarmo surface, brought about by the recurrence of an arid climate, during which the gully system excavated so far as to penetrate the Chemchemal surface under the silt-cover. This degradational phase lasted into historical times, when it was again briefly interrupted by deposition during the last millenium B. C.

Basing himself upon the site at Barda-Balka, *Wright* identifies the depositional phase 4 as Würm Pluvial, and by extrapolating backward he tentatively correlates the dissection of the Chemchemal surface (3) to the Riss/Würm Interpluvial, the deposition of the Chemchemal silts (2) to the Riss Pluvial, and lastly the formation of the Chemchemal-A surface (1) to the Mindel/Riss Interpluvial. Older physiographic cycles are recorded by still higher erosional surfaces not completely removed during the phase 1.

Elsewhere in Kurdistan, *Bobek* (1940) has identified three types of valley alluviation in Hakari province. Firstly there are fluvioglacial outwash gravels occasionally leading downstream from the Würm glaciers, while recent gravels fill the soles of the freshly dissected valleys further down.

Conglomerates of older date occur as well, as their degree of dissection shows. However the latter have not been dated any closer. The Levalloiso-Mousterian layer of the Mazar-Herd Cave (near Sulimanieh), dated at ,older than 25 000 years' by radiocarbon (*W. F. Libby* 1954), corresponded to a period of intense cold and apparently an expansion of the ice fields in the Kurdish mountains according to *D. A. E. Garrod* (c. f. *Huzayyin* 1941, p. 105-6). No further details can be given as the article was not obtainable.

In the southern Lut Desert there is also evidence of two cycles of sedimentation and deflation. The two most prominent features of the area are the Namakzar salt pan or kevir, and along the eastern margins of the desert, a great field of dunes covering at least 9000 km^2 and achieving a depth of 200 m (*A. Gabriel* 1935, 1942). *G. Stratil-Sauer* (1952, 1957) describes two distinct types of sediments, according to age and texture, deposited in the basin during the Pleistocene. The older sediments, fragments of which are preserved to a depth of 250 m in the northern sections of the basin, consist of horizontally deposited conglomerates, sands, clays and remains of a formerly salt-saturated kevir bottom. Subsequently a period of wind-deflation excavated the basin to well below the present level of the basin during which the finer materials were deposited in the great dune fields of the eastern basin. During the second period of sedimentation sandstones, sands and clays were deposited to at least 20 m[13]), likewise with layers of salty kevir material showing a stratigraphy indicative of repeated changes of the water or ground-water level. After this a renewed period of wind scour deflated the younger sediments quite severely at a time when the greater part of the Iranian kevirs were also non-existent or much smaller as can be gathered from the stationary or fixed dunes on the southern and southeastern edges of the kevir basins (c. f. *Stratil-Sauer* 1952). Subsequently a return to moister conditions (during the Holocene) gave the interior basins their present form with water-saturated kevir floors and a pronounced reduction of aerial deflation.

Obviously both older and younger sediments were deposited while the water or ground-water level of the kevir (the Namakzar) was very much higher, and especially the older sediments represent an extraordinary phase of fluviatile activity in the surrounding mountains whereby gravels were deposited into the center of the kevir lake. As *Stratil-Sauer* points out, the denudational basis of such interior basins is arrived at when the excavating forces have exposed the sediments lying close to the rainy-season water-table of the kavir. In other words, the excavation of the older sediments to well below the present level of the present Namakzar kavir indicates a very low water-table and implicitly a much more arid climate prior to the deposition of the younger sediments — a water table quite possibly lower by as much as 250 m! This means that one can tentatively identify two pluvial periods of decreasing intensity, separated by a very pronounced interpluvial and succeeded by modern postpluvial condi-

13) *Stratil-Sauer* assigns the younger sediments an upper limit of 260—280 m, the 'lacustrine loess' to 335—355 m. However *Gabriel* (1935, 1942) sets the thickness of the latter at 150 m, which would imply a much greater depth for the younger sediments.

t i o n s. Both sediments were deposited beneath or close above the water-table of the kevirs, and both were excavated while the same water-table had sunken by perhaps 250 and 20 m respectively — something that illustrates the succession of pluvial and interpluvial in every sense of those words.

While once on the topic, the question of the great salt kevirs *per se* must be briefly touched upon. The great interior basins of the Iranian Plateau came into being after the uplift and folding of the early Tertiary (*Gabriel* 1935, p. 19—25) and the weathered materials of the mountains were necessarily deposited in the lowest basins which were gradually filled up higher and higher with gravel, silt, dust and salts which have buried the earliest lacustrine deposits. These kevirs or playas were re-created during each pluvial period. Both *Gabriel* and *Hedin* (1910/2, p. 228) agree that the average descent from the edge to the middle of the kevir in its present form is some 50—75 m, and considering that there are gypsum terraces several meters above the present rim at Kabr Fatimeh and Gechi (*Gabriel* 1942), the amount of water formerly filling these vast expanses of tensof thousands of square kilometers to a depth of over 75 m at maximum, stands in strong contrast to the small playas found in the innermost parts of the kevir to-day. The greater part of the salt crusts are easily passable at all seasons to-day, and we find it very difficult to agree with *Bobek* (1954) that a mere 4° C. lowering of the mean temperature could account for these pluvial kevir lakes of the Pleistocene.

Falcon (1947) refers to wadi terraces, to a maximum of 80 m, in the Makran coastal area but gives few details. *Huntington* (1935) describes six alluvial terraces along a stream giving rise to the Anau Oasis, just north of the Kopet Dagh in Khorassan. From his description we can describe the following physiographic cycles. An erosional surface at 100 m was alluviated after which renewed downcutting was interrupted by a second phase of aggradation at 30 m. Further vertical incision, briefly halted at 15 m continued until the broad plain of the main valley was alluviated at 6 m. In recent times dissection has progressed further, interupted only by a temporary phase of deposition leading to the formation of a 2 m terrace — the high-water-level we suppose. Thelast area where fluviatile terraces have been repeatedly observed in Iran is the southern flank of the Elburz, but from the observations of *Bobek* (1937) these watercourses appear to have been largely supplied by materials from the periglacial zone and have therefore been briefly referred to in Chapter 4.

With the exception of postglacial occupation of the Belt and Hotu Caves in Mazanderan, few caves have been systematically excavated in Persia proper, where our present knowledge of the Palaeolithic is about as scanty as in Anatolia. The Kara Kamar cave, situated near Haibak, Afghanistan, has been excavated and even radiocarbon dated (*Coon & Ralph,* 1955), but the findings have not been very profitable for geologic purposes. It was found that whereas the local Upper Palaeolithic began over 32 000 years ago, there has been aeolian deposition of a loes-like material from before 30 000 to about 9000 B. C.

What resembles a climatic succession for the Iranian Pleistocene has been described by *E. Huntington* (1905) for the Basin of Seistan and its highly variable, shallow Hamun Lake. Considering that the present depth during the greater part of the year seldom exceeds 2 meters, *(S. Hedin,* 1910, 2) and rarely exceeds 4 meters at the time of maximum flooding *(Huntington* 1905, p. 293-302), the strandlines at 4.5 and 8 m (above the level of January, 1904) identified at Bereng, Lutuck and Seh-Kudeh represent a sizeable increase in water volume, indicating as they do long-term average conditions on the basis of quite impressive beaches. Considering the flatness of the Hamun Basin the volume of the 8 m lake was well over 10 times that of the present. *Stratil-Sauer* (1957) further recognized a beach at 15 m. *Huntington* (1905, p. 286—91) took some 15 profiles of the local deposits, chiefly at points behind a well-marked modern beach and in five cases at least unliable to any shifting of the lake bed (as *Bobek* 1954 has suggested). The profiles in general indicate a succession of lacustrine transgressions and regressions of the Hamun as witnessed by alternating whitish or greenish lacustrine clays and pink or brown subaerial deposits. The former are uniform in texture and colour and are typically lacustrine, while the last are discontinuous, highly weathered clays, silts or sands showing ripple marks, raindrops, fossil leaves and reeds and other signs of subaerial deposition, particularly by temporary floods. A very interesting profile was taken 4 miles inland from the abrasional coast near Kharibka on the northwest shore. Under many feet of gravels, a 7 m profile showed 10 lacustrine transgressions during which, on the average some 15—20 cm of greenish clays were deposited *(Huntington* 1905, Plates 6 and 7). On the whole however, *Huntington* suggests that a succession of 10 transgressions (fluvials) and regressions (interfluvial epochs) would account for the observed facts. Although these profiles serve to show the extent and frequency of local climatic variations, they cannot be in any way associated with definite phases of the Pleistocene chronology. Elsewhere *Huntington's* observations were of a more general and superficial character and do not seem to serve any further purpose.

Before closing, the more recent Russian investigations in Turkmenistan are of interest. *Tolstov, Kess & Shdanko* (1954) state that whereas the Sarykamish and Assaka Andan Depressions were dry and subjected to aeolian excavation during the first half of the Pleistocene, they were filled with water from an arm of the Amu Darya, and overflowed into the Caspian via the Uzboi Channel during their more recent Quaternary history. The Sarykamish, which lies at 40—45 m below m. s. l. was filled to 58 m m. s. l. until the flow of the Amu Darya decreased (presumably towards the close of the Pleistocene), and new shorelines cut at the 0 m contour. This inland sea was quite salty, favourable to the spread of *CARDIUM EDULE* (Leitfossil of the post-Chvalyn Caspian) which persisted until the lake disappeared entirely at the close of the last millenium B. C. Originally the Amu Darya possibly flowed directly across the Karakum to the Caspian while in the later period it flowed further north, originally into the Sarykamish, gradually shifting course again until it emptied into the Aral Sea completely, which surprisingly has apparently not stood higher than some 6 m over its present level (*A. Schultz* 1927). The Pleistocene history of the Caspian Sea has been considered in detail in Chapter 3, and with respect to the Last Pluvial we can restate that the Chvalyn transgression achieved 75—77 m above the present level during the Early Würm, and 26—28 m during Main Würm (*Leontgev & Fedorov*), 1953). The two submaxima were separated by a regression during which terrestrial deposits of alluvium etc. were deposited. On the Caspian littoral the 75—77m shoreline corresponds to the level of the numerous subrecent fan deltas, as for example in the Asref region (*Bobek* 1937).

After the Chvalyn Transgression there has been a decrease in moisture, as can be gathered from the subsequent incision of the streams and the deposition of loess at the close of the Palaeolithic period. This loess is up to 10 m thick north of Asterabad, and may have been whipped up from the exposed sediments of the shrinking pluvial Caspian Sea. Local aridity at the time of deposition is certain as *Bobek* (1937) points out that if the pre-

Table VII: The Iranian Succession.
(based upon *Wright* 1952; *Stratil-Sauer* 1957; *Gabriel* 1942; *Grahmann* 1937; *Leontyev & Fedorov* 1953 and others).

Iranian Index	Chemchemal Plain	Lut Basin	Caspian Sea	Suggested Correlation
1	Renewed dissection (1–3)	Modern conditions	Mangyshlak Regression and New Caspian Transgression	Holocene
2		Recreation of the Namakzar	Shrinkage in stages to 16 and 10-12 m above present	Early Holocene
3		Deflation of the ‚younger sediments'		Late Würm
4	Deposition (Jarmo-B) of 60 m of silts (4–6)		Late Chvalyn Transgression 27 m	Main Würm
5		Deposition of 20 m 'younger sediments'	Inter-Chvalyn Regression	Interstadial
6			Early Chvalyn Transgression c. 74 m	Early Würm
7	Dissection of Jarmo-A	Deflation of ‚older sediments'	Atel Regression	Riss/Würm
8	Silt deposition Chemchemal-B	Deposition of 250 m ‚older (fluviatile) sediments'	Chozar Transgression of c. 25-28 m	Riss
9	Lateral planation - Chemchemal-A.		Postbaku Regression	Mindel/Riss
10	Older cycles of deposition and dissection (10–12)		Baku Transgression	Mindel
11			Gurov Regression	Günz/Mindel?
12			Apsheron Transgression	Günz??

sent moist Caspian forest had been growing in the area at the time, the loess would have been transformed to brown forest soils, which is not the case as the lower 6—7 m are completely unaltered. From this *Bobek* concludes that the lower tree-line against the steppe must have been several hundred meters higher than at the present. In the Belt Cave nearby, *C. S. Coon* found such a loess layer, containing very few artifacts, which has been dated at 10,320 B. C. ± 825 by radiocarbon *(E. K. Ralph* 1955), and it appears that the maximum period of loess deposition and the associated drier climate occured at about this time. Similarly in the Karakum desert, *Schultz* (1927) assigns the origin of the fixed longitudinal dunes to an Urwüste characterizing the Turan in the final glacial period. The indications are, in short, in favour of a phase of early postpluvial aridity as already seen elsewhere as well, with a rainfall less than that of the present and a late Upper Palaeolithic date, somewhere in the 10th and 11th millenia B. C. seems most likely. From the fact that this postpluvial phase appears most definite in these millenia, a relationship with the Alleröd — Two Creeks Interstadial experienced in higher latitudes may be suspected and is by no means impossible.

In concluding this regional investigation of the Iranian Plateau, it was possible to show the existence of Pleistocene pluvials with some conviction and employing some of the select data, the results are presented in tabular form above.

7. Some Notes on the Palaeolithic Chronology and Retrospect.

Throughout the preceding regional discussion the prehistoric industries of the Palaeolithic have been constantly used as guideposts to fix the relative chronological position of the geological features, so that a brief discussion of the place of the Near Eastern Palaeolithic industries in the worldwide chronology of the Pleistocene would seem adequate at this point. However it is not intended to enter into any controversial discussion on typological problems. A fine general study of the typological and chronological problems of the Near Eastern Stone Age has already been given by *Huzayyin* (1941, Part II) and more recently by *R. Neuville* (1951, p. 245-264), and especially by *D .A. E. Garrod* (1956) and *H. Fleisch* (1956). All in all these allow fairly reasonable correlations with the Somme sequence (c. f. *Breuil* 1938) indirectly through the associated raised beaches. This precludes the unscientific and arbitrary shifting of industries, shorelines and associated glaciations still being attempted by a number of prehistorians.

The Lower Palaeolithic of the Near East, in particular of Egypt and Syria, begins with an Abbevillian facies, characterized by crude trihedral specimens made of pebbles. This industry is found in situ in the 55—60 m Lower Milazzian shoreline of Lebanon *(Fleisch* 1956, also Table II) which suggests a Günz/Mindel age. The surface finds scattered all over the present deserts as well as pluvial associations at Jafr suggest that its long duration also embraced at least one of the pluvial phases, possibly the Mindel.

The 30 m Nile terrace contains an industry described as primitive Chellian, Chellian and Chelleo-Acheulian, according to the newer nomenclature Abbevillian to Lower Acheulian. On the other hand, the 45 m terrace of Lebanon already contains Middle Acheulian in situ along with Tayacian. Here the regression between the 45 and 30 m beaches (probably Mindel) is associated with a Tayacian and a Lower Levalloisian industry. Further, obvious Riss pluvial deposits in the Judaean caves contain Middle Acheulian and Upper Tayacian. In short, the industries of the 30 m Nile terraces are in part certainly older than the Tyrrhenian Transgression. Possibly this may explain the apparent contradiction of local pluvial activity during what seems to be a high eustatic sea-level. It may not be quite unjustified to suspect that the 30 m Nile terrace contains Mindel Pluvial materials with Mindel-age implements, subsequently modified or redeposited in part to conform to a higher sea-level. This may be the approach whereby the labyrinth of the Egyptian Pleistocene can be fathomed. Extending the analogy, we suggest that the 30 m Nile terrace complex may represent the Mindel and Mindel/Riss, the 15 m terrace complex the Riss and Riss/Würm. Although in many cases climatic aggradation upstream was subsequent to eustatic aggradation downstream (e. g. *Mensching* 1953, *Woldstedt* 1952), the industries of the Nile terraces preclude such an interpretation for Egypt where one may envisage a reverse process.

In the Fezzan the scarcity of Lower Acheulian (‚late Chellian') surface finds suggested a dry climate to *M. Dalloni* (1948, p. 73), while the great abundance of the main Acheulian, also associated with wadi terraces by *McBurney* (1947), indicate a Middle Pleistocene moist interval. During the closing stages of the Acheulian, chiefly during the Last Interglacial, a local Levalloisian industry began to evolve in Egypt while the imposition of some newly arrived Eurasiatic elements led to the development of a complex Levalloiso-Mousterian facies in Syria. The revision of the European classification has led to some confusion in the matter of Near Eastern Middle Palaeolithic nomenclature — the Moustier flake sensu stricto with a distinct sloping lateral retouch, the Levalloisian with an occasional steep trimming but with little lateral retouch. As the typology itself is not as important as the chronological ordering in this place, we propose to follow the common usage of ‚Levalloiso-Mousterian' in referring to the Near Eastern Middle Palaeolithic in general. The position of the Micoque and Lower Levalloiso-Mousterian in the Lebanon appears to be that of Riss/Würm while we considered the late Lower and Upper Levallois of the Nile Valley as early last glacial. On the other hand, the ‚Upper Levalloiso mousterian' characterizes the Early Würm of Libya, judging by Haua Fteah, and seemingly occupied a similar position in Palestine-Syria according to Miss *Garrod* (1938, 1956). In Egypt the Lower Sebilian, which is merely a new local development of the Egyptian Levalloisian technique, seems to fall within the Interstadial of the Würm, just as the earliest Upper Palaeolithic, the Emiran of Palestine *(Garrod* 1953). To the earliest stages of the last glaciation as well can be ascribed the Upper Levalloiso-Mousterian of Cyrenaica.

Throughout the Near East it appears that the Interstadial was characterized by the appearance of the first Upper Palaeolithic industries, usually at first of a transitional type. As the Lower Sebilian of Egypt is stratigraphically connected with a drier climate, so also *Neuville* (1951, p. 261) already suspected the same in Djebel Kafzeh. Miss *Garrod* (1953, 1956) was able to point out this stratigraphic position of the Upper Palaeolithic I directly. The Upper Palaeolithic is characterized by a further increase in local differentiation. In Libya it evolves in a marked Capsian-like blade industry, quite evolved in a radiocarbon dated horizon from 10,000 B. C., and which had taken on a strong microlithic character before its replacement by a primitive Neolithic facies about 5000 B. C. The Egyptian Sebilian appears to be strictly an autochtonous development, in contrast to Lybia and Syria, and consists of an evolution towards a ‚Diminutive Levalloisian' as *Huzayyin* (1939, p. 207—8) has called it. The inadequacy of the term ‚Sebilian' to account for two special local variants evolving from the same root makes the designation of *Huzayyin* appear a little more appropriate. This ‚Diminutive Levallois' graded into a microlithic stage that can be observed until the onset of the Neolithic. Lastly, the Upper Palaeolithic of Syria has been studied in a fine manner by Miss *Garrod* (1953, 1956.) Further differentiation of the later Palaeolithic blade industries into Upper Palaeolithic II—VI, comprising the Main and Late Würm phases, covers a development previously designated as Middle and Upper Aurignacian (*Garrod* 1938). Not only does the younger Old Stone Age of the Near East differ from its Euroean counterpart in its emphasis on autochtonous development. The micromesolithic development was merely a gradual transition, and not subject to such a revolutionary introduction as in Europe at the end of the Upper Dryas. The microlithic stages of Northeast Africa were paralleled by the Natufian industry in Palestine, whose earliest phases probably overlap with the Kebaran, Upper Palaeolithic VI stage.

The Neolithic industry with its polished stone implements and usually the earliest food-producing economy as well, was substituted rather suddenly in most areas, probably by new ethnic or tribal groups. At present the earliest village remains known are those of Jericho dated at 6050 B. C. by *Zeuner* (1956). The bottom of the preceramic Neolithic of the Belt Cave, Iran, gave a radiocarbon date of 5840 B. C. (*E. K. Ralph* 1955). The oldest preceramic village material at Jarmo*, Kurdistan, was dated at 4755 B. C. (*Arnold & Libby,* 1951) while the oldest, preceramic Neolithic of Haua Fteah is assigned 4835 B. C. by *H. E. Suess* (1954). The Fayum Neolithic, dated 4400 B. C. by *Libby* (1951) is certainly not the oldest Egyptian Neolithic site, nor does that date represent the oldest material of the Fayum ‚A'. All in all the first transitions to the Neolithic must have been made well before 8000 years ago, but the general adoption of this polished stone industry in Southwest Asia and Northeast Africa does not seem to have taken place before the first half of the 5th millenium B. C. In Anatolia

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* *R. J. Braidwood* has kindly informed the writer that a recent radiocarbon investigation will probably yield a considerably older date.

and Northwest Africa this introduction probably took place a thousand years later.

Following this general outline, Table VIII below summarizes the position of the Near Eastern industries in the world-wide chronology.

Table VIII: The Chronology of the Near Eastern Palaeolithic. (after *Huzayyin* 1941; *McBurney & Hey* 1955; *Suess* 1954; *Sandford & Arkell* 1933, 1934, 1939; *Caton-Thompson* 1946, 1952; *Dalloni* 1948; *Garrod* 1953, 1956; *Neuville* 1931, 1951; *Garrod & Bate* 1937; *Fleisch* 1956)

Glacial Correlation	Libya	Egypt	Palestine-Syria	Lebanese coast
Boreal to Upper Dryas	Microlithic and evolved Capsian-like blade industry	Microlithic	Natufian Kebaran (U.P. VI) Upper Palaeolithic III-V	
Late Würm Main Würm	Upper Palaeolithic blade industry	Middle & Upper Sebilian	Upper Pal. II	
Interstadial	Earliest traces of blade indus.	Lower Sebil. (Diminutive Levallois.)	Emiran (U. P. I)	
Early Würm	Levalloiso-Mousterian	Upper Levallois.	Upper Lev.-Moust. Middle Levallois.	Leval.-Moust.
Riss/Würm		Lower Lev.	Lower Lev., Micoque, Upper Acheul.	Levallois & incipient Mousterian
Riss II Riss I	(Acheulian)	Upper Acheul.	Middle Acheul. Middle Acheul. & Tayacian	
Mindel/Riss	(Lower Acheul.)	Lower Acheul.	Tayacian	Tayac., Middle Acheul., Lower Levallois.
Mindel Günz/Mindel	(Abbevillian)	Abbevillian	Abbevillian	Abbevillian

Retrospect and Summary. Last of all a brief review of the results obtained in the previous pages shall be attempted. Table IX correlates the results of Tables II—VII in the form of the index numbers associated to the physiographic stages and restates the suggested correlation to the world-wide chronology. The stages of the Near Eastern succession are enumerated by a final index code of which stages 1—3 have only been incidentally and very incompletely noted in the course of the discussion and which along with stage 4 will be considered in detail in the subsequent chapter. (c. f. also Map 4).

The characteristics of the physiographic stages can be summed up as follows:

1—3. HOLOCENE Stages (or postglacial period proper) c. 8000 B. C. to the present, with Mesolithic, Neolithic and metal industries. Climate more or less similar to that of to-day, with a predominance of vertical incision, denudation, and a lowering of the water table, a process intensified by the presence of man.

4. SUBPLUVIAL Stage (Upper Dryas of final glacial stage) c. 9500 to 8500 B. C. represents a temporary moist interval. This ‚Subpluvial' phase discussed in detail in the next chapter appears to have been associated with the last ‚cold snap' of moment in the area under consideration.

Table IX: The Near Eastern Chronology (physiographic stages)

<table>
<tr><th>Near East Stage No.</th><th>Libya Phase No.*)</th><th>Egypt*)</th><th>Syria*)</th><th>Anatolia*)</th><th>Iran*)</th><th>Suggested Correlation</th></tr>
<tr><td>1</td><td rowspan="2">1</td><td rowspan="3">1</td><td>1</td><td rowspan="5">1</td><td rowspan="2">1</td><td>Subatlantic</td></tr>
<tr><td>2</td><td>2</td><td>Subboreal</td></tr>
<tr><td>3</td><td>2</td><td rowspan="2">3</td><td rowspan="2">2</td><td>Preboreal to Atlantic</td></tr>
<tr><td>4</td><td></td><td rowspan="2">2</td><td>Upper Dryas</td></tr>
<tr><td>5</td><td rowspan="2">3</td><td>4</td><td>3</td><td>Late Würm</td></tr>
<tr><td>6</td><td>3, 4</td><td>5</td><td>2</td><td>4</td><td>Main Würm</td></tr>
<tr><td>7</td><td rowspan="2">4</td><td>5</td><td>6</td><td>3</td><td>5</td><td>Interstadial</td></tr>
<tr><td>8</td><td>6</td><td>7</td><td>4</td><td>6</td><td>Early Würm</td></tr>
<tr><td>9</td><td>5</td><td></td><td>8</td><td>5</td><td></td><td>R/W-Würm</td></tr>
<tr><td>10</td><td>6</td><td>7</td><td>9</td><td>6</td><td>7</td><td>Riss/Würm</td></tr>
<tr><td>11</td><td></td><td></td><td>10</td><td>7</td><td></td><td>Riss - R/W</td></tr>
<tr><td>12</td><td rowspan="2">7?</td><td>8, 9</td><td>11</td><td rowspan="2">8</td><td rowspan="2">8</td><td>Riss II</td></tr>
<tr><td>13</td><td>10</td><td>12</td><td>Riss I</td></tr>
<tr><td>14</td><td></td><td></td><td>13</td><td></td><td></td><td>M/R - Riss</td></tr>
<tr><td>15</td><td></td><td>11</td><td>14</td><td>9</td><td>9</td><td>Mindel/Riss</td></tr>
<tr><td>16</td><td>8?</td><td>12</td><td>15?</td><td>10</td><td>10</td><td>Mindel</td></tr>
</table>

5. POSTPLUVIAL Stage (particularly representative of the Two-Creeks Alleröd Interstadial) c. 16,000 — 9500 B. C. was characterized by a complete cessation of any pluviation, and during its last half by a climate more arid than to-day and a very effective wind-denudation on a scale unknown at present. Characteristic was an evolved Upper Palaeolithic facies strongly differentiated locally.

6. WÜRM PLUVIAL II (Main Würm) c. 23,000 — 16,000 B. C. comprised the second and minor submaximum of the Würm Pluvial and in all eventuality the maximum extent of the montane glaciers of Anatolia and Iran. It may well be that the morphological agency of the increased cold (mean temperature some 4° lower) was of greater significance than that of increased precipitation north perhaps of latitude 30°. In fact the pluvial character of stage 6 was very limited and seems to have been confined to the beginning of the interval, possibly to the readvance of the continental glaciers to their Upper Pleistocene maximum extent. South of latitude 22° there are no geological traces of any pluviation during this phase. The leading industry was of an individualized early Upper Palaeolithic character.

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*) Numbers refer to tables III—VII.

7. WÜRM INTRAPLUVIAL (the 'Göttweig' Interstadial) seems geologically hinted at in so far as that the rainfall was probably not more than in recent times. However the trend of the temperature curve is little known.

8. 9. WÜRM PLUVIAL I (Early Würm) represents the Würm Pluvial par excellence throughout the Near East. Little is known about the behaviour of the montane glaciers but it appears probable that the temperature was by no means as low as during the Würm maximum. Peculiar indeed is the onset of full pluvial conditions before the great continental glaciers had actually begun their fullscale expansion, while the rainfall subsequently declined somewhat during the advanced stages of the Early Würm. This is not a local idiosyncrasy but seems characteristic of the Mediterranean pluvials in general, as for example in the Grotto Romanelli in Apulia (*G. A. Blanc* 1921) and in the Grotte de l'Observatoire, Monaco (*Boule & Villeneuve,* 1927) where the horizons corresponding to each glacial subphase are ushered in by stalagmitic layers indicating maximum pluviation at the very beginning of the glacial relapses. Hagfet Et Tera C, Djebel Kefzeh I—K and Jabrud B present a similar picture in the Near East, although the latter suggests that a number of alternating, distinct very humid and dry phases filled in the detail of the initial pluvial phase. Highly indicative appears to be the Upper Levalloiso-Mousterian facies of the Middle Palaeolithic.

10. The LAST INTERPLUVIAL (Riss/Würm Interglacial) is ubiquitously represented by a rainfall lower than that of to-day and pronounced aeolian denudation. Characteristic are the Upper Acheulian, Micoquian and a Lower Levalloiso-Mousterian industry.

11. The Transition to the Last Interpluvial seems to be recorded in a few localities as a period of relatively good precipitation, perhaps comparable with to-day.

12. 13. The RISS PLUVIAL (Riss I and II) can apparently be recognized in the greater part of the Near East as a colder and moister period of greater intensity and duration than the Würm Pluvial, and there are some indications of two subphases. The Upper and Middle Acheulian and the Tayacian are typical. This pluvial is also separated from the preceding interpluvial by what seems to be a transitional stage (14).

15. The GREAT INTERPLUVIAL (Mindel/Riss Interglacial) is apparent as a period of warmth and general aridity preceding the Riss Pluvial. A Lower Acheulian industry is particularly characteristic.

16. A MINDEL (?) PLUVIAL is suggested indirectly at a number of localities, but definite information is lacking.

An earlier pluvial and interpluvial period are indicated in a very few of the locations discussed, but in general very little can be said about the Lower Pleistocene of the Near East. The early Villafranchian of Egypt at least appears to have been quite moist.

Chapter VI: Postpluvial Variations of Climate

1. Introduction.

With the first appearance of the Mesolithic industries in the Near East after about 10,000 B. C. the thread of the climatic chronology unravelled during the course of the last three chapters enters into the immediate proximity of prehistory with its rapidly evolving cultures, the beginnings of animal domestication and eventually the food-producing ‚Neolithic' economy out of which sprang the ancient civilizations of Egypt and Mesopotamia. This same time interval has been the subject of intensive investigation in northern Europe and whereas an outstanding climatic succession has been delineated for these northerly regions, the changing climatic environment enjoyed by man during these critical and decisive millenia in the evolution of civilization in the Near East is next to unknown.

Frequent references to supposed historical changes of climate in the eastern half of the classical world can already be found in the Greek and Arabic authors, and similar speculations have continued into the twentieth century. However climatic variation was only considered as a means to an end, either to substantiate or refute the deterministic theories abounding at the time. Consequently this fretting speculation by travellers and other non-specialized observers was disastrously affected by the introduction of new and less fallible methods of investigation in northern Europe, leading to the triumph of the historical possibilistes and those vehement adherents of a theory of a static climate ‚since glacial times'. However, little observed by the cognate fields, a new and less circumstantial technique, the intensive geomorphologic study of select type areas was beginning to accumulate a great number of unintegrated and often obscure contributions to the theme of postpluvial climatic variation chiefly focused, as we have seen, upon the pluvials of the Pleistocene epoch. Largely neglecting this newer literature and often based only upon that highly disputable criterion of nomadic migrations, *C. E. P. Brooks* (1926, 1949) presented a general survey of Near Eastern climatic fluctuations. Only the more profitable although still quite scetchy syntheses of *D. M. A. Bate* (1940) and *S. A. Huzayyin* (1941) marked the first great step to a new inauguration of palaeoclimatological study in the desert margins of the Old World during the Holocene. Subsequently, *G. W. Murray* (1951) and *H. Bobek* (1954) have attempted to give a regional outline of climatic evolution in Egypt and Persia respectively, but both of these noted field-researchers were hampered by the impossibility of comparing overall data from the wider base area essential to such a study.

The term ‚postpluvial' has been purposedly substituted for ‚postglacial' in this chapter, as it has become obvious during the course of the discussion above that these terms are chronologically not equivalent. The postglacial period is usually regarded as beginning with the drainage of the Baltic ice-lake about 8000 B. C., while the last Würm pluvial subphase had probably ceased several thousand years earlier, apparently with the end of the last glacial maximum some 18,000 years ago. In fact, it looks as if the general characteristic of the Late Glacial interval in particular was a rather arid climate in the Near East, with a rainfall considerably less than to-day in view of prevailing temperatures still a little below those of the present.

To restate briefly, the post-Middle Sebilian shrinkage and probable disappearance of the Fayum pluvial lake and the severe wind erosion of the exposed lacustrine sediments was connected with an arid climate associated with great aeolian activity (fig. 5). Similarly in Lybia, where *Murray* (1951) points to the striking absence of surface finds of Upper Palaeolithic and microlithic flint implements in Cyrenaica, *C. Rathjens* (1928) was able to ascribe the deposition of the Tripolitanian loess to an arid period with more frequent and stronger southerly winds than are known to-day, somewhere between pluvial and historic times. The Jordan and its tributaries cut deeply into the soft Pleistocene sediments, leading to the isolation of the ‚upper terrace' and aggradation gravels of Pluvial C. (Fig. 14). The vertical incision proceeded to below the present alluvial plain by at least 9 m, and after the subsequent aggradation of the ‚lower terrace' or modern floodplain, degradation has only been able to excavate a shallow channel since Neolithic times. Similarly in the Chemchemal Plain of Kurdistan, *H. E. Wright* (1952) points out that the site of Jarmo was occupied about 5000 B. C. (earliest occupational layers radiocarbon dated 4756 B. C. ± 320 by *Arnold & Libby*, 1951) when the postpluvial erosion had already incised the small river valley to four-fifths its present depth of 120 feet.

The loess deposition on the southern Caspian shore was alluded to as well as evidence of greater aridity than we know to-day. The deflation of the ‚younger sediments' of the southern Lut Basin in Iran necessarily implies a great fall of the water table and a disappearance of the subsequently recreated playa. As these ‚younger sediments' were deposited subaerially and to some extent subacqueously to some 20 m depth and then excavated to well below the level of the present Namakzar Kavir, we must suppose a great decrease in moisture since the last local pluvial and a water table somewhat lower than that of the present.

However despite these certain indications of greater aridity, especially during a time-span embracing 15—10,000 B. C., there are nevertheless indications of short, minor rainfall ameliorations corresponding, we suggest, to the later glacial readvance stadia. The 9—10, 7—8 and 3—5 m wadi terraces of the eastern Kharga Scarp (*Caton-Thompson* 1952, p. 3-11) seem to indicate a series of minor temporary improvements of local moisture conditions subsequent to the last, pluvial subphase with tufa formation (early Upper Palaeolithic). The scanty industries found in situ do not allow any correlation.

2. The Late Glacial Relapse and a Subpluvial in the Near East.

The Late Glacial period was probably still appreciably cooler than today, as the angular limestone fragment horizons of the Haua Fteah cave continue from a depth of 470 to 1260 cm (*Mc Burney* 1953). In view of the final transitional zone and interpolating between the radiocarbon dated cultural horizons, a date of c. 8000 B. C. for the beginning of modern temperature conditions locally should not be too far from the truth. Likewise a last striking horizon of angular limestone fragments due to thermoclastic weathering occurs with a final Upper Palaeolithic industry at —1.5 m in the cave deposits at Ksar Akil, Lebanon, compared with Early and Main Würm archaeologically dated horizons indicating greater cold and moisture at —15 m and —10 m respectively (*J. F. Ewing* 1947). The last suggests the last world-wike glacial readvance leading to the formation of the Salpausselkä and Mankato end-moraines, whose beginning is dated at ca. 9400 B. C. by radiocarbon in America (*Flint & Deevy,* 1951)[14]), and there is ample evidence of a similar phenomenon in the montane regions of the Near East.

The glacial forms of the Würm retreat in the northwestern Caucasus are very plentiful, and *A. v. Reinhard* (1925) identified three retreat stages there with snowline depressions of 8—900 m (Teberda), 550—600 m (Konatchyr) and 3—400 m (Amanaus). The striking resemblance to the well-known Alpine stadia led him to suggest a correlation to the Bühl (Schlern), Gschnitz and Daun respectively. The results *Reinhard* obtained for the southern flanks of the Caucasus are quite similar and the last Amanaus-‚Daun' stadium was characterized by snowline depressions of 4—450 m in the Kodor Valley, 380—390 m in the Ingur Valley, 370 m for the Adish, and 300 m for the Mushur glaciers. It should be noted, however, that the glaciers of the southern Caucasus enjoy a heavy precipitation out of all proportion with the Near East and are further favoured by orographic factors. It appears likely that the last Amanaus stadium was contemporary to the Salpausselkä.

The situation in Iran and Anatolia is not so gratifying, largely owing to a lack of systematic observations. *R. Leutelt* (1935) has made some observations in the Pontic Mtns. of Lazistan, but there is a certain lack of clarity in his conclusions with respect to the glacial retreat stadia. He speaks of Würm retreat stages corresponding to the Gschnitz, Daun and the rather doubtful Eggessen, however giving no general figures for the snowline depressions. As the Würm snowline depression was a mere 6—700 m in Lazistan (*Erinc* 1949) one would incline to correlate these three stadia with those of *Reinhard* in the Caucasus, as it is certain that the classical alpine values will all have been distorted in Lazistan as well as in the remainder of the Near East proper. In the Tochal group of the Elburz, *Bobek* (1937) noted stadial moraines indicating snowline depressions of 700 and 450—500 m compared with a Würm maximum depression of 800 m, while in the Tacht i-Sulaiman values of 700, 450—500, 300, 250, 170, 100, and 50 m were obtained, even though the retreat stages are generally indistinct and their occurence sporadic. Despite a lack of time for a more detailed survey, *Bobek* (1940) also noted an often subdivided and double retreat phase with a snowline depression of 350 m (Würm 700 m) in the

14) The geochronological dates are about a thousand years more recent, and *H. Gross* (1954) suggests a date of 8800—8100 B.C. by taking a mean of the geochronological and radiocarbon dates.

Cilo and Sat Dagh of Hakari. Lastly, this repeated mid-way value of 300 m is also given by *Desio* (1934) for the Zardeh Kuh (Zagros), compared with a Würm snowline depression of 600–650 m. It is unlikely that the 300–350 m stadial reoccurring in the Zagros, Elburz and eastern Anatolia should be older than the Upper Dryas and it may quite possibly qualify along with the Amanaus stadial of the Caucasus as equivalents of the Salpausselkä-Mankato in the Near East, but although such a last readvance of the already quite small Würm cirque glaciers of the highlands seems very likely, no proofs can possibly be given.

Our knowledge of precipitation trends is little more specific, although it appears as if this last glacial relapse did not pass unnoticed in the rainfall curve of the Near East. Although locally there are signs of a distinct, more pronounced erosion with angular wadi gravels, *Mc Burney* (1947) stresses that the post-Middle Palaeolithic moisture increases in Libya cannot have been very significant in comparison to the last major pluvial activity of the fossil wadis in Tripolitania. However, at Heliopolis in Egypt, *S. A. Huzayyin* (1941 b) notes a pre-microlithic, Upper Palaeolithic industry with noticeable Neolithic tendencies found in a 30 cm thick bed of gravels brought down during some ‚semipluvial' phase by local torrents washing down towards the Nile.

In Palestine a similar interruption of the characteristic early postpluvial aridity of the Near East can also be noted. Miss *Bate* (1940) points to a faunal change in Palestine among species with widely differing biological requirements in Natufian[15]) times, where the disappearance of a half dozen species of gazelles, a hedgehog and a species of hyaena suggests the oncoming of a more humid phase. In the Jordan Valley, degradation ceased at the beginning of the Holocene (to be considered in the broader sense of the word), and at first some 2 m of sand were deposited by a swifter river able to carry a greater load than at present, remarkable since only the finest materials can be transported to this particular point to-day (*Picard* 1929). Perhaps the 80 cm horizon of well rounded gravels at the base of the ‚lower terrace' exposed at Eddesiye at the Jarmuk estuary (*Picard* 1932) was also contemporary. *Picard* mentions a 2 m strandline of Lake Tiberias, and the present author has noted numerous comparatively recent terraces on the northwestern end of the Dead Sea between the Wadis Mukallik and Madba Aiyad (Fig 16). Aneroid determinations gave approximate elevations of 10, 12—15, 20, 25, 35, 45 and 50 m above the present Dead Sea level (392 m below m. s. l. in 1948) for these minor abrasional terraces cut into the seasonally-banded, varve-like Lisan sediments possibly connected with the older (constructional?) terraces of *Blake* already described in Chapter 5. It is not possible to date the younger terraces by cultural associations as it is next to hopeless to find prehistoric sites close to this sterile and forbidding body of water, yet on comparison, we suggest that the terraces from 10 to 50 m are morphologically as fresh and as well-preserved as the Neolithic terraces of the Fayum, so that an early Holocene date for the earliest does not seem improbable.

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15) *S. A. Huzayyin* (1952a) suggests an interruption of postpluvial aridity from the abundance of surface finds of an industry parallel to the Natufian in the desert of North Sinai.

Lastly the Ghar i-Khamarband (Belt) and Hotu caves near Ashraf on the Caspian coast of Iran offer dating possibilities for the temporary humid interval noted earlier for Libya, Egypt and Palestine. The entrances of the two caves lie at 15.4 and 18.4 m respectively above the 1951 level of the Caspian, so that both will have been submerged during the Chvalyn Transgression and this is confirmed by varved clay or kaolin deposits in the lowermost levels. The stratigraphy of the Belt Cave according to *C. S. Coon* (1951) and the radiocarbon dates and reorganization of the material by *E. K. Ralph* (1955) are the following:

A. Subrecent material.

B. (95—105 cm) Gritty soil with software Neolithic; *CAPRA, OVIS* and *BOS* sp. (5325 B. C. ± 260).

C. (150—160 cm) Ashy soil with preceramic Neolithic; faunal composition similar to (B.). (5835 B. C. ± 330).

D. (175—190 cm) Dark brown soil with Upper Mesolithic; *GAZELLA SUBGUTTEROSA, BOS PRIMIGENIUS, CAPRA* sp., and *CERVUS ELAPHUS* (6615 B. C. ± 380).

E. (200—230 cm) Lense of loess up to 75 cm thick containing few implements (10, 320 B. C. ± 825).

F. (230—250 cm) Ashy soil with intercalations of creamy clay and red ashy soil; *PHOCA* sp., gazelle, *BOS PRIMIGENIUS* and red deer. (9525 B. C. ± 550).

G. Varved clay alternating with gritty clay; sterile.

It should be noted however that *Arnold & Libby* (1951) obtained even more confusing radiocarbon dates of 6054 B. C. ± 900 for layer F, 8610 B. C. ± 1200 for layer D and 6135 B. C. ± 1400 for a combination of B and C. A further counting of a larger sample from D (*Libby* 1951) gave 6584 B. C. ± 500. All in all there seems to have been a certain amount of site contamination or redeposition in both caves. The curious levels of trench D of the Hotu Cave (*Coon* 1952) have been partly radiocarbon dated by *Ralph* (1955) and the sediments analyzed by *J. P. Miller* (c. f. *Coon* 1952):

Gravels I. Angular gravels up to 1.5 inches in diameter; sheep, ox.

Gravels II. Same; sheep, red deer, ox with Subneolithic industry dated at 6115 B. C. ± 500.

Sands II. Fine calcareous sand or silt: sheep and gazelle.

Gravels III. Very angular limestone fragments up to 6 inches in diameter; sheep and ox.

Gravels IV. Angular limestone fragments up to 2 inches in diameter; sheep. (7235 B. C. ± 590).

Red gravels I. Blackish silt with rootlike calcareous fossils; molevole *(ELLOBIUS)*. (7265 B. C. ± 570).

Red gravels II. Same with *PHOCA* sp., gazelle, sheep; blade industry dated at 9905 B. C. ± 840).

Red gravels III. Reddish earth with great abundance of plant root ends.

Black layer. Fine calcareous sand or silt.

White clay (kaolin). Sterile.

There may well be climatic implications contained in this profile, but the inadequate geological analyses of these Iranian caves leaves much to be desired, so that particularly for the Hotu Cave very little can be said.

The faunal contents with one exception are not of particular interest, as the maximum of the ‚steppe form' *GAZELLA SUBGUTTEROSA* in the Late Mesolithic is likewise paralleled by maxima of the ‚moisture-loving' forms *BOS* sp. and *CERVUS ELAPHUS*. This one exception is the small species of Caspian seal, still extant to-day, of which 34 samples were found in the Belt Cave, 4 in the Hotu. Of these, 19 were found in the Belt layer dated at 9500 B. C., 8 in a slightly younger layer of the same cave, and three in the Hotu layer dated at 9900 B. C. so that one must assume that the Caspian shore, which had apparently only left the immediate area shortly before, was very close nearby, closer than at any other time since the beginning of the post-Late Chvalyn human occupation. The early late glacial level of 16 m identified by *Leontyev & Fedorov* (1953) is probably too high and it therefore seems feasible to place the 10—12 m ‚Dagestan Stadium' in the 10th and 9th millenia B. C. Stratigraphically the Belt profile merely shows that normal cave deposits during the 10th millenium preceded a return to arid conditions, as witnessed by the inter-Mesolithic loess lens which we believe represents one of the oscillations to an arid climate recorded in the upper 3—4 m of the Mazanderan loess by 3—4 alternating layers of light coloured loess and dark, clayey transformed loess beds *(Bobek* 1937). Similarly a brown cave earth layer in the Kara Kamar Cave (Afghanistan), dated at 8625 B. C. ± 300 *(Coon & Ralph,* 1955) suggests a return to moister conditions when compared with the previous loess deposition.

From this scetchy evidence one may, for the Near East, suggest the possibility of a moderate and temporary moist phase, which may possibly be associated with the last glacial relapse of the 10th millenium. It must be emphazised however that all postpluvial humid fluctuations cannot be compared with the pluvials proper, being relatively insignificant geologically. Their importance lies rather in the ecological environment they provided during the rapid development of the earliest Near Eastern cultures at this time. From all indications an identification with the Makalian phase of East Africa could one day be possible, but pending more conclusive evidence to the contemporaneity of ‚tropical' and ‚subtropical' pluvials we prefer to adopt a quite independent nomenclature here, not limited by regional or cultural designations. Consequently we shall simply and arbitrarily call those periods with a rainfall similar to or less than that of today by the term ‚Postpluvial' phase, with a suffixed number for purposes of identification. Similarly the post-Würmian moister intervals shall be designated ‚Subpluvial' phases, so that the original arid period from perhaps 16,000 or at latest 13,000 B. C. becomes ‚Postpluvial I', the moist interval of the 10/9th millenium B. C. ‚Subpluvial I', and the succeeding drier phase, ‚Postpluvial II'.

3. *Climatic Variation during the Early Holocene.*

a) The Postpluvial II Phase.

The weak moist phase described above and designated as ‚Subpluvial I' at best represented a temporary amelioration of moisture conditions, a prolonged interruption of the general trend of earlier postpluvial aridity which from all indications seems to have continued at least a millenium or two after the close of the Subpluvial I.

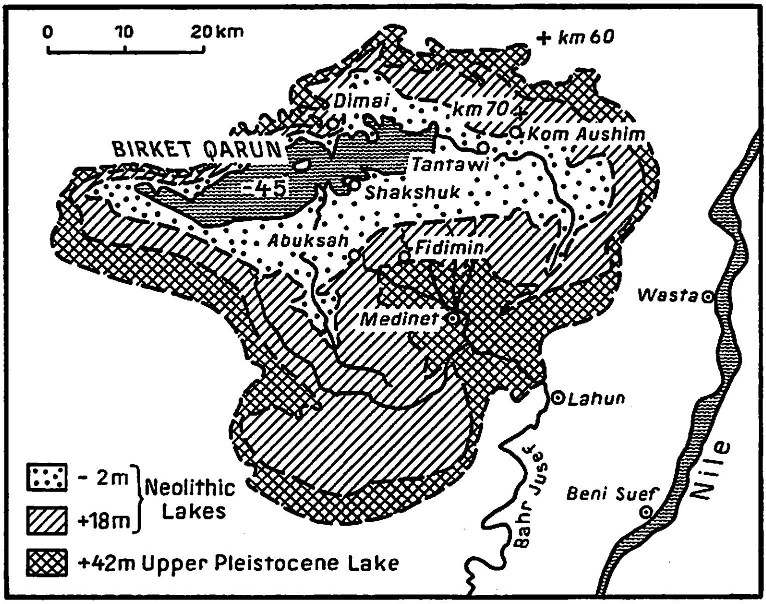
Throughout the Near East a lack of evidence to the contrary suggests that temperatures rose to their present values during the 8th millenium, while the waters of the world oceans rose rapidly in the so-called ‚Flandrian Transgression' as the continental ice masses rapidly disintegrated during the Preboreal and early Boreal. In response to this rising sea level the Nile will necessarily have begun to aggrade its bed, raising its level till it overflowed across the Hawara Canal into the Fayum a second time, giving rise to a new lake at 18 m of local pre-Neolithic date *(Caton-Thompson & Gardner* 1929, 1934 p. 15—17). The lack of any associated cultural sites or in fact of any ‚Mesolithic' implements per se suggests to us that the climate and vegetation of the unsubmerged parts of the oasis cannot have been very inviting to man. The Survey of Egypt *(O. H. Little* 1936) contended that the Fayum lake had a shoreline at 22—24 m somewhere between the 12th and 18th Dynasties, basing themselves on the typology of a single pot found in situ for the date. *Caton-Thompson, Gardner & Huzayyin* (1937) refuted these contentions, suggesting that the 22—24 m beach appears to be the storm-beach of the 18 m Neolithic lake. *N. M. Shukri & N. Azer* (1952) have been able to show indisputably on mineralogical grounds that the 22—24 m ‚Gisr' beach formations are of Palaeolitihic date, as the mineral content does not compare favourably with that of more recent Nilotic sediments. Consequently a free connection with the Nile a little above its present level at Beni Suef will already have provided the necessary gradient for the establishment of the 18 m lake. *Pfannenstiel* (1953) already noted that a rise in Mediterranean sea-sevel by some 5—7 m during the Flandrian Transgression (maximum perhaps about 4000 B.C.) would have dammed back the Nile to a higher level at least to the latitude of Beni Suef. To this one may add the greater Nile discharge evident from Khartum *(Arkell* 1948). Strong alluviation in the lower Nile Valley apparently led to a silting-up of the Hawara Canal at the time, as the 18 m Fayum lake began to drop shortly after its formation while the level of the Nile bed apparently continued to rise. The Fayum lake dropped slowly with successive halts at 10, 4 and - 2 m m. s. l., becoming increasingly brackish as is witnessed by the first appearance of the brack-water mollusc *HYDROBIA PERAUDIERI* in addition to the ubiquitous *CORBICULA AFRICANA* after the fall from the 18 m beach *(Caton-Thompson & Gardner* 1934). *Caton-Thompson &Gardner* maintain that the Fayum remained fully isolated from the Nile Valley until Ptolemaic times, and that the lake stands at the various levels from 10 to - 2 m were due to a greater rainfall than to-day which would have balanced evaporation. However it is physically inconceivable that precipitation ever counterbalanced evaporation in the Fayum basin in recent geological times. The present rate of evaporation of the Birket Qarun is 184 cm a year *(Shafei* 1952). With a lake level at +10 m the surface area of the former lake will have been 1290 km², the - 2 m lake 890 km². The annual evaporation of these bodies of water will have been at least 2.33 and 1.62 km³ annually, bearing in mind that mean temperatures were at least as great as now during the ‚Climatic Optimum'. The ‚drainage basin' of the Fayum Depression is some 5300 km^2 and providing an immediate loss of 50% by evaporation for precipitation not falling directly on the lake surface (in all probability well over 75%), an annual rainfall of some 700 mm would be necessary to supply the lake with 2.3 km^3 water annually. Such a figure is quite absurd in view of the geomorphology and relief of the northern part of Egypt. Surely a so moist climate would have left other tangible evidence in the Fayum area and elsewhere. One must imagine that a certain amount of Nile water entered by the Hawara Canal during the flood season peak each year, generally enabling the Fayum lake to maintain its level and counterbalance evaporation for the greater part of predynastic and dynastic times.

A similar return to more arid conditions in Palestine after the Subpluvial I is possibly indicated by a lower level of Lake Tiberias, where *R. Köppel* (1932b) found innumerable silex implements of preceramic date to a depth of 1—2 m below the present water level and to a distance of 20—30 m out from the present shore. Three primitive quais built at such a lower level suggest a post-Palaeolithic date. Further more conclusive evidence comes from the Belt Cave in Persia where the Mesolithic horizon dated in the 10th millenium by radiocarbon is overlain by a loess lens which apparently represents one of the final alternating layers of the southern Caspian loess *Bobek* (1937, 1953) has shown to be evidence of sizeable climatic oscillations. The normal cave sediments of the overlying Mesolithic horizon dated at c. 6600 B. C. is dominated by a steppe form *GAZELLA SUBGUTTEROSA* but also contains *BOS PRIMIGENIUS* and *CERVUS ELAPHUS*, which with the absence of loess suggest an unmistakable trend to moister conditions, probably with a climate not much different than that characterizing the present.

Briefly, following the Subpluvial I there was apparently a relapse to more arid conditions for possibly some 1—2 millenia which were gradually replaced by a climate closer to that of the present during the first half of the 7th millenium.

b) The Subpluvial II Phase or Neolithic Moist Interval.

The climatic improvement already noticeable during the later stages of the Postpluvial II stage took on an important character in the following centuries and deserves recognition as a second ‚Subpluvial Phase' which was characteristic of the Near Eastern Neolithic *par excellence*, and probably this climatic improvement was associated with the rapid spread of the earliest food-producing economy and the establishment, or rather the resumation of widespread cultural contacts and intercommunications during the ‚Neolithic'. The existence of such a prehistoric moist phase has been suspected for many years now (*Caton-Thompson & Gardner* 1929, *Bate* 1940) but no systematic study of the overall evidence has been made to date so that its duration and character were quite differently assessed by the individual authors. So does *S. A. Huzayyin* (1941), for example, give a date of c. 5500—2500 B. C. (inferring from the European chronology), *G. W. Murray* (1951) c. 8000—4000 B. C. while *H. Bobek* (1953) even speaks of a pronounced arid phase from c. 9000—4000 B. C.



Map 2: The Upper Pleistocene and Holocene Lakes of the Fayum depression (based upon G. Caton-Thompson and Gardner 1934).

Firstly in the Hagfet et Tera Cave, Cyrenaica, the stalagmite horizon A_{III} ushered in a damper phase characterized by the clayey terra rossa of A_{II} with *CERVUS* sp., *BOS PRIMIGENIUS, BOS* sp. and *EQUUS CABALLUS* (?). The associated fairly evolved Capsian-type blade industry overlies the Upper Palaeolithic material sensu stricto and contains no traces of Middle Palaeolithic elements. The younger Capsian in Tunisia has been radiocarbon dated at 6450 and 5050 B. C. (± 400) while the Neolithic of Capsian tradition gave a date of 3050 B. C. (± 150) according to *Kulp, Tyron, Eckelman & Snell* (1952). A 6th millennium date for this Hagfet et Tera horizon appears not too unlikely, provided the contained industry permits such a correlation. *G. Knetsch* also identified a Capsian moist phase (7) in the Djebel es Soda where from the presence of ostrich shells he estimated a rainfall of over 200 mm, and from local red earth formations in the Central Sahara (really contemporary?) a rainfall of 300 mm, compared with 150 mm to-day.

In Northern Egypt, the Fayum was colonized by Neolithic peoples after the establisment of the 10 m beach, as the earliest sites of this industry are found on ground left dry by the falling 18 m lake. Radiobarcon dates of this Neolithic ‚A' industry have yielded figures of 4440 B. C. ± 180 and

4144 B. C. ± 250 (*Arnold & Libby* 1951, *Libby* 1951). In view of the Libyan material and since the earliest Neolithic of the Haua Fteah Cave, Cyrenaica, which should be a little later than the Egyptian Neolithic in general, has been dated at 4850 B. C.± 350 by Suess (1954), a date of about 5500 B. C. should be reasonable. At the close of the Neolithic ‚A‘, the prehistoric Fayum lake began to fall again, temporarily regained an equilibrium at 4 m and then dropped further to — 2 m (m. s.. l.) at which level the formation of an impressive, salient beach, as well as the archeological evidence, suggest a very constant level of perhaps 1700 years, remaining static throughout predynastic times, and extending at least into the period of the 4th Dynasty (c. 2600—2480 B. C.) whose settlements were found along the shoreline (*Caton-Thompson & Gardner* 1934). The absence of landshells in the beach deposits, however, indicates that either there was insufficient rain to give rise to a continuous mat of vegetation or that the drainage was only short and intermittent (*Caton-Thompson & Gardner* 1934, p. 16—17). Some of the floral remains of Old Kingdom date preserved in association with the 10 m lake are *CYPERUS PAPYRUS, HELEOCHARIS, HORDEUM, LATHRYUS* and birch bark, the latter also occurring in Old Kingdom gravels at Kafr Ammar. The fauna included ox, tortoise, fish, *HELIX DESERTORUM,* and judging by a camel hair rope, also the camel.

M. Amer & Huzayyin (1952) have identified several ‚cycles‘ of gravel deposition by lateral wadis interrupted by limited local erosion at the site of Ma'adi. The physiographical sequence following the deposition of the ‚20 m silts‘ is:

1) Local erosion of silt by lateral activity;
2) Deposition of coarse gravels and sands by the Wadi Diglah. After this the Nagada II (Gerzean) settlement flourished at Ma'adi;
3) Renewed erosion of the abandoned settlement fringe;
4) Deposition of new gravel and sand;
5) Mild erosion of surface;
6) Local deposition of fine sands and occasionally of very fine, banded yellow silt in pools caused by rain or fed by water from torrents.

This aggradation of the Wadi Diglah suggests a return to moister climate at least during the whole of Nagada I and possibly until the Early Dynastic period. Greater fluviatile activity is also witnessed by a pebble horizon at Merimde dated stratigraphically above the lowest settlement layer (before 4000 B.C.) by *H. Junker* (1933), and in Upper Egypt the gravels overlying the site of Badari (4000 B.C.) were cemented by a calcareous material, probably during a moister period (*Brunton & Caton-Thompson* 1928, p. 72).

Even in the more elevated areas of the Sahara there was apparently a relative increase in precipitation at the time. The artifacts of the Khargan ‚Beduin Microlithic‘ (Haua Fteah ‚Microlithic‘ dated 5350 B. C. ±300 by *Suess* 1954) are not found near the mound-springs but are lightly embedded in the silt pans collected by rain wash and run-off on the Kharga Scarp, suggesting that the intervals between rain were less prolonged at the time (*Caton-Thompson* 1952, p. 34—5). The rock pictographs incised upon the exposed boulders and scarps throughout the now utterly barren Libyan Desert and the Fezzan, as far south as latitude 22° N in Egypt, were first classified by *D. Newbold* (1928) into the following groups:

A) Bushmen series (Late Palaeolithic and Early Neolithic). Realistic giraffes and ostriches.

B) Early Libyan (Later Neolithic to Old Kingdom). Older and better drawings of hunters, cattle, sheep, horses and antilopes.

C) Middle Libyan (Middle and New Kingdom). More recent, simplified and conventionalized drawings of the same array.

D) Roman and later. Dromendaries and dogs.

The full array of the drawings further includes ibex, oryx, gazelles, lions and even people in the posture of swimming (Gilf Kebir). *L. Frobenius* (1937) who observed pictographs of an almost savanna-like fauna in the Fezzan wadis Issaghen and In Habeter, identifies a group of wild animals (including elephants, rhinoceros, buffaloes, crocodiles, wild sheep, giraffes and ostriches), and a group of domesticated animals. However he only speaks of converging cultural groups and does not recognize any chronological sequence, adopting a general Capsian date. The petroglyphs are here all in wadis near springs, in contrast to the more scanty fauna represented in the emptiness of the Libyan Desert, but there is also local evidence of greater moisture, as for example a small lake once exceeding 10 m in depth at In Habeter (*Frobenius* 1937, p. 8). *O. H. Myres* (1939) referring to the countless sites with instruments, ostrich shells, shell-beads, querns and grinders spread across the Libyan Desert between Nile and Uweinat suggests a late Upper Palaeolithic or ‚Neolithic of Capsian tradition' date (the latter industry dated at 3050 B. C. in Tunisia, c. f. *Kulp* and others, 1952) and in all cases they preceded the general use of pottery in the area. Most recently *P. Graziosi* (1952) has reorganized the whole material of the Fezzan into four further subdivisions:

1) ‚Berguig hunters' series (Neolithic). Large, naturalistic representations of tropical fauna (elephants, rhinos, giraffes), hunters, wild game and possibly domesticated oxen (which *Frobenius* however identifies as *BUBALUS* sp.).

2) ‚Pastoral art' series. Naturalistic pictures of oxen large and small, hunters, rhinos, giraffes and ostriches. However the elephants are poorly made, conventionalized and infantile, suggesting they were now extinct in the Fezzan and merely drawn from tradition.

3) ‚Bitriangular series' (after 1600 B. C.). Appearance of horses and horse-carriages, disappearance of the rhinoceros.

4) ‚Camel series' (after 500 B. C.). Decadent and found only along wadis and at water holes. The giraffe, ostrich and horse have disappeared along with the domesticated ox.

Graziosi connects the first series of the Fezzan with the fresh traces of water action in the dry wadi Masauda, and with stations such as Bir el Kelb on the border of dried playas.

H. A. Winkler (1938/39) permits an even sharper chronological correlation for the animals depicted on the grafitti of the Upper Egyptian deserts:

1) Nagada I (Amratian) and earlier (i. e. to c. 3600 B. C.). The ‚Earliest

Hunters' and ,Early Oasis Dwellers' in both the Libyan and Eastern Deserts depicted a multitude of giraffes, elephants and ostriches.

2) Nagada II (Gerzean) (c. 3600—2850). The giraffe and elephant have become scarce on the drawings of the ,Early Nile Dwellers' and the ,Autochtonous Mountain Dwellers'.

3) Dynastic Period (c. 2850—332 B. C.). The giraffe, elephant and ostrich are no longer depicted, the attention of the artists being limited to the array of gazelles, antelopes, ibex and domesticated species. Lions first cease to be drawn during the Arab period, after the 7th century A. D. with certainty.

The occurence of the giraffe, elephant and ostrich in the Libyan and Eastern Deserts can only presuppose a more luxuriant vegetation and a somewhat greater precipitation, as all three favour a savanna or parkland and avoid the drier steppes. As they are further difficult to hunt we can assume they were not exterminated by man at this early period, leaving only the possibility of a climatic explanation. One could suppose the rainfall declined a little during the 4th millenium, and again very sharply about the time of the 1st Dynasty about 2850 B. C. This last is born out by the lack of native elephants, giraffes or ostriches on Egyptian documents after the generous development of tomb reliefs beginning with Snofru about 2600 B. C. Elephants in particular appear very frequently on slate palettes and ivory pieces dating from shortly before the historical unification of Egypt under Menes. A systematic investigation of the ungulates pictured on Egyptian monuments is under way by the writer, and there appear to be good indications of a certain decimation of the remaining local fauna between the end of the 5th and beginning of the 12th Dynasties (c. 2350—1990 B. C.). To-day, with the exception of an odd ibex or a few gazelles in the remotest areas, Egypt is almost devoid of game animals, nor would the vegetation outside of the riverine zone be capable of supporting the great variety of antilopes, gazelles, ibex and deer appearing in the Old Kingdom tombs at Gizah, Sakkara, Medum and Abusir. The dry snap indicated by the faunal evidence about 2850 B. C. coincides strikingly with the interval of erosion (3) at Ma'adi, while we assign the last climatic deterioration following the 5th Dynasty (c. 2480—2350 B.C. after *A. Scharff*, (1950), to the onset of modern climatic conditions at the end of the Subpluvial II phase.

The main period of aggradation of the ,lower terrace' of the Jordan Valley is connected with a grey-black marshy loam, well seen overlying the gravel horizon and a 70 cm light grey loam to a depth of 1 m in the Eddesiye profile *(Picard* 1932). The further occurence of this grey-black soil to a depth of 1 m between Jenin and Affule in Samaria, reaching to the bottom of the wadis and containing mollusca which cannot live in any of the dry wadis of the area to-day, suggests a meso-neolithic period of greater rainfall and greater warmth to Picard. Similar black earth layers have also been found in the Wadi Musrawa and at Tel Aviv (*P. Range* 1938), in the southwestern Carmel area *(J. Vroman* 1938), as well as at Ksar Akil and Tripoli *(Ewing* 1951), where one contained Mesolithic tools at its base. From a study of the zoological biotypes found in the post-Natufian or early Neolithic level of the Abu Usba Cave, Mount Carmel, *Stekelis & Haas* (1952) have suggested a period of somewhat greater rainfall than the present, possibly amounting to 70—80 cm or over (compared with 55—60 cm to-day). Typical steppe species are absent, and reptilian types such as *OPHISAURUS APUS, AGAMA STELLIO* and *CHAMAELEO CHAMAELEON*, numerous thrushes and the mollusc *CYCLOSTOMA OLIVIERI* all favour a quite dense vegetational cover and usually exist under somewhat more bountiful rainfall conditions. In Arabia, *H. Philby* (1933) found gravel beds and other lacustrine deposits containing fresh-water molluscs. These deposits in the northern fringes of the Rub al-Khali contained innumerable Neolithic-type implements. In the Hasa, *P. B. Cornwall* (1946) found a chalcolithic site situated beside lacustrine sediments likewise abounding in fresh-water shells near Uquair. This former lake bed remained dry even after a 100 mm rainfall in December 1940, the influx of drainage barely able to form small channels in the overlying sediments. In general there is much evidence in favour of a numerous Neolithic population in the Syrian Desert, living with an abundance of water, pasture and game (*S. Passarge* 1951, p. 473—4). In Baluchistan and the Makran, Sir *A. Stein* (1934) found numerous chalcolithic sites marked by great stone barrages (Gabar-bands) intended to serve as reservoirs and secure irrigation for valleys which are now utterly desolate, which fact *Stein*, an opponent of ‚climatic change‘ in historical times, can only explain by a substantially moister climate some four millenia ago.

As an interesting sidelight the biblical references to the Deluge are confirmed in ancient Babylonian tradition, and the Gilgamesh Epic found in Assurbanipal's library seem to suggest a catastrophic storm in Mesopotamia accompanied by strong winds, unusually great electricity, and much rainfall extending over a period of several days and causing at least a part of the Lower Euphrates delta plain to be temporarily inundated. Stratigraphy seems to have confirmed this controversial legend, in particular since *L. Woolley* (1954, p. 31—35) was able to find as 8—11 foot thick uniform layer of water-lain mud, material brought down from the middle stretches of the Euphrates and deposited in water at least 25 ft. deep upon the Neolithic site at Ur. The flood layer of Ur separates the Ubaid I and II horizons, and must date from about 3700 B. C. (*H. Quiring* 1950). The occupation of Uruk only took place in later times, so that this level is missing there[16]). One may at least speculate upon the meteorological implications of the phenomenon. At the present time major floods occur on the Euphrates when exceptionally great quantities of winter snow in Anatolia are suddenly melted by strong, warm and moist southerly winds which add their own precipitation to the swollen rivers. However permanent snow

16) *Lees & Falcon* (1952) have shown that *Woolley's* flood is not contemporary with many other known floods of early historical date. These authors attribute the various floods to earth movements on the basis that the plain of Iraq is a tectonic basin still subject to periodic subsidence to-day. As well as this may be, severe floods are bound to reoccur episodically in an alluvial basin originally but little controlled by human hand. Whether the Ur flood is the Deluge or not is of course problematical, particularly as contemporary floods are not confirmed from elsewhere.

was at a lean minimum during these millenia, as *S. Erinc* (1952) was able to state that the present cirque glaciers of Anatolia, and in particular the Mt. Erciyes glacier, are generally recreations following an almost total disappearance, most probably during the Climatic Optimum. Consequently an extraordinary amount of rainfall in the central portions of the drainage basin in particular appears to have been mainly responsible, possibly aided by southerly winds damming back the flood waters and preventing their escape into the Persian Gulf.

In review, the close of the 6th millenium was marked by an increase in humidity and rainfall sufficiently great, despite the accompanying rise of temperatures during the Climatic Optimum, to permit the flourishing of a more exubriant fauna and flora in areas climatically unsuitable today, and was thereby of great significance to the human habitant. From the archaeological and geomorphological evidence from Egypt and the Sahara there were apparently two temporary decreases in rainfall during the Subpluvial II, one of them after Nagada I (c. 3600 B. C.) and the other in Early Dynastic times after about 3000 B. C. Although of minor importance geologically speaking, morphological traces nevertheless are not lacking and help substantiate the other evidence, so that one can again count with a rainfall on a scale somewhere between that of the present and that of a genuine pluvial.

Chronologically the Postpluvial II a and b would coincide approximately with the Preboreal and Boreal periods respectively in Europe while the Subpluvial II clearly was almost synchronous with the Atlantic phase. From a meteorological standpoint this chronology and climatic succession proves to be of considerable interest, as it has long been a popular theory that the postglacial Climatic Optimum corresponded to an extensive period of maximum aridity in lower middle latitudes. Further below it shall be noted that the Postpluvial III phase, which coincides more or less with the European Subboreal, was more arid than the present day, so that there appears to be a curious parallelism between moisture trends in Europe and in the Near East.

c) The Postpluvial Phase III.

The climatic fluctuations of the last 4000 years have not been of sufficient duration or magnitude to leave much physiographical evidence, and it becomes increasingly necessary to resort to archaeological evidence and literary sources. Following upon the last moist spell of Subpluvial II the rainfall of the Near East deteriorated severely and during the maximum of the short but variably quite arid period, the Postpluvial III as we shall designate it, the average annual precipitation of the Near East was less than that of any other time since c. 6800 B. C.

It appears that the ancient Fayum lake began to fall after the end of the 4th Dynasty (c. 2480 B. C.) stopping briefly at a level of —11 m and this fall continued to at least —13 m, at the time when Ptolemy Philadelphus (285—247 B. C.) began the systematic project of reducing the lake to its present low level at —45 m, reestablishing the connection with the Nile by excavating the silted-up Hawara Canal (*Caton-Thompson & Gardner* 1929, 1934). There appears to have been a general exodus from the Libyan Desert in 5th and 6 th Dynasty times, represented by the (Temehu) Libyans and the Nubian C-group, a feature apparently associated with the abandonment of many Neolithic sites in the Sahara and the impoverishment of the savanna fauna of the rock pictures during the last half of the third millenium. A pronounced reduction of rainfall and pasturage in Egypt and the Libyen Desert quite certainly took place after 2400 B. C. from all considerations of the evidence.

As a first literary source the Old Testament may be cited, since the biblical references to severe droughts and catastrophic famines have a definite bearing to rainfall conditions in ancient Palestine. Particularly, attention should be drawn to the fact that of over eleven specific references to severe and prolonged droughts or famines found in the Bible[17]), only two belong to the period after 850 B. C. We find reference to such droughts in the days of Abraham (c. 1800 B. C.), Isaac and Jacob, during the rule of the judges, and the reigns of David (c. 1010—970 B. C.) and Ahab (876—53 B. C.). Furthermore *R. Köppel* (1932a) describes a Dead Sea level of —8 m on the grounds of a submerged marine erosional bench for which he suggests a date of c. 2500—1200 B. C. on acount of a specific Bronze Age type implement nearby. It may also be recalled that the A_2 horizon of the Umm Qatafa Cave suggests a climate less humid than the present during the Bronze Age.

It has been suggested by some archaeologists that the number of known Neolithic and Bronze Age sites from the steppe of Mesopotamia are in the ratio of 5 : 1 and implying that many settlements had to be abandoned after the middle of the third millenium due to a declining rainfall. In the Asterabad loess area, *H. Bobek* (1937) points out that the numerous Bronze Age tepehs of the area were obviously occupied at a period when the luxuriant forest was replaced by steppe and loess deposition, probably recorded in the final oscillating layer of the upper loess. And in the Karakum Desert, *A. Schultz* (1927) identifies a period of recent desert conditions during which the mobile dunes, found especially in the vicinity of the Amu, came into existence at a time corresponding to the European Subboreal. After the 10—12 m Dagestan stage some 10—12,000 years ago, the Caspian Sea fell slowly but steadily, temporarily regaining an equilibrium at the —4 m Samur stage and then dropping to a —20 to —22 m level known as the Mangyshlak Stadium (*Leontyev & Fedorov* 1953). From trends as known from Europe (the Volga Basin!) and as delineated here for southwestern Asia, the Mangyshlak probably was contemporary to the Subboreal and Postpluvial III, rather than to a period 4—6000 years ago as the Russian authors suggest without any reason. A large estuary of gravels and boulders up to 30 cm in diameter built up by the Samur at a —3.5 to —4 m level suggests the river carried considerably more water than to-day (as no gravels are transported this

17) I Gen. 12; I. Gen. 26; I. Gen. 43; I. Gen. 47; Ruth 1; II Sam. 21; I Kings 17, 18; II Kings 4; II Kings 6; Joel 1; Jeremiah 14.

far now), which speaks in favour of placing the Samur stage in the Subpluvial II. Although fairly fresh abrasional strandlines occur at —4, —8 and —12 to —14 m (below present level) in Alexandrov Bay, there is actually no proof of a post-Chvalyn date for the submarine Mangyshlak forms other than shelly sand beds similar to present beach sand incompletely overlying the submerged marine terraces with their foot at 20—21 m below present level. We believe it far more possible that at least a great part of these last submarine features are of considerably older date belonging to the interpluvials. In the Sarykamish Depression the water inflow of the Daryalk and Dandan arms of the Amu let off steadily in Late Uupper Pleistocene times and the lake sank from 58 to 0m m. s. l. (*Tolstov, Kess & Shdanko* 1954). This 40—45 m deep lake was inhabited by *CARDIUM EDULE* and may possibly be of post-Dagestan age, although *Grahmann* holds that this brack-water mollusc actually survived throughout the Chvalyn in favoured localities and only began to spread out again with increasing salinity of the waters. *Tolstov, Kess & Shdanko* believe this condition remained until the end of the Bronze Age, after which the lake was left entirely to itself and reduced to a playa.

At Enkomi-Alasia, Cyprus, *C. F. A. Schaeffer* (1952, p. 358—9) identified six gravel beds alternating with sand, which at least suggest a period of particularly abundant rainfall. An alluvial layer of almost 1 m depth accumlated after this, stratigraphically dated at 1150—1100 B. C.

All in all the existence of a dry period between c. 2400—850 B. C. seems relatively certain, although the indications of a temporary fluctuation in the late 12th century B. C. from Cyprus suggest that the maximum aridity had been reached before that date, possibly midway in the 2nd millenium. But that the Postpluvial III phase was by no means over until at least 850 B. C. is borne out by the repeated biblical references to very severe droughts in the early 1st millenium B. C. Chronologically this Postpluvial III period corresponds well with the European Subboreal, just as the Subpluvial II was contemporary to the Atlantic of Europe. The climatic relationship as regards a pattern of the general atmospheric circulation is not quite so obvious, and presents an inviting problem for further research.

4. Climatic Fluctuations during the historical Period (after 850 B. C.)

a) Introduction and Review of the Criteria.

Perhaps our best evidence to show that moister conditions of greater permanency had set in comes from *Wright's* geological study (1952) of the archaeological sites of the Chemchemal Plain in Kurdistan, where alluvial fill deposited to a depth of almost 10 m in a deep erosional gully of the Qadhai Chai contained pottery tentatively identified as Late Assyrian (750—600 B. C.). However none of the other rivers nearby were sufficiently advanced in their cycle of erosion to go over from degradation to aggradation, a process absent in the general area since the pluvials. Probably this isolated and temporary exception records a fluctuation to moister conditions.

From this time onwards climatic conditions in the Near East seem to have approached a norm resembling that of the present in all respects. One may deduce this largely from a lack of evidence to the contrary. From the scanty historical information available from literary sources we can do little more than suggest that the last five centuries B. C. were very similar to the first half of the 1st millenium A. D. In later Roman times we know a little more, and this situation is considerably improved in Byzantine and Islamic times. However before going into detail it will be advisable to discuss two of the criteria — the Caspian Sea fluctuations and the complex of Nile high and low water levels.

Although *E. Brückner* (1890) believed the Caspian Sea level fluctuates in direct proportion to the high-water level of its by far most important tributary, the Volga, *L. S. Berg* (1934) has pointed out that whereas the rainfall of the Volga drainage basin increased after 1881, and especially after 1900, the Caspian has fallen steadily, alone by 3.5 m during 1900—1925[18]). Evidently the evaporation over the Caspian or over the whole watershed increased considerably. *A. Wagner* (1941) believes that since only the winter rainfall of Russia had increased, the evaporation over the northern watershed remained the same, and he concludes that evaporation over the Caspian itself, in all probability over the southern half of its great expanse must have increased. An indication that the Caspian Sea fluctuations tend to reflect Near Eastern moisture as well as local temperature trends can be obtained by a comparison of the recorded variations of the annual maxima of the Dead Sea *(M. R. Bloch)* and the Caspian *(W. Köppen* 1936, *G. A. Taskin* 1954) for the only comparable, 17-year period 1929—1945. The linear correlation of the relative movements of both non-outlet lakes is fair, yielding a coefficient of correlation of $r = + 0.30$, compared to negative correlations with river discharges (Tigris, Euphrates, Diyala) in the Near East. The long-term (e. g. 5-year) fluctuations of the Dead Sea (J. Enge 1931; Table X) and the Caspian *(Köppen* 1936) show a quite satisfactory correlation and one may at least consider the historical fluctuations of the Caspian Sea as a criterion of Near Eastern climate.

Table X. Dead Sea Levels 1928—1946.
(The Dead Sea Works Ltd., courtesy of *M. R. Bloch)*

1928	393.13	(meters below m. s. l.)	1938	395.04
1929	392.07		1939	395.00
1930	392.78		1940	395.02
1931	392.84		1941	395.25
1932	393.29		1942	395.26
1933	394.00		1943	395.16
1934	394.57		1944	394.99
1935	394.64		1945	394.45
1936	395.17		1946	394.29
1937	395.40			

18) The Baku guage measurements (published in *Köppen* 1936) only show a drop of 80 cm during 1900—1925, a figure more compatible with absolute measurements taken at various intervals during the last 125 years.

Table XI. **C a s p i a n S e a L e v e l s 1 9 2 8 — 1 9 4 5.**
(from data published by *W. Köppen* 1936, and *G. A. Taskin* 1954).

1928	309	(cms. with respect to the Baku guage)	1937	224
1929	327		1938	193
1930	315		1939	163
1931	303		1940	147
1932	311		1941	143
1933	308		1942	152
1934	286		1943	155
1935	267		1944	153
1936	246		1945	134

The curious pattern of Nile levels has long proved to be a perplexing problem, which is by no means simplified by the doubtful reliability of most of the data. However as a first point a clear distinction must be drawn between total v o l u m e, and high and low-water l e v e l s. Very interestingly the total Nile waterflow 1871—1900 was 10% above average while that of 1901—1920 was 14.5% below normal (*Hurst, Black & Simaika* 1951), which is in full accord with the mean annual precipitation of Jerusalem amounting to 736 mm in 1880—1900 and 660 mm in 1900—1915, not to mention the 80 cm fall of the Caspian during 1900—1925. This again lends support to the theory that rainfall trends north and south of the Sahara are very similar. However the problem of high and low-water level patterns is a little more complicated, and other than that we know that the flood-level is solely determined by the Blue Nile and its tributaries in Ethiopia, while the equatorial drainage entering through the White Nile above the mouth of the Sobat makes up less than 5% of the Nile volume (*W. Pietsch* 1910), we do not as yet fully understand this pattern of maxima and minima. Guage measurements from the Roda Nilometer near Cairo have been recorded since A. D. 622 with several interruptions. However the unscrupulous falsification of the figures for revenue purposes lends great questionability to all but the most recent figures (*H. G. Lyons* 1905), and the shifting alluvium of the river bed renders the average flood height inaccurate so that only the difference of low water and flood levels is of any use (*Brooks* 1926). In view of these difficulties the Nile flood levels should already fall out of consideration, but these classical results have a peculiar fascination which has captivated many past researchers. Most recently *J. Hövermann* (1954) has reconsidered the postulate of Anaxagoras, suggesting that solid precipitation persisting over a longer period as a snowcover in the highest regions would not combine with the flood maximum and pass unnoticed a little later, at least as far as the guages were concerned. However the present climatic snowline lies at 4700—4800 m (*J. Werdecker* 1955) so that the lower limit of snowfall — even if we set it as low as 3500 m to account for any fluctuations during the historical period — will not even include 2.5% of the Ethiopian drainage basin of the Nile. Obviously such an explanation cannot hope to account for the peculiarities of the Nile floods, nor can any satisfactory reason be given why the seasonal distribution of rainfall should vary appreciably from year to year, something which is not, strictly speaking, applicable in any part of the monsoonal rainfall zones. Nevertheless it is not illogical that, following *Hövermann,* seasonal distribution and absolute amounts of precipitation in Ethiopia, as well as the historical fluctuations of the lower limit of snowfall will all have played a part in making the problem rather complex. Consequently, lacking Nile volume measurements from before 1868 we can only cite some of the outstanding features of the Nile floods and their variations, without being able to offer any precise explanation of the latter.

b) The classical Period (500 B. C. — A. D. 600).

A generation ago it was a common axiom that the Graeco-Roman-Byzantine period, characterized by great economic wealth and an expansion of settlement and civilization into the fringes of the marginal lands, was a Golden Age blessed by bountiful rainfall with running waters and fertile oases in what is now desert. But the renowned publications of *E. Huntington* (1911 et al.) and *L. Caetani* (1911) were not the first exposition of this concept of progressive desiccation since pluvial times, they were merely the last and greatest exponents of a classical and now almost forgotten theory. Already *Al Mas'udi* (French translation 1861, p. 219), writing in A. D. 942, puts the following words (translating freely) into the mouth of a very aged man spoken to the Muslim general *Khalid:*

> ‚I can remember having seen a woman of Hirah leave on a journey with nothing but a loaf of bread as provision, since right until her arrival in Syria, she passed nothing but flourishing villages, well cultivated fields covered with fruit trees, and a myriad of ponds and running waters. As you see, there is nothing but waterless desert to-day.'

The somehow fascinating evidence of Roman bridges and piers in permadently dry wadis, well-heads, spring-houses and inscriptions referring to springs where none exist to-day captured the imagination of *Huntington, Caetani, H. C. Butler* (1920) and many others. It is a tempting and alluring picture but lacking in genuine conviction. Most of these ruins in Syria still fall within the 200 and many even within the 500 mm isohyet to-day, and *E. Kirsten* has shown that the appearance of Syrians in great numbers throughout the western Roman Empire during the 6th century A. D. should prove that the ‚villes mortes' were abandoned due to the insecurity resulting from the Byzantine-Sassanid wars (especially the internecine struggles of A. D. 572—591 and 603—628.) Only the topic of disused wells and cisterns deserves mention. To-day many of the wells are repaired, some remain dry and all too many are no longer economically feasible with what little water they have. A few examples should suffice. Roman wells at El Heita and El Sagia in the Wadi Qena, Egypt, were cleared but found to be virtually useless *(W. F. Hume* 1925, p. 133). *L. W. B. Rees* (1929) could prove that the water table at El Azrak, Jordan, had fallen by 2 m since classical times, and *H. J. L. Beadnell* (cited by *Murray* 1951) *mentions* that a shaft was passed through 22 m of moist sandstone before reaching the actual water level at Bir Misaha, west of

Aswan. The water table has really fallen, but this is not necessarily a matter of decreasing rainfall in historical times, for it appears that the ground water of the deserts is largely fossil, i. e. derived from the pluvials of the Pleistocene.

In short, although we believe small-scale variations of climate occurred continually during historical times, we nevertheless strongly negate any overall climatic change in the sense of progressive desiccation within the last 2500 years. In addition to the historical data cited below for the Nile levels *(O. Toussoun* 1925; *C. E. P. Brooks* 1926, 1931) and the Caspian Sea fluctuations *(E. Brückner* 1890), we have used data from the detailed weather chronology assembled by *R. Hennig* (1904) as supplemented from *N. Ekholm* (1901). Unless otherwise mentioned these sources have been used ad libidem to identify the short-term fluctuations of the historical period below.

Table XII. Ptolemy's Weather Record.
(as worked out by *Brooks* 1931 and Miss *L. D. Sawyer* 1931).

Wind frequency in Alexandria.

Ptolemy after	N	NE	E	SE	S	SW	W	NW	Variable
Sawyer	11	0	2	2	30	8	25	14	8
to-day	35	11	7	4	5	5	5	25	3

Days with	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Rain (Ptolemy)	4	3	0	5	3	1	2	0	3	4	3	2
Fine rain (Ptolemy)	1	0	1	3	4	5	0	0	2	0	2	2
Rain to-day	11	6	5	1	1	0	0	0	0	1	7	10
Thunder (Ptol.)	1	0	1	1	2	2	1	1	1	0	0	0
Thunder to-day	.7	.5	.3	.2	.3	.1	0	0	0	.4	.7	1.5
Great heat (Ptol.)	0	0	0	0	0	3	8	6	1	0	0	0
Great heat now	0	0	0	2	6	12	0	1	3	2	0	0
Weather changes after Ptolemy	4	0	3	2	4	0	2	1	4	1	0	1

According to *Herodotus* the Nile floods of the mid-5th century B. C. were relatively high, as they also were again during the 1st century A. D. according to both *Strabo*'s and *Pliny*'s accounts, while there is evidence of a great drought lasting many years in Central Asia about A. D. 80. However the Nile floods became considerably lower during the 2nd century (after *Plutarch* and *Aelius Aristeides),* and the traveller *Cosmas* refers to perennial snowfields in Ethiopia at the time *(Hövermann* 1954). The year 145 is signalled out by catastrophic floods throughout the Mediterranean. It is noteworthy that *C. E. P. Brooks* with Miss *L. D. Sawyer* (1931), after investigating the weather record of Claudius Ptolemy (observabat A. D. 127—151) taken at Alexandria, believe the observations were actually taken in Alexandria but that they only record abnormal weather conditions. *Brooks* believes that the two entries of rain in July and four entries of thunder for June to August indicate occasional, rare depressions interrupting the steady, fine summer weather of the eastern Mediterranean basin. *Ptolemy* records south winds on five occasions as well as three weather changes during July and August, whereas such conditions are unknown to-day. Great heat was further concentrated in July and August, whereas to-day May and June are the hottest months. If these observations really are authentic documents recording conditions in Alexandria, we may infer along with the other data that the first half of the 2nd century was moister than the present, and that this century as a whole was moist in contrast to the drier 1st century A. D.

There are records of great heat and drought around A. D. 260, and about 310 Cyprus suffered from 36 years of extraordinary drought. In A. D. 333 the level of the Dead Sea, which *J. Enge* (1931) has shown to fluctuate in proportion to the local rainfall, was the same or probably a little lower than that of the present. Between 360 and 363 there are further indications of droughts in Asia and Africa, but by the close of the century, a period of moister and cooler conditions set in. The Nile floods of the last half of the 4th century were higher (according to *Ammianus Marcellinus*) and there was an abnormally great rainfall in A. D. 395, while the winters 400/01 and 418 or 421 were extremely cold. In 401 the Black Sea was supposedly frozen for twenty days (*Ekholm* 1901). This more humid phase was cut off about A. D. 450, and the years 454 and 484 were very dry.

In the 5th century A. D. we encounter one of the first historical levels of the Caspian, where the Red Wall of Aboksun (c. f. *Huntington* 1919, p. 319) supposedly built by the Sassanid *Firuz* (A. D. 459—484) to keep out the White Huns (who ruled western Turkestan c. 375—567), is submerged by at least 3.5 m of water to-day. Since the Sassanids counterattacked the White Huns effectively after A. D. 425 and by 455 had diverted their attention towards India, this time interval seems reasonable. *Leontyev & Fedorov* (1953) note that the material employed in building the quais and wall of Derbent somewhere between the 6th and 8th centuries indicate a long-term stand at —3 to —4 m (‚Derbent stadium'). Following another severe drought from A. D. 512—517 in Palestine, moister conditions prevailed until the late 6th century when we can point out four phenomenally critical years 591, 593 or 594, 598 and 605 or 606 when a period of uninterrupted drought and heat lasted nine consecutive months in the Byzantine Empire. Arab legends further records a seven-year drought ‚in the days of Muhammad', a severe drought in A. D. 630, and during the nine month long drought of the ‚Year of Destruction' in 640, the heat ‚burnt the soil of Arabia to ashes' as the Arabic authors have put it (*K. W. Butzer* 1955, p. 110, 117—118).

c) The Islamic Period.

All indications show that there was an extremely dry snap between about 590 and 647 which latter date marks the gradual beginning of a long series of seldom interrupted records of very cold winters or wet years in Asia Minor such as 673, 717/18, 763/64, 800/01, 829, 859/60 and 1010/11, which are curiously paralleled by exceptionally low Nile floods between A. D. 700—1000, which reached an absolute minimum A. D. 750—800.

Table XIII. Characteristic Nile Floods per Century.
(after Prince *Toussoun* 1925, esp. p. 366—411, from Roda guage)

Century	Weak	Good	Strong
5 B. C.	6.89 meters	8.48	9.54
1 A. D.	7.42	7.48	9.54
2	6.36	7.42	8.48
4	6.89	7.95	9.01
7	5.99	6.87	7.79
8	6.64	7.43	8.11
9	5.99	7.17	8.26
10	5.99	7.70	8.69
11	5.74	6.59	7.41
12	5.76	6.77	7.66
13	6.29	7.17	8.18
14	6.35	7.50	8.62
15	5.69	6.90	8.00
16	7.70	8.38	9.10
17	7.06	7.68	8.40
18	7.49	8.34	9.22
19	6.13	7.75	9.26

When *Istakhri* visited Derbent between 915 and 921, six salients of the wall were submerged so that a Caspian level of +10.3 m above the present is suggested by *Brückner*, but submerged houses at Baku and in the Bay of Resht imply a —2.7 m level during the 12th century. Perhaps this temporary low level occured at the time of the accentuated dry years 1158—60 in the Mediterranean world, since the years 1099/1100 and 1129 were still cooler and humid in the Near East. After this drier interval, the Caspian rose very rapidly at the end of the 13th century and attained a maximum of 12.7 (?) m. supposedly reaching a well-known holy grave, before it began to fall again in A. D. 1307. Although *Berg* (1934) would discount this and the 915/21 maximum on the grounds that the indicating mollusc, *CARDIUM EDULE*, of the modern Caspian Sea does not occur ‚continuously' above +6 m, such very temporary high levels cannot be expected to produce wholesale movements of the mollusca, while the excuse of ‚sheer accidents' cannot explain the numerous exceptions to this +6 m continuous occurence of *C. EDULE*. Neither can the mediaeval inflow of the Amudarya be called upon to account for this high level, since Russian work on the Sarykamish Depression *(Tolstov, Kess & Shdanko* 1954) has revealed that there has been no recent noteworthy or sustained flow of water in the Uzboi Canal, as the Bronze Ages sites of the lowest Uzboi terrace have not been disturbed. Between the 14th and late 16th centuries a branch of the Amu once again found its way into the Sarykamish, and from four different irrigation systems dated archaeologically, a 50—52 m relative level was attained about A. D. 1400, falling to 10—15 m during the 15th and again reaching 20 and then briefly 30 m during the 16th centuries. Since the Uzboi threshhold lies at 52—55 m, only small amounts of water at the times of maximum expansion will ever have entered the Caspian.

During the early 15th century the Caspian rose once again, flooding parts of Baku, and simultaneously the Nile flood-levels were so low 1398-

1421 as to cause severe famines in Egypt. The flooding of the Sarykamish and of Baku at the beginning of the 15th century may be related and connected with a somewhat greater rainfall in the Caspian drainage basin, and in the Amu headwaters, possibly inducing the latter to bifurcate again. It should be noted that the last great flood of the Amu in 1878 did precisely this, with a result that a short-lived 8 m lake was recreated in the Sarykamish. For the last three centuries of the present era, the Caspian levels have been analyzed by *L. S. Berg* (1934) whose chief and more convincing results are given in Table XIV.

The next information comes from the first half of the 17th century, when we note some very cold winters in Asia Minor such as 1608 and 1621 when the Bosporus was icebound, as well as the lowering of the climatic snowline with a readvance of the Near Eastern glaciers. *H. Bobek* (1940, 1937) identifies numerous moraines of Fernau age in Kurdistan, implying a considerable advance of the Cilo and Sat Dagh glaciers, while similar moraines occur in the Tacht i-Sulaiman group of the Elburz. *S. Erinc* (1952) has assigned a major advance to the Anatolian glaciers during the 17th century, confirming the observations of *R. Leutelt* (1935) in Lazistan. The snowline depression appears to have been between 50 and 100 m in both Iran and Turkey. Whereas the Ethiopian highlands enjoyed little or no snowfall in the 16th century, the snowline apparently hovered at about 4200—4400 m in the early 17th century according to many detailed travel descriptions of contemporary Europeans (*Hövermann* 1954).

Table XIV. Caspian Sea Levels since 1550 A.D. (after *L. S. Berg* 1934) (variants from *E. Brückner* 1890).

Date	Source	Meters above 1925 level (-26.2 m msl) (+ 263 cm Baku guage)	
1556	*Hanway*	—0.3	
1580	*Burrough*	—0.1	
1636	*Olearius*	1.1	(*Brückner* 1638 = + 5.2 m)
1668/70	*Stryuis*	1.7	
1716	*Bell*	0.3	
1719	*Ban-Berden*	0.6	(*Brückner* 1715/20 = + 0.6 m)
1720	*Ban-Berden*	0.1	
1722	*Hanway*	0.0	
1723	*Soimonow*	0.6	
1726	*Soimonov*	0.9	
1742	*Tatitchev*	2.8	
1743	*Tatitchev*	2.5	
1744	*Tatitchev*	2.2	
1764	*Tokmauev*	2.7	
1765	*Tokmauev*	2.8	
1766 and 79	*Rosen*	3.0	
1797	*Rosen*	2.6	
1809/14	*Kolodkin*	3.0	(*Brückner* 1815 = + 2.7 m)
1820	Survey map	1.8	
1821	*Muravlev*	1.5	
1823	*Basargin*	1.1	
1824	*Basargin*	0.8	
1825	*Basargin,Sokolov*	1.4	
1830	*Mikhalevskii*	0.8	(*Brückner* 1830 = + 0.7 m)

(for guage readings since 1839 see *W. Köppen* 1936)

d) The most recent Past and Conclusions.

In Lazistan *Leutelt* (1935) identified a slight glacial readvance whose terminal moraines resembled those of the 1850 stadia of the Alps in terms of vegetation cover, oxidation and freshness of forms. Similarly *Erinc* (1952) noted terminal moraines of similar age at 3150 m for the Erciyes glacier compared with Fernau moraines at 3040 m. *Bobek* (1940) remarks that the Mia Hvara glacier of the Cilo Dagh was 3—400 m longer while the Gavaruk glacier was 500 m longer and 15 m thicker during the middle of the last century. Similarly there was a subrecent stand of the Sercal glacier of the Tacht i-Sulaiman with a snowline depression of 50 m *(Bobek* 1937). The date seems quite likely as the Azau-Baksan glacier in the Caucasus advanced very rapidly and overran a spruce forest in 1849, reaching its maximum extent since at least two centuries *(Wagner* 1941, p. 68—9). Between 1873—1911 it retreated some 1.5 km from this stand. From a number of travel descriptions from Ethiopia, *(Hövermann* 1954, *Werdecker* 1955) it appears that while the lower limit of snowfall was at about 3300 m during the years 1830—50, little or no snow fell in Abyssinia during the last half of the 18th century, as has been the case since about 1880. Since this last general advance there has been a fairly steady retreat of the montane glaciers that has been accelerated since the 1930's. *Erinc* (1952) further observed that the Mia Hvara glacier's tongue retreated from 2550 m to 2800 m between 1937—1948, and that of the Suppa Durak from 2600 to 2900 m during the same period. This retreat strongly suggests the ‚recent climatic fluctuation' experienced in higher middle latitudes, and a glance at the meteorological means from long term records of a few stations (c. f. *H. H. Clayton* 1927, 1934, 1947) lend some support to this:

Alexandria	m. a. t. 1871—1910:	20.53°	1911—1940:	20.73°C
Beirut	m. a. t. 1875—1920:	21.15°	1921—1940:	21.55°
Bushire:	m. a. t. 1878—1910:	24.1 °	1911—1940:	24.1 °
Krasnovodsk	m. a. t. 1881—1910:	15.67°	1911—1940:	15.73°

Analyzing a few selected time intervals, *L. Lysgaard* (1949) was able to show this trend even more conspicuously:

Alexandria					
	January	1884—1913:	13.6°	1911—1940:	14.4°
	July	1884—1913:	25.5	1911—1940:	25.8
	Year	1884—1913:	20.2	1911—1940:	20.7
Beirut					
	January	1884—1913:	13.3	1911—1940:	14.0
	July	1894—1923:	27.5	1911—1940:	28.0
	Year	1893—1922:	20.9	1911—1940:	21.3

However opposite trends occur in the records of both Athens and Quetta. More universal and distinctive for the Near East has, however, been the decrease in precipitation during the last two generations. Employing the world weather records, the following can be said about mean annual precipitation:

Alexandria	1887—1910:	220 mm	1911—1940:	173 mm
Beirut	1876—1910:	932 mm	1911—1940:	863 mm
Bushire	1877—1910:	284 mm	1911—1940:	261 mm
Quetta	1878—1910:	246 mm	1911—1940:	230 mm

so that one can speak of a general, considerable decrease of rainfall which is paralleled elsewhere as well. If we average the decrease from these four long term records for the years 1881—1910 and 1911—1940, one could give a first approximation of 10—15% for this overall decrease on the 60-year mean. That this decrease is distinctly borne out in the non-outlet lake levels of the Caspian and Dead Seas as well as by the Nile volume has already been referred to above. Ecologically this climatic deterioration has also made itself felt, and whereas travellers' descriptions indicate a rapid extinction of organic life and increasing desolation in the Libyan Desert and in Tibesti (*Hassanein Bey* 1936, *W. Thesiger* 1939), a sharp decrease of rainfall in Syria during 1920—1934 resulted in a series of bad crop failures. However as the well known temperature trend of higher latitudes was interrupted since 1938 by the repeated occurence of very cold winters, the decline in Near Eastern precipitation has apparently been reversed, the cold winters of higher latitudes most often being accompanied by bountiful rainy seasons in the eastern Mediterranean basin. It does appear likely that the present climatic fluctuation and thereby the menacing desiccation of the Near East has at least been interrupted.

Reviewing the climate of the historical period, it is clear that there has been no long-term trend of desiccation ‚since Roman times', rather we may divide the associated climatic phase, for which the name Postpluvial IV is suggested, into two subphases of which the first of IVa period c. 850 B. C. — A. D. 700 was generally characterized by lake levels equal to or lower than those of the present, by numerous records of warm summers and severe droughts and few references to cold winters or wet years; the subsequent Postpluvial IV b phase, except for two intervals in the 12th and 20th centuries, was characterized by Caspian Sea levels well above those of the present, by many cold winters and other indications of a greater rainfall or lower evaporation. In short, the earlier IV a subphase (at least its second half) was a little warmer than and also drier than the later IV b subphase. Within this latter period we can identify distinct but temporary maxima of humidity from A. D. 700—1000, during the late 13th, the early 15th, the first half of the 17th and the beginning of the 19th centuries.

5. *Summary and Conclusions.*

The results of the above investigation of climatic variation during the postpluvial period complements and rounds off the sequence arrived at in Chapter 5, and our last results and suggestions may be briefly and tentatively summarized below the headings of the different climatic phases identified for the Near East in the course of Chapter 6, and which replace the provisional physiographic stages 1—5 outlined in the previous chapter;

POSTPLUVIAL I. During this period following the close of the Würm Pluvial II about 16,000 B. C., wind-erosion was particularly pronounced, temperatures apparently still a little lower, and the rainfall of the Near East somewhat less than that of the present, probably reaching a minimum during the 12th millenium. At least one distinct moister interval falls within this period but was of shorter duration and less morphological significance than the subsequent moister phases.

SUBPLUVIAL I. (probably about the 10/9th millenium B. C.). A moderate and likewise temporary improvement of rainfall conditions seems apparent. It appears that a last readvance of the disappearing Würm glaciers took place at about this time, accompanied by lower temperatures effective to at least as for south as latitude 33° N.

POSTPLUVIAL IIa. (Perhaps 85/8000—6800 B. C.) Following the temporary humid relapse probably associated with the last glacial readvance of the late 10th millenium, temperatures rose and typical postpluvial conditions of aridity set in with a rainfall a little less than that of the present.

POSTPLUVIAL IIb. (ca. 6800—5000 B. C.) marked on improvement in precipitation, characterized by moisture conditions closely resembling those of the last century of our era.

SUBPLUVIAL II. (c. 5000—2400 B. C.) This Neolithic moist interval, as it has already been called, enjoyed a rainfall somewhat greater than that of the present despite indications of higher local temperatures. A higher rate of evaporation consequently implies that the increase in precipitation was appreciable, probably on a plane halfway between that of a pluvial and modern conditions. There appear to have been temporary decreases in rainfall shortly after 3600 B. C. and again about 2850 B. C.

POSTPLUVIAL III. (c. 2400—850 B. C.). A renewed decrease in precipitation during the late 3rd millenium led to a longer period of variable arid conditions probably accompanied by greater warmth, with an average rainfall a little below that of the present, but interrupted by at least one quite moist spell (in the 12th century B. C.).

POSTPLUVIAL IVa. (c. 850 B. C. — 700 A. D.) Ushered in by a short interval of quite moist conditions, the period was characterized by a rainfall about the same as, or rather a trifle less than to-day, but subject to continuous small-scale fluctuations over an appreciable range, such as the humid spell in the early 2nd century A. D. In general the winters still appear to have been a little warmer. A very severe drought between perhaps A. D. 590—645 can be determined, which however, only represents a minor climatic fluctuation prior to a change to slightly different conditions of rainfall and temperature.

POSTPLUVIAL IV b. (c. 700 A. D. to the present). After about A. D. 650 an increasing number of quite cold winters were recorded in the Near East, during which the Black Sea was apparently ‚frozen' on two occasions (in A. D. 673 and 800/01), and ice even formed on the Nile (in A. D. 829 and 1010/11). The rainfall was a little higher on the average but marked by continuous short-term fluctuations over a fairly wide range. Only since 1900 can one speak of a certain climatic deterioration which has been destructive to organic life in such marginal pastures as the elevated plateaus of the Libyan Desert. This very recent climatic fluctuation is associated with a 1—15% decrease in rainfall, a fall in level in lakes with interior drainage, a decreased Nile volume and a retreat of the peripheral zone glaciers. In contrast to the rainfall trend there seems to be no fully general tendency to higher temperatures and one is inclined to see a major cause of the retreat of the glaciers in a decrease in precipitation, in itself largely confined to the winter season, and not exclusively in a temperature amelioration.

Chapter VII: The Atmospheric Circulation of the Near East during the Upper Pleistocene and Holocene

1. Introductory Comments.

Attempts at a reconstruction of the atmospheric circulation of the Pleistocene glacial epochs have been many and varied, and no attempt to give an exhaustive survey of them will be made here. Several authors have earned the priority with general surveys that have, despite much dissension, served as the starting point for most subsequent researchers. The comprehensive studies of *F. Klute* (1928, 1930) were founded on physical and empirical facts drawn especially from glacial morphology, and many of his most important conclusions are still held as common axioms to-day. *G. C. Simpson* (1934) occupies a leading position in the English-speaking world on the basis of his theoretical treatise just as *A. Penck* (1913) in Germany who scetched the groundlines of the earliest theoretical reconstruction some twenty years earlier. In following years the works of *W. Meinardus* (1937), *Klute* (1949) and *G. Viete* (1949, 1950) all contributed to the solution of circulation problems associated with the subtropical pluvials. After this, one may speak of a certain revolution within the concepts usually applied in this field, ushered in by the parallel work of *H. C. Willet* (1949, 1950) and *H. Flohn* (1950). However the recent acceleration of activity in the field of palaeoclimatological research has gone even further, and in the most recent articles of *Flohn* (1952, 1953) and *C. C. Wallén* (1953) one may view some of the most advanced aspects of meteorolgical experience.

Before we can discuss, criticize and supplement the work of *Willet* and *Flohn,* complemented by that of *Klute, Meinardus* and *Viete* on the topic of the pluvials, it is necessary to refer to *Simpson*'s theory of pluvials at first. *Simpson*'s reconstruction in effect demands four glaciations and two pluvials, so that the First Pluvial would correspond to Günz, Günz/Mindel and Mindel, the Interpluvial to the Mindel/Riss and the Second Pluvial to the Riss, Riss/Würm and Würm glaciations. Apart from the extreme inlikelihood of four such schematic glaciations, our whole investigation with regard to the Saharo-Arabian desert complex has yielded results highly unfavourable to this hypothesis. The Early Würm stage was seen to correspond to a distinct pluvial phase which appears to have continued in a weaker form after an interstadial during the Würm maximum. Previously the climate was similar to that of the present, and there is no hint of a pluvial maximum during R/W as *Simpson's* scheme would demand.

Another theory, representing an all too common heresy that can be refuted on empirical as well as on theoretical grounds, it that of *J. Dubief* as presented by *L. Balout* (1952). *Dubief* and *Balout* believe that the jet stream moved equatorwards during glacial while the stronger ‚etesians', due to an intensified circulation, blocked the monsoons (of West Africa). During the interglacials the jet stream and the ‚etesians' were weakened, permitting the monsoonal rains to penetrate far northwards bringing showers to the edge of the Atlas. Firstly, it should be pointed out that the trade winds (the ‚Etesians' of *Balout)* depend upon the structure of the subtropical high pressure belt and that a well developed jet stream ranging far southwards is usually accompanied by a disintegration and weakening of the high pressure belt and the associated trade winds. Secondly the empirical evidence does not support a shifting desert belt, rather most indications suggest that tropical and subtropical pluvial episodes occur simultaneously. Not only have we found a ‚pluvial' (or better Subpluvial) along the poleward margins during the Climatic Optimum, but also a real pluvial in the same area during the Würm Glaciation, and not a period of desiccation and aridity as *Balout* has suggested. Both these moister intervals are unequivocally associated with local intensifications of the Mediterranean westerly circulation, and pluvial characteristics become increasingly weaker going southwards from latitude 30 to 23° N so that we can not regard a southerly source of moisture at all feasible (c. f. also *Butzer* 1957c).

2. *General atmospheric Circulation Patterns.*

H. C. Willett (1949) and *H. Flohn* (1950) have identified two distinct types of circulation patterns which in their opinion show a trend towards glacial or interglacial climates. In the words of *Willett* (1949, p. 46), „the nature and the sense of the changes of the general-circulation pattern during the geological epochs is essentially the same, on a larger scale, as that which occurs in the climatic, secular and anomalous variations of the general-circulation pattern." These two circulation patterns will be reviewed briefly below according to the concepts of *Flohn* (1952, 1953).

The high index or zonal circulation pattern is characterized by a well developed jet-stream, little disrupted by travelling shallow cold waves and warm air thrusts. The polar high is weak and often replaced by an upper air trough, while the subpolar low pressure belt and the subtropical high pressure belt, each divided into separate cells, are well developed. The zone of maximal frontal activity is shifted polewards, the trade wind circulation is disturbed only by occasional shallow cold waves and cyclonic activity in the tropics is only moderate.

During periods of low index or meridional circulation the planetary westerlies are weakened and dominated by very extensive quasistationary wave movements. Extensive upper air troughs extend far equatorwards and introduce polar airmasses into the tropics, while tropical air reaches far polewards in compensation[19]). There is a corresponding divi-

19) When disturbances in the middle and upper troposphere over low latitudes combine with troughs in the polar westerlies, the resulting upper air troughs may reach from pole to equator and poleward flow of heat probably takes place mainly along such troughs (*H. Riehl* 1950).

sion in the lower atmosphere where a pronounced warm anticyclone often develops over the polar areas, the subpolar low pressure belt is largely dissolved, and the zone of maximal frontal activity is shifted towards the equator. The subtropical high pressure cells are weakened and separated by discernible troughs disturbing the normal trade wind circulation, and permitting deep cold waves to invade the tropics, favouring a more lively and increased cyclogenesis in the equatorial convergence belt.

It is now generally accepted that periods of low index circulation bear resemblance to a glacial circulation, while we suppose that a very pronounced high index circulation pattern should approximate to that of an interglacial and ultimately of the ‚normal climate' of geological time. However *Flohn* is careful to emphasize that the rapid fluctuations of the glaciers during recent decades is an indication that the only two stable conditions of the Arctic Ocean are a complete glaciation and a complete absence of ice. In view of the latter, meteorologists lack actualistic experience with a full interglacial circulation, and any speculations in this direction must be guided by caution.

Although the general trend since 1850 and especially since 1900 has been the dominance of a high index circulation, *Flohn* points out that the cold winters of the years 1928/29, 1939/40, 1941/42, 1946/47, 1948/49 were ushered in by world wide low index circulation anomalies, during which the upper air troughs were deepened and shifted westwards or southwestwards and deep cold waves penetrated into the tropics where they favoured the development of tropical hurricanes and similar disturbances in the easterlies. The persistant upper air minima over Central Europe from 1939 to 1942 introduced cold air masses into the Mediterranean Basin and further, leading to abnormally great rainfall as far as the Sudan, and more frequent cyclonic disturbances passed from the Black Sea into Central Russia. Simultaneously the frontal zone lay far equatorwards due to blocking action in the upper atmosphere in low latitudes[20]), leading to a greater rainfall during the Mediterranean summer. Similarly the world wide advances of the glaciers in the 17th and early 19th centuries were in all probability associated with phases of low index atmospheric circulation.

The only great variation between the work of *Flohn* and *Willett* pertains to the subtropical dry belt which the latter believes to be strengthened and shifted towards the equator. *Flohn* however strongly believes that the horselatitudes were narrowed in from both sides and the trades weakened. The last seems to be better substantiated by the morphological evidence, as well as by meteorological principles (*K. W. Butzer* 1957c).

Unfortunately we cannot put a finger on a similar dictum for the interglacial periods, although *Flohn* (1950) refers to the periods of pronounced high index circulation of the last decades during which the subtropical

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20) ‚Blocking action' is characterized by a breakdown of the upper westerly circulation flow over the eastern Atlantic or Pacific into a more cellular motion with quasi-stationary wave disturbances superimposed upon the zonal motion, so that the flow pattern changes abruptly, and is characterized by a surface anticyclone (‚blocking high') just downstream from the point of breakdown (*D. F. Rex* 1950). The more meridional type of blocking action is connected with the appearance of a series of cyclonic and anticyclonic vortices.

high pressure belt shifted up to 5 or 10 degrees latitude polewards with resulting droughts over wide areas in Europe, Asia and North America. Nevertheless there are some very strong negating factors to an identification of greater mean world temperatures and longer periods of intense high index circulation as we know them, as it was possible to show that the Climatic Optimum, which was 2—3° C warmer than to-day on the average, corresponded to periods of greater moisture, at least in part, throughout the Saharo-Arabian deserts and elsewhere in subtropical latitudes as well.

It was to account for this discrepancy, which he had already been able to recognize, that *S. A. Huzayyin* (1936, 1941 p. 137—146) proposed the concept of two distinct types of interglacial atmospheric circulation (following the earlier definition of *G. C. Simpson)* connected with w a r m and c o o l interglacials, of wich the former are humid and the latter dry in subtropical latitudes. However empirical evidence weighs too strongly against such a notion as all the interglacials were ‚warm' interglacials, as is witnessed by the raised beaches which in all probability indicate a greater melting of the residual ice masses.

This objective analysis of the general circulation anomalies of extreme years as particularly carried out by *Flohn* and *Willett* is of incommensurable value not only in presenting a theoretical justification of our conclusions and a qualitative reconstruction of the Würm circulation, but in understanding the mechanisms involved in the small- and long-term variations of climate we have noted during our survey of the Holocene period.

3. The meteorological aspects of the Near Eastern Climatic Succession.

The local intensification of the westerly circulation of the Mediterranean during the glaciations is almost universally recognized, but very little attention has ever been focused upon the possibility of recognizing distinct stages of pluviation corresponding to the periods of ice formation and to the duration of the ice maximum. It is to the credit of *G. Viete* (1950, 1951) that a clear emphasis has been put upon the two distinct types of atmospheric circulation necessarily accompanying the formation of the continental ice sheets and during the period of the glacial maximum. The former was particularly characterized by large-scale solifluction, a cold oceanic climate and possibly cool summers; the latter coincided with widespread loess deposition and a much drier, cold continental climate *(Büdel* 1950). The preciser classification and synthesis of *Woldstedt* (1956) gives a similar picture with the main solifluction associated with the Early Würm advance, but also with the Main Würm readvance, and chief loess deposition during the Stettin, Brandenburg and Pommeranian stadia. In essence the periods of glacial advances and readvances were, from all considerations of the evidence, moist and cool in Europe, those of the glacial standstills, cold and dry. Consequently in a broad way one could designate the Early Würm climate predominantly oceanic and moist, the Main Würm as predominantly continental and dry. Although *Flohn* (1953) has also given consideration to this distinction as well, the possible effect on the pluvials has been neglected so far.

It was noted in Chapter 5 that the Würm Pluvial of the Near East was directly associated with Würm I (in the sense of *Woldstedt, Gross, Ebers* etc.[21]) and particularly so with its earlier stages. The Würm I was in fact very considerably moister and certainly not as cold as the Würm II. The Würm Pluvial II on the other hand was very weak, passing unnoticed south of 22° N with only incomplete traces of pluviation preserved further north, apparently reserved to the earlier, readvance stadia of Würm II. On the basis of a contemporary snowline depression of 700—800 m and the deep-sea cores we postulated at 4° C decrease of mean temperature from the local upper air lapse rate of the atmosphere. *H. Poser* (1947) notes that in maritime, oceanic climates the summer temperatures would be most pronouncedly effected, while in a continental climate the winter temperatures would be more effectively modified, something quite feasible for the Near East from considerations of the present-day circulation. For purposes of ablation, such a temperature decrease is less effective in preserving the ice fields during the summer and we suggest that this factor was largely responsible for the relatively small depression of the snowline, rather than a decrease in solid precipitation.

However, although we do maintain some pluviation during Würm II, we suggest the possibility of the effective rainfall increase being locally limited to an intensified westerly circulation in a belt between perhaps 25—38° latitude, north of which, very particularly in the montane regions, the reduced rate of evaporation accompanying the 4° C temperature decrease may have been as effective as the absolute increase in rainfall. This can be theoretically supported by some further considerations, as the Siberian anticyclone, less exposed to the penetration of barometric minima in the westerlies and intensified by the presence of the glaciers and lower temperatures will have been much deeper, persistant and effective than to-day. However the postulated local intensification of the westerly circulation in latitudes 25—38° will have counteracted any appreciable blocking of eastward moving depressions within the Near East proper. Secondly, the 90—100 m marine regression will have laid the entire Persian Gulf dry, removing that source of atmospheric moisture, particularly for Iraq, while the expanded surface of the Caspian will not have increased precipitation due to colder waters and the more extensive cover of ice during winter.

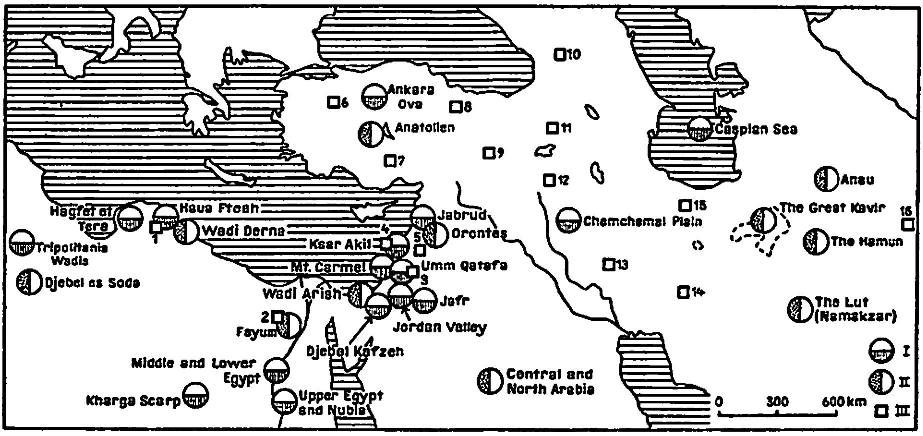
Accordingly the atmospheric circulation of the Last Pluvial maximum during Würm I deserves some attention here. The lack of a great continental ice sheet to the north, at least till the last stages serves to lessen the complications and enables us to conceive of the general atmospheric circulation as a simple intensified phase of low index type. The implications of this type of circulation pattern have been fully discussed above and we prefer to discuss some of the implications in particular and in detail. *El Fandy* (1946) notes that if the centre of the important Cyprus low lies near to the African coast so that the isobars run more or less north-south for a good distance inland, then rainfall in Egypt is generally heavy and

21) In the remainder of this section Early Würm = Würm I, Main Würm = Würm II for the sake of simplicity.

extends for greater distances inland than when the centre of the low is farther north and the isobars have the usual west-east position. With the equatorward shift of the westerlies and their intensification in latitudes 25—38° N, just this can be expected to happen. Similarly the variations in intensity of the low is practically governed by the fluctuations of the polar current (*El Fandy* 1946), and a low index circulation is highly favourable to frequent invasions of intensely cold and deep polar airmasses. Persisting deep Cyprus lows are further responsible for long spells of cold in the Eastern Mediterranean Basin, although the evidence from the Haua Fteah Cave suggests that Würm I was not excessively cold locally, and that maximum cold was reserved for Würm II. To restate, the atmospheric circulation of Würm I appears to have been an example of a classical period of intensified low index pattern.

During Würm II we must count with the general lowering of mean temperatures by 4° C, a factor of not inconsiderable significance. The temperature gradient of the Libyan Desert to the Mediterranean may possibly have been weakened a little, enabling travelling depressions to continue in more southerly or southeasterly directions instead of taking the general west-east route. Lower upper air temperatures as well as a lowering of the level of condensation will have appreciably increased the frequency and amount on convectional rainfall. In short, possibly excluding the montane areas of Anatolia and northwestern Iran, one should expect a greater rainfall for Würm II in comparison to the Würm I, which discrepancy can only be explained by a radically different general circulation. *W. Meinardus* (1937) points out that the decrease of evaporation due to a lowering of temperature is proportional to the absolute temperature and would amount to less than 2% of the total evaporation. Consequently one cannot describe the general decrease of temperature of the world oceans as the primary cause in changing the world condensation cycle. However *Meinardus* points out that the increase of evaporation with increasing wind velocity is appreciable, being proportional to $\sqrt{W}$ where W is the wind velocity in meters per second. The Old World loess deposits — also in the Near East — as well as the Palaeolithic storm beaches of the Fayum — may suggest locally stronger winds, a possible factor increasing the evaporation over the Near East and thereby counterbalancing the lower rate of evaporation due to the temperature decrease. Nevertheless the presence of the great ice sheet, which *Klute* (1949) still calls a thermal and baric cold hearth, has so complicated the picture that one can no longer explain everything in terms of general circulation patterns. Although there was a relative increase in precipitation in lower middle latitudes and in the tropics, the overall picture appears to be one of a marked slackening of the condensation cycle in comparison to the Würm I and to the present.

With regard to the intervening interstadial - intrapluvial there is not much to say other than that there was evidently an indifferent and relatively drier phase separating the two submaxima of the pluvial. However the interstadial, probably a period of high index circulation, cannot alone be held responsible for the change in atmospheric circulation between Würm I and Würm II, as the recovery of the lost ground as well as the achievement of the maximum extent of the glaciers should at first again require a circulation identical with that of Early Würm or Würm I, a major phase of glacier formation.



Map. 3: Distribution & Classification of Würm Pluvial-Glacial Evidence.

I. Sites with evidence for a two phased Pluvial with WPI 〉 WPII
II. Clear evidence of a Pluvial with no possibility of Differentiation
III. Evidence of decresed temperatures

1. Haua Fteah	7. West Taurus	13. Mazar Herd
2. Fayum	8. Pontic Mtns.	14. Zardeh Kuh
3. Umm Qatafa	9. East Taurus	15. Elburz Mtns.
4. Ksar Akil	10. Caucasus	16. Hindu Kush
5. Mt. Lebanon	11. Armenia	
6. NW Anatolia	12. Kurdistan	

A far as the late glacial period is concerned there appears to have been a complete cessation of pluviation in the Near East by the time the great retreat of the Nordic ice sheet was underway, and during the final stages of the Lower Dryas period the aridity of the Near East increased to achieve a climax about 14,000 years ago during the pre-Alleröd period. The increasingly unfavourable moisture conditions before the onset of the Subpluvial I ca. 9500 B. C. are certain judging by widerspread evidence from all parts of the Near East, although we do not know whether the interruptions of the retreat of the ice corresponded to slight fluctuations of greater rainfall. Suggestions to this effect may be inherent in the 9—10, 7—8 and 3—5 m wadi terraces of the Kharga Scarp which chronologically fall between Würm Pluvial II and the Neolithic Subpluvial II. The deterioration of the ice was obviously a result of increasing temperatures and an unfavourable atmospheric circulation.

The Subpluvial I, tentatively assigned to the 9th millenium and associated with a final cold snap seems due to a temporary phase of pronounced low index circulation, characterized by the Mankato-Salpausselkä glacial stadia. Thereafter during the Postpluvial IIa and b conditions appear to have been similar to the late glacial phase Postpluvial I — arid, and possibly still associated with appreciably stronger desert winds (khamsin) and greater wind erosion and deposition. Once again the aridity and slowly increasing temperatures appear to have been world-wide, suggesting a reduction in the world condensation cycle. The Subpluvial II, however, presents the most curious problem associated with the entire chronology. Why should a phase most resembling an interglacial climate in view of a world-wide rise of temperature by 2—3° C not display characteristic interpluvial conditions in the Near East? The period corresponding to the European Atlantic was distinctly moist in these subtropical latitudes, as *Huzayyin* (1941, p. 137—46) realized phen he attempted to consider the Climatic Optimum as the type model of a ‚warm' interglacial climate. Firstly he suggests that a rise in temperature would lead to increased evaporation over the oceans and an all around acceleration of the circulation system over the whole earth so that moisture bearing currents penetrated far into the continents. This is already quite unlikely as the increased evaporation of the oceans due to a 2—3° increase in temperature is insignificant. *Huzayyin* goes further to state that the reduction of cold anticyclonic fronts would permit storms to take less defined courses, and „stray" southwards into the Sahara for example. This is of course directly opposite to the truth, as the increased horizontal temperature gradient of Sahara-Mediterranean would be more inducive than ever to make travelling depressions follow a zonal flow pattern due eastwards. Although *Huzayyin*'s concepts are inapplicable, we cannot offer a solution to this riddle at the moment. This phenomenon only serves to show so very clearly that present meteorological theories are still very deficient, as no satisfactory explanation can be provided. And why should suddenly the last third of the thermal maximum, corresponding to the European Subboreal be dry?

This brings us to proposition (1) of this meteorological analysis. There has clearly been a striking correspondence between moisture trends in Europe and the Near East compared phase by phase so far. The moist oceanic climate associated with the Würm I was contemporary to the Würm Pluvial proper (WP I), while the greater moisture necessarily implied by the glacial readvances of early Würm II and of the Upper Dryas coincided with WP II and the Subpluvial I respectively. Both the Atlantic and the Subpluvial II were moist, and again the contemporary Subatlantic and Postpluvial IV were moister than the preceding phases. On the other hand the dry or drier periods of Europe — the interstadial[22]), later Würm II, Late Würm (with exception of the Upper Dryas), Preboreal, Boreal and Subboreal — had remarkably close counterparts in the intrapluvial, and the Postpluvial phases I, IIa, IIb and III. In brief one could parallelize that every third-order drier or more humid fluctuation in the European climatic succession corresponded with a tendency to more arid or moister conditions respectively in this sector of the subtropics. This can possibly be explained by world-wide accelerations or decelerations of the condensation cycle if one could show an identical case for the tropics. As our know-

22) Judging by the shrinkage of the glaciers and the absence of solifluction, the interstadial was most probably a little on the dry side in Europe.

ledge of palaeoclimatology does not permit such a postulate as yet, and as there are no satisfactory physical explanations for such a phenomenon, it may prove better to search elsewhere for another answer within the broad belt of the circumplanetary westerlies, very possibly in a more complicated process of blocking action than is envisaged in the simplified notions of a zonal or meridional circulation pattern. The patterns of rainfall decreases or increases with relative frequency and persistance of upper air ‚blocking' noticeable on the illustrating maps in *Rex* (1950) do not present any coherent picture separating the Mediterranean and temperate climatic provinces, in fact, such a division does not seem to be apparent at all.

The parallelism of increased cold in Europe with increased moisture in the Near East, e. g. the early Middle Ages, the late 13th, early 15th, early 17th an early 19th centuries, seems fairly close for the historical period, and the recent climatic fluctuation seems to indicate the converse so that the useful applicability of the low and high index circulation types theory cannot be denied. On the other hand, the peculiar individuality of the Climatic Optimum as well as proposition (1) have illustrated that simple invocations of either of these two flow type patterns cannot hope to explain the totality of cases arising from a comparison of the European and Near Eastern climatic successions for the last 100,000 years. Thus proposition (2): although the ordinary meridional or zonal atmospheric circulation pattern types are of great applicability and value in palaeoclimatic reconstructions, they cannot account for the totality of meteorologic situations appearing from geologic evidence within the Quarternary. As a possible solution it is suggested that upper air blocking patterns are a more highly complicated phenomenon than the circulation types of *Willett* and *Flohn* can account for in their present, elementary form.

It was noted that WP I was probably cooler than to-day but there is little evidence available in this regard, being almost entirely reserved in favour of an appreciable temperature lowering during WP II. Similarly the overwhelmingly greater part of the pluvial evidence is associated with WP I rather than WP II, and with the early stages of both. This phenomenon implies unequivocally that great changes in the atmospheric circulation patterns, apparently in the form of a pronounced low index type, set in at the very onset of the glacial phase preceding any appreciable world-wide lowering of temperature (proposition 3). This means that the circulation pattern changes were not a secondary result of a universal ‚cooling-off' and the appearance of ice-sheets, rather since the circulation changes per se were of greater world-wide significance during the initial stages of the glaciation we insist that either temperature and circulation changes were simultaneous and dependent upon a higher primary cause, or that the latter were earlier than the former. However temperature was not the initial primary factor involved in the changeover from interglacial to glacial period. Proposition (4): the primary ultimate cause of glaciation is to be sought in variations of ultra-violet or particle emissions of the sun and not in absolute variations of solar radiation, as already suggested by *Willett* (1949a, 1950) and originally conceived by *Huntington & Visher* (1922) who believed that sunspot variations were responsible for circulation changes, irrespective of temperature.

In connection with proposition (1), (3) and (4) we note lastly that all attempts to explain the subtropical pluvials as a secondary effect of the presence of the ice sheets are essentially based on false premises, the pluvials being essentially limited to the advance phases of the glaciers and to the very onset of the glacial periods. Consequently proposition (5): the subtropical pluvials are the direct consequence of primary changes in the general circulation of the atmosphere and are not secondary effects of the presence of continental glaciations.

4. *Some qualitative Contributions to the Amplitude of Climatic Variation.*

Following this discussion of some of the meteorological problems and aspects of the varying atmospheric circulation over the Near East during the Quaternary, the question of the amplitude of the associated local climatic fluctuations must be considered in this final section. As already emphasized at the start, no real quatitative evaluation of the magnitude of precipitation variation involved in the pluvials, or for that matter, during the postpluvial period as well, can be hoped to be made. Possibly specialized hydrological studies of the non-outlet lakes of the Near East, especially the Dead Sea, could offer a means of estimating the rainfall from a reconstructed hydrological budget, but as yet there is no unamity as to the true rate of evaporation of the specific localities; the exact rainfall, flow-off and evaporation from the drainage basins are but scantily known and river capture and related morphological changes must be borne in mind as well.

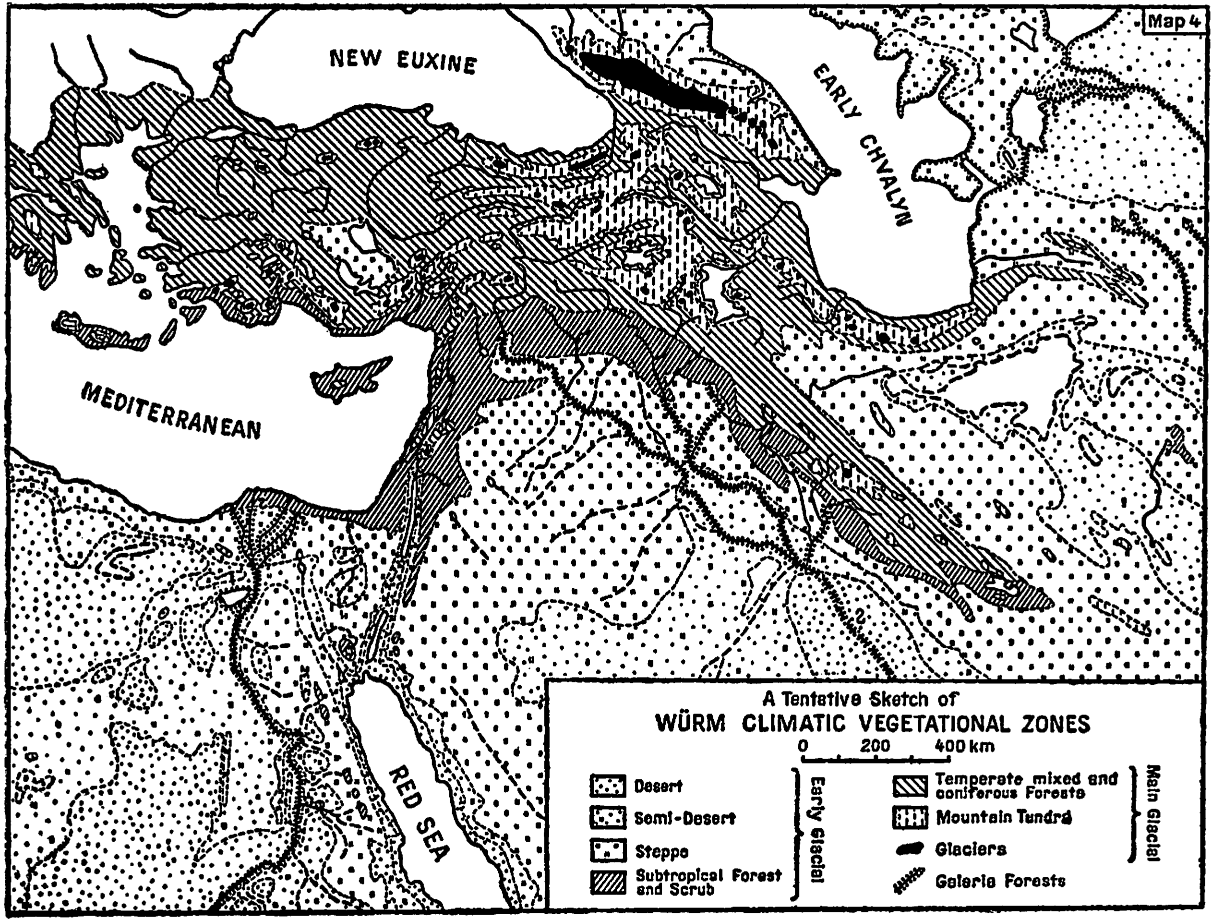
H. v. Wissmann (1956) in a very recent article has attempted a reconstruction of the Würmian vegetation of Eurasia which includes the Near East, with the exception of Egypt. For this he has based himself upon the dicta of *Bobek* and *Louis* for Iran and Anatolia respectively, as well as the slightly misinterpreted 1937 article of *Picard* for Palestine. The results merely present the modern distribution of the vegetational belts modified by lower temperatures, so that changes of humidity are almost entirely excluded. Consequently the entire Syrian Desert ist still given as ‚desert or semi-desert' something that we would deny, for here, as in the Red Sea Hills of Egypt there was in good probability a steppe vegetation. An icecap is placed upon Mt. Lebanon and surrounded by a wide periglacial zone, the former being incorrect, the latter a bit exaggerated and not based on any observations whatever of fossil solifluction. The lower limit of Würmian periglacial activity in the Lebanon area is not estimable on theoretical grounds as definite data on even the present snowline is lacking, but should not have been below 1200 m as frost pattern soils only occur above 1900 m to-day. Lastly the deserts of Iran and Turan are a little too extensive on *Wissmann's* map, and we refer to the reconstruction of *Frenzel & Troll* (1952) with regard to the latter. *Frenzel & Troll,* basing themselves on a good deal of palaeobotanical evidence and judiciously extrapolating for the intervening areas consider a steppe vegetation dominant in the Kizil and Kara Kum, something which we believe to be true for the Würm Pluvial I in the sense of the designation ‚steppe' as employed by these authors.

Despite the lack of palaeobotanical evidence, a very tentative attempt to reconstruct the climatic vegetational zones of the Near East has been made (Map 4), partly in view of the already existing schematic or cartographic representations of the same (*Büdel* 1949, *Flohn* 1953, *v. Wissmann* 1956), partly to present a qualitative representation of the amplitude of the Last Pluvial. The northern peripheries — Greece, Caucasia, Turan — have been taken from *Frenzel & Troll* (1952) with some slight modifications in the latter area to bring the picture on an equal scale.

The climatic vegetational zones employed are defined as follows where p is the mean annual precipitation in centimeters, t the mean annual temperature in ° C:

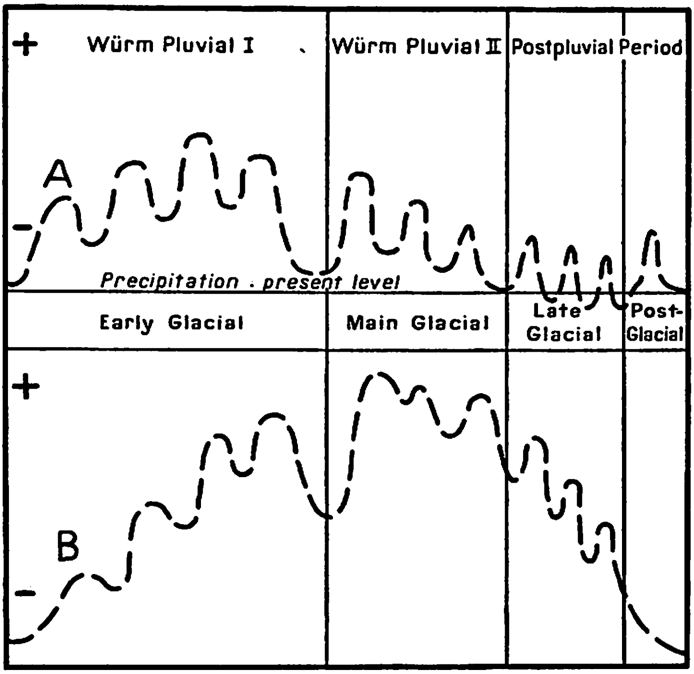
1) Desert: $p < 0.3\ t$
2) Semi-desert: $0.3\ t < p < t$
3) Steppe: $t < p < 2.5\ t$
4) Subtropical forest and scrub: $p > 2.5\ t$, $t > 10°$
5) Temperate mixed or coniferous forest: $p > 2.5\ t$, $t < 10°$
6) Mountain tundra: above the lower limit of cryoturbational activity, i. e. to roughly 700 m below the Würm climatic snowline.
7) Glaciers.
8) Galeria forests.

The picture presented is scetched on the basis of the macro-evidence from the geology and stratigraphy of the select areas discussed above, analogously extrapolated considering the relief and distribution of the present isohyets, degree of fossil dissection of topography, exposition and major cyclonic paths. The changed coastal topography and Pleistcene inland water surfaces are reproduced according to the finding of Chapters 3 to 5, adopting in particular the 100 m isobath as the Würm shoreline of the sea coasts. In order to convey the maximum extent of the phenomena involved, a certain anachronism is inherent in the picture: the glaciers, periglacial areas and regressions are considered as existing during Würm II, the vegetational belts and inland lake expansions are those of Würm I. For the Pontus-Caspian-Sarykamish-Aral system the reader is referred to Chapter 3, as well as to the Soviet Geological Service wall-map (1932) of Quaternary deposits in the European parts of the USSR. The pluvial extent of the inland seas — Fayum, Konya, Tuz, Van, Urmia etc. has already been discussed in Chapter 5, and the outline of the salt pans of Iran (the Kavirs) and Turan have been included. The topography of the Nile Delta and Tigris-Euphrates confluence is of course problematical, and they have been subject to continued sweeping changes in historical times, so that their present configuration has been arbitrarily given for lack of anything better.


Map 4
NEW EUXINE
EARLY CHVALYN
MEDITERRANEAN
RED SEA
A Tentative Sketch of
WÜRM CLIMATIC VEGETATIONAL ZONES
0 200 400 km
Desert
Semi-Desert
Steppe
Subtropical Forest and Scrub
Early Glacial
Temperate mixed and coniferous Forests
Mountain Tundra
Glaciers
Main Glacial
Galeria Forests

The results are obviously only tentative and provisional considering the arbitrariness of the procedure employed, but the overall visualization is both instructive and gratifying. Firstly it is not compatible with the schematic diagram of *Büdel* (1949, 1953) if this were extended to the Eastern Sahara. The greater part of the Libyan Desert was and still is desert, one of the few world deserts which shows no traces of a fossil drainage system. The discovery of Palaeolithic surface finds between the dune ridges of the southern sand-sea (*Murray* 1951) does however suggest a certain fixation of the dunes during the Würm, so that a semi-desert climate seems to have been dominant on the slightly elevated sections, with a moist, local steppe climate on particularly well-exposed scarps such as the Kharga with up to 500 mm precipitation. The rolled wadi gravels of the Red Sea Hills imply a rainfall greater than 200 mm which gradually tapered off southwards. The relative changes of precipitation as figuratively given by *Flohn* (1953) comes somewhat closer, yet also exaggerates the degree of pluviation a little, particularly in latitudes 30—35° N. In short, an extension of the Würm vegetational zonation from Europe and northern Eurasia into the subtropical latitudes of the Near East illuminates that the current literature not only attempts to minimize, but also to overemphasize the pluvials and exaggerate their amplitude. *F. K. Hare* (1953a) already has pointed out the discrepancy between the theoretical isobaric reconstruction of *Willett* (1950) with the fairly optimistic Würm vegetational map of northern Eurasia by *Frenzel & Troll* (1952). The pronounced winter low of 1000 mb suggested by *Willett* for the Central Mediterranean would have resulted in a much more luxuriant vegetation than the palaeobotanical reconstruction of *Frenzel & Troll* would allow for Central Asia and the Ukraine. In view of the geological evidence we feel that a schematic representation of the sequence and amplitude of the chronological aspects in the form of a strictly tentative and relative curve of temperature and of rainfall variations during the Upper Pleistocene and Holocene would serve an important complementary role beside the diagrammatic representation of the areal extent of the palaeoclimatic phenomena (Diagrams 1—3). The words of *F. Klute* (1930, p. 170), with respect to the Mediterranean Basin pluvial epoch, express the moderation necessary in judging the evidence: ‚Es handelt sich also um keine Pluvialperiode im Sinne eines dauernd feuchten Klimas, sondern um eine Mehrung der gelegentlichen Regengüsse oder des Zuflusses. Es war somit der Klimacharakter in diesen Gebieten nicht prinzipiell verändert.‘

A last aspect of the pluvials should also be remarked. In view of the comparative aridity of the late glacial and interglacial periods in general — even to some degree of the main glacial interval — one must regard the ‚pluvials‘ as relatively brief and temporary interruptions of the normal climate of the regions under consideration. Only the phases of ice formation, and particularly the early glacial intervals were apparently quite moist, only a small fraction of the total duration of the Quaternary. The Pleistocene period was by no means a ‚pluvial age‘ in the subtropical deserts of the Old World.

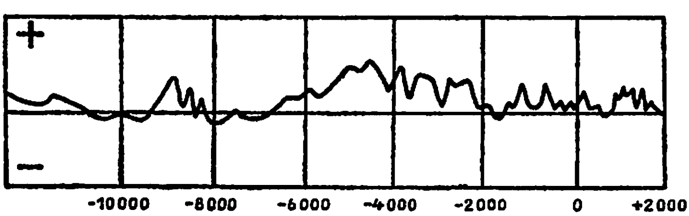


Diagr. 1:

A = Schematic curve of precipitation trends of Upper Pleistocene (Würm Glaciation) and Holocene in Near East.

B = Schematic curve of fluctuations of the Nordic continental glacier (modified after Woldstedt 1956).

In phase to allow comparison of precipitation and temperature fluctuations.



Diagr. 2: Relative trend of Near Eastern precipitation during the Late Glacial and Postglacial.

Quartärstratigraphie und Klima im Vorderen Orient

Kap. I. Einleitung und Rückblick auf die Europäische Chronologie.

Es wird versucht, den Gang der Klimageschichte des jüngeren Pleistozäns und des Holozäns aufzuzeigen. Dies setzt einen Überblick über die heutige Witterungsdynamik dieses Gebietes voraus und eine Untersuchung des Charakters der Würm-Pluvialzeit soll weitere Beiträge zur diluvialen Zirkulation im Mittelmeerraum liefern. Dagegen muß die eigentliche Chronologie der Klimaschwankungen auf stratigraphische und morphologische Forschungen gegründet werden. Als Ausgangspunkt für die Gliederung der Eiszeiten werden die Chronologien von *Woldstedt, Flint, Schönhals, Gross, Ebers* usw. verwandt, welche stratigraphisch, prähistorisch und besonders durch eine große Anzahl von Radiocarbonbestimmungen einigermaßen gesichert sind. Im wesentlichen beruht diese Gliederung auf zwei risszeitlichen Vereisungsmaxima, entsprechend den Endmoränen der Saale-Eiszeit und des Warthestadiums, sowie einer zweiphasigen Würmzeit, durch ein Interstadial in Früh- und Hauptwürm getrennt.

Kap. II. Die atmosphärische Zirkulation des Vorderen Orients.

Während des ganzen Jahres überwiegen westliche Windkomponenten über 500 mb. Die Regenzeit, von Oktober/November bis April/Mai wird durch eine westliche Zirkulation in der niedrigeren Atmosphäre ermöglicht, und der vorwiegend zyklonale Niederschlag wird hauptsächlich durch wandernde Höhentröge im Westdrift ausgelöst. Obwohl letztere in den Sommermonaten nicht gänzlich fehlen, schließen die starken Inversionen in geringer Höhe sowie der niedrige Wasserdampfdruck nennenswerte Niederschläge aus. In dieser Zeit beherrschen nördliche oder nordöstliche Winde die Bodenzirkulation, die einen passatischen Charakter annimmt. Eine Untersuchung der niederschlagsgünstigen Witterungslagen lehrt, daß die primäre Ursache von weiträumigen, langfristigen Niederschlagsschwankungen in der Stärke und Lage des lokalen Jet Stream und der Westdrift zu suchen ist.

Kap. III. Glazial-Eustasie und das marine Quartär des Vorderen Orients.

Hohe Strandlinien bei 80—120, 55—60, 45—50, 30—35, 15—20, 5—10 und 2—4 m sowie mehrere dazwischenliegende Regressionen können an den meisten Küsten festgestellt werden. Die erfreulichen Untersuchungen im Libanon (zuletzt von *Fleisch)* ermöglichen durch die prähistorischen Industrien der Strandterrassen einen befriedigenden Vergleich mit der Terrassenfolge von *Breuil* in Frankreich, dessen Auffassungen mit der Gliederung *Woldstedts* in Einklang gebracht werden können. An den libanesischen, palästinensischen, ägyptischen und libyschen Küsten können mehrere Verzahnungen von Pluvialsedimenten mit marinen und äolischen Bildungen, die den Meeresregressionen entsprechen, gezeigt werden. Diese bestätigen eine Parallelisierung der Feuchtzeiten mit den großen Vereisungen Europas und Nordamerikas.

Kap. IV. Eiszeitliche Vergletscherung und Periglazialerscheinungen.

Weder die heutige noch auch die eiszeitliche Vergletscherung der Hochlandsregionen von Anatolien und Iran hat flächenmäßig eine große Bedeutung. Zu keiner Zeit ging sie über das Stadium von Kargletschern und vereinzelten Talgletschern hinaus. Jedoch dürfte die Schneegrenzdepression von etwa 700 m eine allgemeine Temperaturerniedrigung von 4° C während des Kältemaximums der Würmeiszeit andeuten. Dieses ist durch Tiefseebohrungen im östlichen Mittelmeer bestätigt worden. Ältere Vereisungen, i. B. zur Risszeit, sind nur vereinzelt festzustellen. Periglazialerscheinungen, die auch einen guten Indikator für das thermische Klima darbieten, sind vorerst nur lückenhaft für die Jetztzeit beschrieben, und noch weniger für die Vorzeit bekannt. Doch scheint es, daß die untere Grenze der Kryoturbationserscheinungen auch eine Depression von ungefähr 700 m während der letzten Eiszeit erfahren hat.

Kap. V. Die mittel- und jungpleistozäne Pluvialchronologie.

Dieses Kapitel stellt den Kern der Untersuchungen dar. Trotz zahlreicher Felduntersuchungen herrschte bisher noch keine klare Kenntnis über diese Frage, so daß eine kritische Verwertung aller Feldbeobachtungen auf Grund der modernen geomorphologischen und bodenkundlichen Kenntnisse wünschenswert erschien. Besonders schöne Folgen bieten die Höhlensedimente von Haua Fteah, Hagfet et Tera, Umm Qatafa, Djebel Qafzeh, Ksar Akil und Jabrud. Die morphologische Entwicklung im Djebel es Soda, Wadi Derna, im Niltal, im Fayum, im Jordantal, bei Ksar Akil, in der Ankara Owa, in Kurdistan, in der Lut usw. bietet weitere wertvolle Ausgangspunkte. Einige Lokalitäten wie z. B. die Kharga Oase und das Niltal, können nicht einwandfrei geklärt werden und bedürfen neuer Untersuchungen. Leider sind die Spuren altpleistozäner und teilweise sogar mittelpleistozäner Pluvialzeiten durch die starke flächenhafte Denudation vielfach so verwischt, daß sie schwer gedeutet werden können und große Vorsicht erheischen.

Kap. VI. Postpluviale Klimaschwankungen.

Die besonders schwierige Aufgabe, die Klimaphasen der Spät- und Nacheiszeit zu erkennen, benötigt, in Anbetracht des Fehlens von Pollendiagrammen, die Heranziehung einer großen Masse von sehr verschiedenartigem Material. Höhlensedimente, kleinmorphologische Tatsachen, archäologisches Material, Radiocarbon-Datierungen und schließlich historische Angaben ermöglichen eine vorläufige Klimachronologie, die in Zusammenhang mit den Ergebnissen von Kap. V folgendermaßen lautet:

1. Mit einiger Sicherheit kann man ein erstes Pluvial in die Mindelzeit verlegen. Ein noch früheres Pluvial sowie Interpluvial wird gelegentlich angedeutet.

2. Das *Große Interpluvial* (Mindel/Riss Interglazial) ist als lange Trocken- und Wärmeperiode gekennzeichnet. Unteres Acheul als Leitfazies.

3. Das *Riss-Pluvial* (Riss I und II) ist als Feuchtzeit und Kaltzeit von großem Ausmaß ausgebildet. Es gibt Anzeichen für zwei Hauptphasen. Mittel- und Jungacheul, Acheulio-Levallois sowie das Tayac waren vorherrschend.

4. Das *Letzte Interpluvial* (Riss/Würm Interglazial) ist überall als Trockenzeit festzustellen, zusammen mit bemerkenswerter äolischer Denudation. Jungacheul, Micoque und Unteres Levallois-Moustier dienen als Leitfazies.

5. Das *Würmpluvial I* (Frühwürm) stellt die eigentliche Würm-Feuchtzeit dar. Bemerkenswert ist ein Niederschlagsmaximum vor einer ausgeprägten Temperaturerniedrigung, und noch vor dem Kältemaximum der Eiszeit. Dies scheint ein Charakteristikum der Feuchtzeit für den ganzen Mittelmeerraum zu sein. Oberes Levallois-Moustier.

6. Das *Würm-Intrapluvial* („Göttweig' Interstadial) scheint geologisch angedeutet als eine Zeit geringerer Niederschläge.

7. Das *Würmpluvial II* (Hauptwürm) von ca. 23,000—16,000 v. Chr. stellt nur ein unbedeutendes zweites Niederschlagsmaximum dar, das fast auf die Wiedervorrückungsphase der Eismassen und hauptsächlich auf die Breitengrade 23—30° N beschränkt war. Hauptkältemaximum mit Gletschervorstößen, Schneegrenzdepression von etwa 700 m und Temperaturerniedrigung von 4° C. Jungpaläolitische Industrien regional stark differenziert.

8. Die *Postpluvial I*-Phase (Spätwürm) von ca. 16,000—9500 v. Chr. war trockener und noch etwas kühler als heute und durch ausgeprägte Windabtragung gekennzeichnet.

9. Das *Subpluvial I* (Jüngere Dryaszeit) vor etwa 11 000 Jahren war wieder etwas feuchter. Niedrigere Temperaturen mit einem letzten Vorstoß der kleinen Würm-Kargletscher des Hochlandes.

10. Das *Postpluvial IIa* von etwa 8000 bis 6800 v. Chr. war wieder etwas trockener als heute und anscheinend wärmer als das Subpluvial.

11. Das *Postpluvial IIb* (ca. 6800—5000 v. Chr.) war dem heutigen Klima ganz ähnlich.

12. Das *Subpluvial II* (ca. 5000—2400 v. Chr.) war ziemlich feucht, mit Niederschlägen, die sich auf etwa halber Höhe zwischen denen des Würmpluvials und denen der Neuzeit bewegten. Etwas größere Wärme als heute (Klimaoptimum).

13. Das *Postpluvial III* (2400—850 v. Chr.) war wieder trocken und wahrscheinlich noch wärmer als heute.

14. Das *Postpluvial IV* (seit etwa 850 v. Chr.) gleicht im großen und ganzen dem heutigen Klima. Die Zeit bis 700 n. Chr. war im Durchschnitt ein klein wenig trockener als die spätere Subphase.

Kap. VII.

Die allgemeine Zirkulation während des Jungpleistozäns und Holozäns.

Beim Vergleich der Chronologien Europas und des Nahen Ostens ergeben sich drei besondere Tatsachen. In beiden Klimabereichen scheint zuerst jede langfristige Feucht- oder Trockenschwankung ähnlichen Charakter zu haben, was auf eine weltweite Beschleunigung bzw. auf ein Nachlassen des Kondensationszyklus deuten könnte. Zweitens sind die subtropischen Feuchtzeiten auf die Vorrückungsphasen der Eiszeiten konzentriert, und erreichten stets ihr Maximum, bevor eine ansehnliche planetarische Temperaturerniedrigung erfolgt war. Also können die Pluvialzeiten keine Auswirkung des Vorhandenseins der kontinentalen Eismassen sein, wie allgemein angenommen wurde. Sie müssen primär durch Änderungen der allgemeinen Zirkulation hervorgerufen worden sein, wahrscheinlich durch ausgesprochene meridionale Anomalien im Sinne von *Flohn*. Die Zirkulationsänderungen haben früher als eine Temperaturerniedrigung eingesetzt und sprechen daher für eine solare Ursache der Klimaschwankungen, insbesondere für Schwankungen des Ultravioletts oder der Partikelausstrahlungen der Sonne (wie *Willett* schon hervorgehoben hat). Drittens haben wir noch keine aktualistische Erklärung, warum der größte Teil des Klimaoptimums im Vorderen Orient feuchter war (obwohl die Interpluviale alle trocken waren), und warum die Zeiten der maximalen Eisausdehnung wesentlich trockener als die der Vorrückungsphasen waren. Als Erklärung reichen die einfachen Begriffe meridionaler und zonaler Zirkulationstypen nicht mehr aus. Vielleicht liegt die Antwort in einer komplizierten ‚blocking action'-Dynamik; auf jeden Fall sind die geologisch bedeutsamen Anomalien der Westwinddrift kaum so einfach wie man bisher geglaubt hat.

Als qualitativen Beitrag zum Ausmaß der Würmzeit werden schematische Niederschlags- und Temperaturdiagramme beigefügt sowie ein vorläufiger Versuch, die klimatischen Vegetationsgürtel des Nahen Ostens raummäßig zu erfassen.

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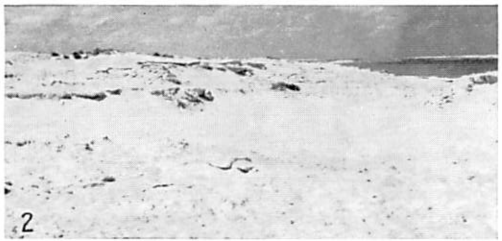


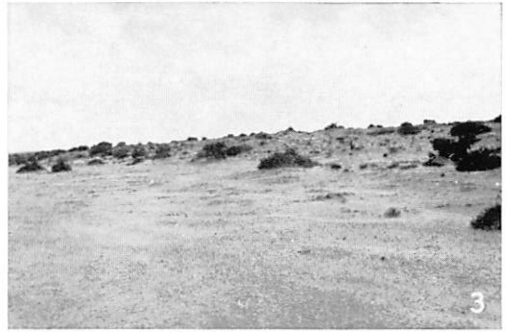
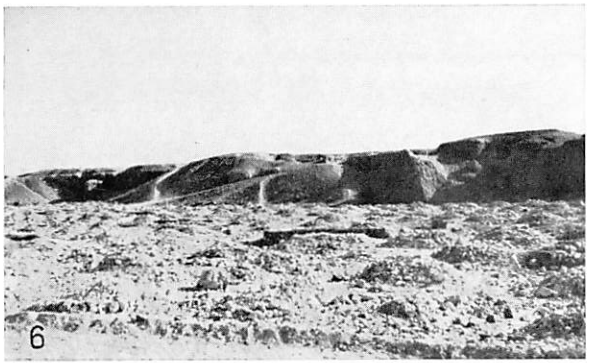


Fig. 1. 2 m raised beach of the Mediterranean between Sidi Abd el Rahman and El Alamein, representing retreat stage from the Tapes or Nizza terrace.

Fig. 2. Strongly eroded former tidal inlet to a fossil lagoon near Sidi Abd el Rahman indicating a + 4 m sea level (Flandrian Transgression).

Fig. 3. Sloping landward margin of a former lagoon corresponding to a + 2 m sea-level (Arab's Gulf).

Fig. 4. Former offshore bar near Sidi Abd el Rahman with +2 m marine abrasional terrace. The nip cut into the face of the calcareous sandstone is due to waves breaking farther out due to a comparatively rapid fall in sea-level.



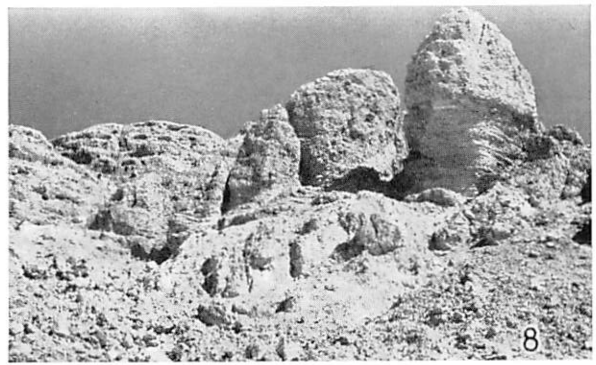
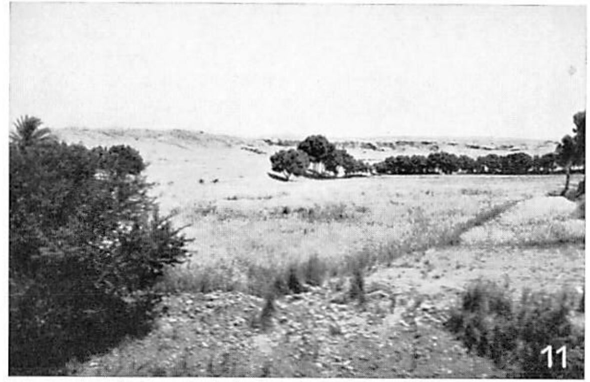


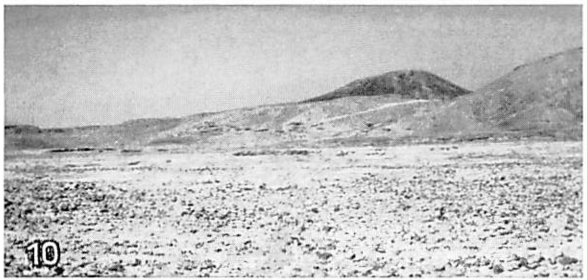
Fig. 5. Strongly eroded terrace of the 22—24 m Fayum Middle Sebilian Lake. The large sandstone slabs were undermined by intensive wind-excavation in early postpluvial times. (North of Kom Aushim).

Fig. 6. Hard, cemented 4 m accumulation terrace in the Wadiyein estuary, with evolved Mousterian in situ. (Near Qurna, facing north.)

Fig. 7. 2 m wadi gravels in middle reaches of Wadiyein (South Valley).

Fig. 8. Upper Pliocene (or Lowest Pleistocene) strata in the Wadiyein, consisting of alternating layers of conglomerates, marls, clay and limestone.





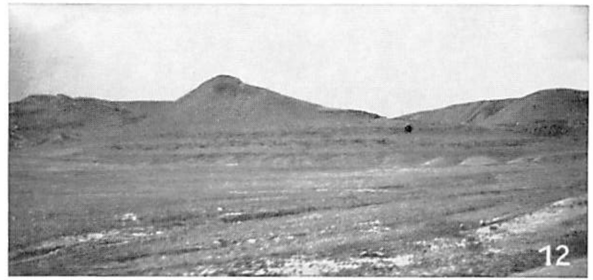
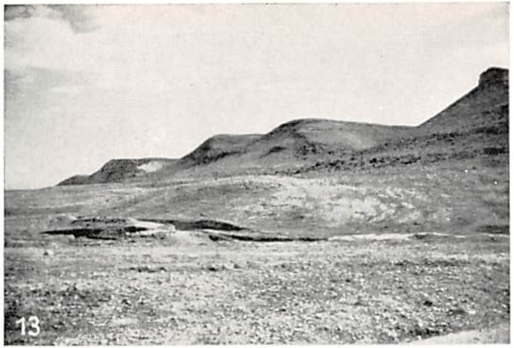


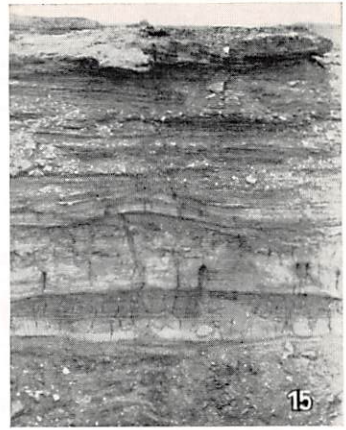
Fig. 9. 2 m wadi terrace in upper reaches of the Wadiyein (South Valley). Canyon walls are formed with Pliocene Gulf deposits shown in Fig. 8.

Fig. 10. Mousterian gravel surface at Medinet Habu (Thebes).

Fig. 11. 15 m igneous and metamorphic gravels with Acheulian artifacts in situ. Nile alluvium (cultivated) in foreground, covering base of gravels. North of Qena.

Fig. 12. Jericho terrace of the Jordan inland sea at about + 200 m. (5 km south of Jericho).





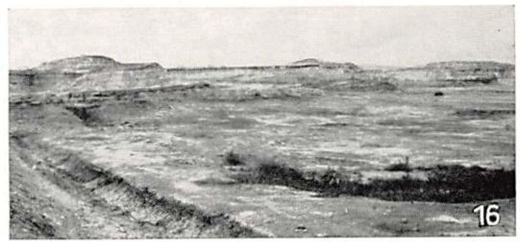


Fig. 13. Part of the Jericho terrace with truncated spurs of the Senonian at edge of the rift-valley fault scarp. (S. of Jericho.)

Fig. 14. Lisan marls left isolated to some 55 m by early post-Würm vertical incision of the Jordan River (at Qasr el Yahud).

Fig. 15. A 1.5 m vertical section of seasonally-banded deposits of the retreating Jordan inland sea (= Lisan marls), consisting of chalks and gypsum alternating with silt bands.

Fig. 16. Postpluvial abrasional terraces of the Dead Sea (Jericho road embankment in left foreground.).

All photos by K. W. Butzer