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PREHISTORIC SURVEY OF EGYPT AND WESTERN ASIA—VOLUME IV

PALEOLITHIC MAN AND THE NILE VALLEY IN LOWER EGYPT

WITH SOME NOTES UPON A PART OF THE RED SEA LITTORAL

THE UNIVERSITY OF CHICAGO PRESS
CHICAGO, ILLINOIS

THE BAKER & TAYLOR COMPANY
NEW YORK

THE CAMBRIDGE UNIVERSITY PRESS
LONDON

THE MARUZEN-KABUSHIKI-KAISHA
TOKYO, OSAKA, KYOTO, FUKUOKA, SENDAI

THE COMMERCIAL PRESS, LIMITED
SHANGHAI

THE UNIVERSITY OF CHICAGO
ORIENTAL INSTITUTE PUBLICATIONS
VOLUME XLVI

PREHISTORIC SURVEY OF EGYPT AND WESTERN
ASIA—VOLUME IV

PALEOLITHIC MAN AND THE NILE VALLEY IN LOWER EGYPT

WITH SOME NOTES UPON A PART OF THE RED SEA LITTORAL

A STUDY OF THE REGIONS DURING PLIOCENE AND PLEISTOCENE TIMES

By K. S. SANDFORD *and* W. J. ARKELL

Internet publication of this work was made possible with the
generous support of Misty and Lewis Gruber

THE UNIVERSITY OF CHICAGO PRESS
CHICAGO, ILLINOIS

COMPOSED AND PRINTED BY THE UNIVERSITY OF CHICAGO PRESS
CHICAGO, ILLINOIS, U.S.A.

EDITORIAL FOREWORD

This volume, like two that precede it in the series, is the outcome of collaboration between Dr. K. S. Sandford and Dr. W. J. Arkell. The latter has contributed pages 13–31, Figures 4–6 and 11–14, and the folding map; with these exceptions, Dr. Sandford is responsible for the volume. Plates I–XVI are from the photographs of both authors, who collaborated in the field in Lower Egypt and between Cairo and the Gulf of Suez in 1928/29 and in the vicinity of el-Kusair on the Red Sea in the spring of 1927. The remainder of the initial field work and the revisiting of much of the ground previously surveyed was done by Dr. Sandford between 1930 and 1933. The text was completed in 1935; no major alterations have been attempted in proof (1938), but short additions and a postscript have been employed to take notice of recent publications.

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Views

[1] All implements are shown natural size in this volume, as in *OIP* XVII and XVIII.

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LIST OF ABBREVIATIONS

Blanckenhorn, *Hdb.*	—M. Blanckenhorn, *Handbuch der regionalen Geologie*, VII. Bd., 9. Abt.: *Aegypten* (Heidelberg, 1921)
OIP	Oriental Institute Publications (Chicago, 1924——)
OIP X	K. S. Sandford and W. J. Arkell, *Paleolithic Man and the Nile-Faiyum Divide* (1929)
OIP XVII	K. S. Sandford and W. J. Arkell, *Paleolithic Man and the Nile Valley in Nubia and Upper Egypt* (1933)
OIP XVIII	K. S. Sandford, *Paleolithic Man and the Nile Valley in Upper and Middle Egypt* (1934)

INTRODUCTION

The major part of this book is devoted to a study of the ancient delta of the Nile, to its development and modification in response to the actions of river and sea, to the environment and cultural progress of early Man in the area. In former times the Delta was far wider than it is at present, river and sea stood at higher levels, and the river was contributing gravel and sand instead of fine silt. The margins of the ancient delta lay over the oasis of Wadi el-Natrun and the Suez Canal; thus changes in the Mediterranean shore line must be considered, and it will be realized that the Isthmus of Suez was at one time a strait that joined the Mediterranean to the Red Sea. Finally, a comparison of the history of a part of the Egyptian littoral of the Red Sea with that of the north coast will be attempted.

Paleolithic Man has been a witness of some of the later developments of river and coast, and his implements occur scattered over the surface; more rarely they are found in gravels and silts, and we were fortunate also to find them so situated in deposits near the coast of the Red Sea. Some association of Stone Age Man with the coral reefs which fringe the Gulf of Suez and the sea to its south may be presumed. In Pleistocene times, as at the present day, reef-building corals were unable to live in the Mediterranean waters, and a new factor in correlating the march of early Man is therefore introduced in this book.

Thus concludes the survey conducted by the Prehistoric Survey of the Oriental Institute northward from the remote citadel of Semnah in the Second Cataract. Companion volumes in the same series deal with Nubia and Upper Egypt, Upper and Middle Egypt, the Faiyum and the Nile-Faiyum divide (Fig. 1).[1] It is hoped that the well known prehistorian Père Paul Bovier-Lapierre will soon be ready for the Institute to publish an account of his long-sustained and remarkable work, with special reference to the environs of Cairo and the Paleolithic gravels of ᶜAbbasiyyah. In the present volume, which makes contact with the northern limits of the ground considered in *OIP* Volumes X and XVIII, many of our own observations in the Cairo district, sometimes made in company with Père Bovier-Lapierre, are included, but local details and references to material in his collection or in those of his friends are naturally omitted.

For the work in northern Egypt the newly issued 1:100,000 contoured maps of the Survey Department of Egypt were used. Detailed mapping could thus be done, and the folding map at the end of the volume is reduced from the sheets of this scale. Accurate levels, where not shown on the Survey Department map, were obtained from bench marks or "spot heights" by spirit level.

The work north and south of el-Kusair was not carried out in such detail. The Desert Surveys, the Geological Survey of Egypt, and the Mines Department have completed several programs of intensive surveying on many sections of this coast in connection with the search for oil. We do not attempt to add to the cartography of the region; we were concerned with investigating the possibility of associating the coral reefs with deposits containing Paleolithic implements.[2] As geologists, however, we were bound to observe any features that appeared to lie outside the information at our disposal in official memoirs.

[1] *OIP* XVII, XVIII, and X respectively.

[2] The initial discovery of flint implements in the Red Sea Hills was made by Mr. G. W. Murray, Director of Desert Surveys; see C. G. Seligman in Royal Anthropological Institute of Great Britain and Ireland, *Journal* LI (1921) 116 f. Some of these implements are described and figured by F. H. Sterns in *Varia Africana* I ("Harvard African Studies" I [Cambridge, 1917]) 48–66 and Pls. I–VIII.

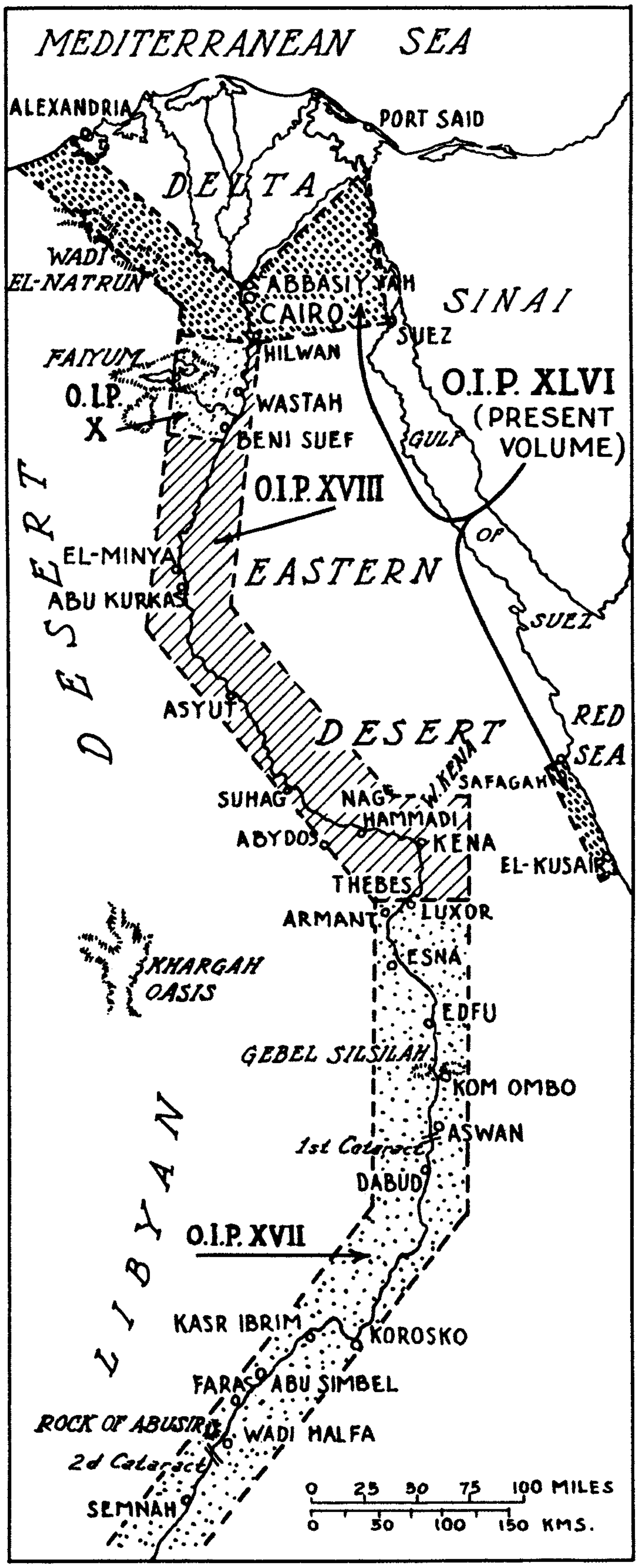

FIG. 1.—SKETCH MAP OF THE NILE VALLEY FROM SEMNAH TO THE MEDITERRANEAN, SHOWING THE AREAS INVESTIGATED BY THE PREHISTORIC SURVEY

A formidable amount of previous work had been done in Lower Egypt, and in an introductory note but a few of those who have worked in the field or studied the paleontological material can be mentioned. Barron did much work between Cairo and Suez. Beadnell made a remarkable field study of the Abu Roash dome, north of the pyramids of Gizah; Blanckenhorn made many journeys in the vicinity of Cairo and gave special attention to stratigraphy and paleontology. To Fourtau a great debt is due for a wide range of important contributions; and the names of Mayer-Eymar, Newton, Stromer von Reichenbach, Zittel, and many other well known paleontologists are prominent in the literature of the region.

With reference to the Nile itself Hull, Hume, Fourtau, Lucas, Willcocks, and in the country around Suez Ball, Barron, Barthoux, Macfadyen, and Sadek, have contributed to present knowledge. Farther south along the Red Sea the names of Beadnell, Hume, Little, Madgwick, Moon, Sadek recur in a sequence of valuable reports. It is beyond the requirements of this volume to refer to every publication and author, although we believe that there are few that we have not read. The reader may refer to two bibliographies which, between them, are exhaustive: the first will be found in Blanckenhorn's *Handbuch der regionalen Geologie*, the second in W. F. Hume's *Geology of Egypt*, I (Cairo, 1925). W. F. Hume and O. H. Little have published an important and authoritative summary[3] with a useful selective list of references.

As in the field work connected with the earlier volumes of this series, the senior officials of the Survey of Egypt and of the Department of Antiquities have given most generous help, advice, and encouragement. Dr. John Ball, Dr. W. F. Hume, Messrs. O. H. Little and G. W. Murray we have had cause to thank on previous occasions, and we do so once more. Dr. Hassan Sadek gave us valuable information and advice concerning the geology of the country between Suez and the North Galalah Plateau. In the field we were most hospitably welcomed by Major and Mrs. Jennings Bramley at Burg el-ʿArab, by M. and Mme Raccaud at the headquarters of the Egyptian Salt and Soda Company in Wadi el-Natrun, and by the Rev. and Mrs. K. Warner at the Royal Air Force station at Abu Suwair, near Ismailia; to them we offer our thanks. Once more we were indebted to Dr. and Mrs. D. L. Askren of Medinet el-Faiyum and to Mr. Enoch E. Peterson, of the University of Michigan, at Kom Aushim in the Faiyum, for innumerable kindnesses, not least for allowing us to leave our cars, equipment, and personal property in their houses for many months before and after the field season of 1928/29. In 1931 Mr. and Mrs. David Crookston of Port Safagah generously gave their hospitality and facilities which enabled work to be continued in this almost waterless region.

We are indebted to Mr. H. J. Hambidge for his beautiful photographs of the flint implements (Pls. XVII–XXX) and for developing the technique of their reproduction by this means. We owe our thanks to Dr. T. George Allen and Mrs. A. R. Hauser for their patience and scholarship in the editing and publishing of our manuscript and its illustrations.

[3] "Raised beaches and terraces of Egypt" (International Geographical Union, Commission on Pliocene and Pleistocene Terraces, *First Report*, K. S. Sandford ed. [1928] pp. 9–15).

I

GEOLOGICAL HISTORY OF THE REGIONS BEFORE THE PLIOCENE PERIOD

As in the earlier volumes of the series, a description of the "solid" geology and the topography is given before an attempt is made to describe the strata with which the book is more especially concerned. Reference should be made to the folding map.

FORMATIONS AND STRUCTURES REPRESENTED WEST OF THE DELTA

The oldest rocks are seen in the center of the Abu Roash dome, a remarkable faulted inlier on the edge of the Western Desert immediately west of Cairo and north of the pyramids of Gizah.[1] Here pebble beds of Nubian sandstone are slightly exposed. Their nearest point of outcrop in the Nile Valley is nearly 300 miles farther south, not far from Kena, Upper Egypt.[2] They are surrounded by almost perfectly displayed inward-facing scarps of Turonian and Senonian (i.e., Middle and Upper Cretaceous) chalk and calcareous shales; according to Beadnell's original section even higher Cretaceous zones may be present.[3]

Above the Cretaceous beds Lower and Middle Eocene beds are completely missing, and Upper Eocene rests directly upon Cretaceous strata with marked dissimilarity of dip or strike. The junction of the two is beautifully displayed in the vicinity of Abu Roash and adjoining hills; a basal conglomerate made of Cretaceous pebbles may best be seen at Giran el-Ful (Pl. I *A*). The overlying few feet of mealy limestone covered by typical Oligocene pebbly sandstone may likewise be of Oligocene, not Upper Eocene, age. The great thickness of the Eocene formation and of the Middle and Upper Eocene and Oligocene beds displayed in the Faiyum (e.g. the Kasr el-Saghah cliffs[4]) is thus strikingly reduced to a few feet. North and west of the Abu Roash dome the country is dominated by Oligocene cobble gravels, a continuation of the desolate country that the tourist sees when he looks westward from the Great Pyramid.

South of Abu Roash, on the other hand, Upper Eocene limestones immediately make their appearance. The pyramids of Gizah and Abu Sir are founded upon *Nummulites gizehensis* limestones, which except in the vicinity of ancient sites and monuments are generally concealed beneath gravels of Oligocene, Pliocene, and Pleistocene age. Eocene rocks are not visible on the west side of the Nile or in the Western Desert north of the latitude of Abu Roash and its immediate environs.

Northwestward as far as Wadi el-Natrun the country is a sea of gravel. It will be shown (pp. 2, 43) that it is made of two parts: the western cobble gravels of Oligocene age, the eastern gravel-flats of Plio-Pleistocene age and of Nilotic derivation. A line drawn from Abu Roash to the eastern end of Wadi el-Natrun defines fairly accurately the extreme western boundary of the post-Pliocene Nile. Moreover, it should be noted that the north side of Wadi el-Natrun is defined and bounded by Nilotic gravels (Pl. V).

The relation of topography to geology is remarkably defined in this region. South of Wadi

[1] H. J. L. Beadnell, *The Cretaceous Region of Abu Roash, near the Pyramids of Giza* ("Geological Survey Report, 1900," Part II [Cairo, 1902]).

[2] *OIP* XVIII 1.

[3] See Blanckenhorn, *Hdb.* p. 18.

[4] See *OIP* X 5 ff.

el-Natrun is another deep and wide depression, Wadi el-Farigh,[5] both of them descending below sea-level. The southern side of Wadi el-Farigh was found to be the northern limit of Oligocene rocks, dipping northward, while the northern flanks are of Pliocene age. The latter in turn form the south side of Wadi el-Natrun, running in a high east–west ridge between the two depressions (with numerous spurs on the southern side). Wadi el-Farigh has thus been hollowed out below loose conglomerates at the junction of Oligocene and Pliocene; Wadi el-Natrun was excavated in soft Lower Pliocene clays, overlapped by more resistant Nilotic gravels on the north (Fig. 2). Miocene rocks of marine facies, which define the west end of Wadi el-Natrun, are probably absent east of that point and do not occur nearer the Nile Valley or Delta. As this marks a certain divergence of view from that indicated in the Geological Map of Egypt published by the Survey Department in 1928 and a reversion to the distribution shown in the map accompanying Volume I of Hume's *Geology of Egypt*, some further explanation is necessary.

North of the Faiyum we had noted the occurrence of hard blue limestone in the basal part of the Oligocene sediments;[6] to the north this becomes more and more sandy, passing vertically and laterally into red, buff, or light-colored quartz sandstone, often exceedingly hard. This in

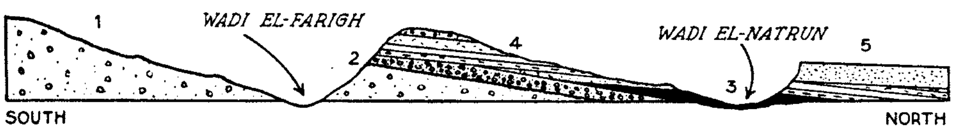

FIG. 2.—DIAGRAMMATIC SECTION ACROSS WADI EL-FARIGH AND WADI EL-NATRUN

5 Plio-Pleistocene sands and limestones
4 Pliocene marls, flinty limestones, etc.
3 Lower Pliocene clays etc.
2 Basal conglomerate of Pliocene series
1 Oligocene gravels, sands, and sandstones

turn becomes pebbly—well rounded yellow quartz and Eocene flint or chert pebbles being the normal constituents. Seams of thin and often impure limestone occur sporadically in this deposit (as on Gebel el-Khashab and in other small localities west of the Nile). The sandstone gives place to coarse cobble conglomerate, the large rounded masses consisting exclusively of Eocene, and perhaps Cretaceous, chert mixed with loose quartz sand. Locally the material may be bound together by weak ferruginous or calcareous cement. The effect of wind action is to remove continually all exposed quartz grains and so concentrate the cobbles. If, however, sand is abundant and cobbles scarce, the formation is entirely removed by wind and a deep, broad hollow is produced. Cobbles from overlying beds frequently roll down the sides or are washed down during rainstorms, and the flanks of the hollow tend to slope gently and to be scarred by sand-incumbered gullies; such is Wadi el-Farigh. It is in these upper beds, derived from southern sources, that are found the great tree trunks and logs of silicified wood popularly known where abundant as petrified forests.[7] No tree trunk is found in a position of growth, all having been derived from elsewhere and floated or rolled to their present positions. Silicification is evidently a later process. The facies of the Oligocene beds of Middle Egypt is thus continued along the sides of the Delta.

It has already been noted (p. 1) that at Abu Roash soft mealy limestone may occur in Oligo-

[5] Wadi el-Farigh refers to the depression south of Wadi el-Natrun, not the shallow drainage line of the same name which deepens toward the Nile and has its origin a little to the east of but high above and entirely unconnected with the depression.

[6] *OIP* X, map at end.

[7] See discussion in *OIP* X 7 f. and XVIII 3.

cene beds, as is to be expected when they are traced northward, in which direction the cobbles were presumably rolled into the open sea. The soft limestone lenticles and patches, to be distinguished from the hard blue limestone already mentioned (p. 2), contain indistinct casts of echinoderms and marine shells.

The basal conglomerate of the Pliocene series, certain beds of which are locally highly fossiliferous, is composed of rolled pebbles, bowlders, and subangular masses of Oligocene sandstone, rolled fragments of fossil (silicified) wood, cobbles, and occasional worn fragments of limestone. It is easily recognized in the field, if the ground is at all broken, and we found no great difficulty in mapping it from Wadi el-Farigh to the Nile Valley.

The Pliocene beds above the basal conglomerate are described in chapter ii. Their stratigraphy is so clear, their lateral and vertical lithological facies change so distinctly, and their fossils are so marked, that one cannot fail to recognize them as a single group from conglomerate (or local equivalent) upward. With the rocks of Oligocene facies they comprise the whole of the solid ground from Abu Roash to the east end of Wadi el-Natrun. But the strike of the base of the Pliocene beds appears to be about east-southeast–west-northwest toward the western part of the wadi, where the topography becomes more involved and its northern scarp is formed by Oligocene beds instead of soft Pliocene beds beneath Plio-Pleistocene gravels, such as are noted farther east.

At the western end of the wadi distinctive Middle Miocene limestones appear. The Oligocene sands and pebble beds are covered by a conglomerate, about 3 feet thick, of subangular blocks of many varieties of Oligocene sandstone, with fossil wood. The conglomerate passes upward into purple sandy limestone and then into mauve, purple, and pink limestone, with bands of light gray or light blue limestone, the whole mounting westward and northward into broken platforms and low scarps, predominantly pink and light-colored. This is typical Middle Miocene limestone, and no trace of it was found farther east on the west side of the Nile. To the northwest or west the country becomes vivid with brilliant red, purple, pink, and yellow rock mounting to the scarp of the Miocene hills which dominate the country in that direction. To the south lies brown Oligocene country, and on the north, separated by a shallow wadi from the Miocene rocks, lies the Plio-Pleistocene scarp, beneath which Pliocene rocks are concealed. In obscure corners in this locality, on the south side of the shallow and narrow depression which is the west end of Wadi el-Natrun, is a conglomerate consisting entirely of Miocene limestone pebbles and small bowlders, with a little fossil wood. This appears to be the base of the Pliocene beds, which therefore lie across the flanks of both the Miocene and the Oligocene strata, cutting out the former toward the Nile. In the remote northwest corner described above the Oligocene and Miocene rocks seem to be planed by marine erosion, and the flat surfaces are probably those of the two formations formerly (and still in part) covered indifferently by Pliocene conglomerate.

Where, then, are the Lower Miocene beds? The only obviously post-Oligocene pre-Middle Miocene rocks are the conglomerates and perhaps the sandy beds immediately above them, unless it is admitted that Oligocene and Lower Miocene beds are indistinguishable. It is probable, however, that the Miocene beds of the mouth of the Nile Valley were gravels largely derived from the great Oligocene spreads (cf. p. 2); such Miocene deposits, if distinguishable, may be expected to occur south of the Pliocene conglomerate that runs eastward from Wadi el-Farigh.

North of Wadi el-Natrun and its western extension into the Miocene hills wide and open plains covered with thin spreads of gravel of Plio-Pleistocene and Pleistocene age extend almost to the present coast east of Burg el-ʿArab, where the gravels are concealed beneath barriers of dazzling white or yellow (where consolidated) oölitic lime sand consisting in large measure of comminuted shells (Pl. XI). The consolidated rock was extensively quarried in Roman times, as it still is near Alexandria; the fresh material forms a dune line, a bulwark which keeps the Mediterranean out of the hollows between the hills (e.g. the finger-like west end of Lake Maryut and the cultivated land adjacent to it). Between Wadi el-Natrun and the coast one passes also from absolute desert (Pl. XII *A*) to land on which rain crops are raised and on which the Romans grew some of their best grapes by means of special agricultural methods (see chap. viii).

Once Abu Roash is left behind, faulting and folding are not seen in the country west of the Delta described in this book. It will be appreciated that the Abu Roash inlier had an earlier history of erosion, since there is a break in the sequence from Upper Cretaceous to Upper Eocene beds. But it was further disturbed, probably in Miocene times, when intrusive basalts invaded the region; numerous exposures occur in its immediate vicinity. Faulting also probably took place at this time. With these exceptions the region seems to have been one of quiescence, in contrast to the country on the east side of the Nile.

FORMATIONS AND STRUCTURES REPRESENTED EAST OF THE DELTA[8]

The contrast between the west and east sides of the Nile Valley from the south northward as far as Hilwan has already been explained in *OIP* Volume XVIII. It becomes even more marked toward Cairo, until the Mukattam Hills tower above the city, while the low line of the Western Desert, save only for the Abu Roash inlier and its adjoining hills, is scarcely visible. This may be explained partly by the dip, which is in some measure from the west toward the Mukattam Hills: they form thus a strike escarpment of hard limestone sharpened by the river at its foot and by quarrying for stone on a stupendous scale since (and before) the building of the Great Pyramid. But this is not all. The top of the Eocene limestones and the base of the Oligocene may be seen at a comparatively low level along the Western Desert edge. The bright Oligocene sands form a ruddy cap to the shining white limestones of the Mukattam quarries and then sweep down to form the brick red, mauve, and brown mass of Gebel el-Ahmar, near ʿAbbasiyyah. As described by Beadnell long ago[9] there is some strong folding in the region from Hilwan to Cairo, the upfolds being on the east side of the Nile in its present position. One might add that from Plio-Pleistocene times onward the Nile has consistently shifted its bed eastward, leaving successive terraces on the western bank. Faulting locally plays a part in these general north–south folds, crossed by other, sharper folds and faults of northeast–southwest trend.[10]

The faults shattered the country between Cairo and Suez, while the folds include spectacular domes and monoclines and the rocks are tilted into such magnificent ranges as Gebel ʿAtakah, which dominates Suez. The clysmic area of the Gulf of Suez is shattered by north–south to northwest–southeast faults which along the flanks of Gebel ʿAtakah mingle with the northeast–southwest to east–west fault belt of the Cairo–Suez road (Pls. I *B*, II, and IX).

Any geologist who works along this road and in the country on either side of it soon becomes aware that the faults and folds are of diverse ages, and the following may be quoted from the report of Dr. Hassan Sadek, who has for some years made a special study of the country between

[8] Some of the information contained in this and the next section occurs also in chap. ii, pp. 20–31, where it has been found necessary to refer to pre-Pliocene history to explain certain features. Most of the places referred to in this section are shown in Fig. 10.

[9] See *OIP* XVIII 7 f.

[10] See *OIP* XVIII 4–8 and Hume, "The surface dislocations in Egypt and Sinai, their nature and significance" (Société royale de géographie d'Egypte, *Bulletin* XVII [1929] 1–11, preprinted from International Geographical Congress, Cambridge, July, 1928, *Report of the Proceedings* [Cambridge, 1930] pp. 207–16).

Wadi ᶜArabah and Gebel ᶜAtakah. His analysis applies with equal force to the region of the Cairo–Suez road:

(1) The district is affected by two main systems of faulting: the first having NW–SE direction varying to NNW–SSE; the second almost E-W. A third series of N-S faults also exists but only noted at a few points.

(2) The NW–SE faults though they determine in many places the occurrence of the Miocene rocks, no evidence was obtained anywhere in the district to show that these latter rocks were themselves affected by them. This points to the faulting being mainly of pre-Miocene age, and may be part of the series of fractures that gave birth to the depression occupied by the present Gulf of Suez, which was subsequently invaded by the waters of the Mediterranean in early Miocene times.

(3) The E-W faulting was obviously of later date than the NW–SE, for it not only cuts off and deflects these latter lines of fracture, but also affects rocks of all ages as far up as the Upper Miocene. This series of faults is therefore of post-Miocene age, *i.e.* possibly of Pliocene age.

(4) The N-S faults seem to be intimately connected with the E-W faults, and the evidence from the east side of El-Akhieder points to their being the same lines of fracture with a change of direction caused by the very nature of the movements which gave rise to them.

(5) Both these latter series of faults seem to owe their existence to the rising of the blocks which they surround, as evidenced by production of semi-domal structure on the downthrow side at the corner points.

(6) Folding takes only a minor part in this country, being only produced in consequence of the bend of the beds into the fault lines or in the rocks on the downthrow sides of the faults. No true synclines and anticlines, which are due to lateral movements of the earth's crust, are here represented; the movements being here mainly of a vertical nature due possibly to the relative rise and fall of blocks of the granitic complex underneath.[11]

It is true that at greater distances from the buried northern end of the Red Sea Hills complex the folds, as described by Hume,[12] take up lines of prolongation that seem to suggest some compression; but that same pressure might well have resulted in the clysmic area in vertical movements such as Sadek describes. Vertical movements are dominant in the rifted region of the Gulf of Suez, Gulf of ᶜAkabah, and Red Sea. Sadek associates the basaltic intrusions with pre-Miocene faults and considers them, in his district, to be of late Oligocene age.[13]

Such profound faulting in Pliocene times is unknown in Lower Egypt proper, that is, in the Delta and the northern end of the Nile Valley, and the mass elevation, the transverse faulting, some folding, and the cutting of the Nile Valley to great depth were completed between Upper Miocene and Pontic (early Pliocene) times.[14]

By adopting the foregoing generalizations a detailed record of the field work between Cairo and Suez may be reduced to the following notes:

1. The oldest rocks of the area are seen in the core of the great flexure of Gebel Shubra Wit (Pl. I *B*), a prominent hill about 3 miles west of Great Bitter Lake. Here Middle Cretaceous rocks are exposed. A highly faulted region of Middle and Upper Eocene rocks, culminating in Gebel Gunaifah to the southeast, adjoins Gebel Shubra Wit, the whole surrounded by Lower and Middle Miocene rocks. This region is described in detail in Macfadyen's important contribution to its geology.[15]

2. An interesting feature of the Miocene rocks—dominantly fossiliferous yellow limestones (Upper Miocene: Tortonian and Helvetian), shales and marls with some limestone bands (Middle Miocene: Schlier), and gritty limestones, sands, and conglomerates (Lower Miocene: Burdigalian)—is the presence in them of pebble and cobble beds which are evidently the product of wadies draining the Oligocene and Eocene plateau farther south. The beds, containing an abundance of silicified wood, are typical of the Lower Miocene or Burdigalian; they occur

[11] H. Sadek, *The Geography and Geology of the District between Gebel ᶜAtâqa and El-Galâla El-Baharîya (Gulf of Suez)* ("Survey of Egypt Paper" No. 40 [Cairo, 1926]) pp. 113 f.

[12] *Loc. cit.*

[13] *Op. cit.* pp. 72–74.

[14] Cf. Edward Hull in Geological Society of London, *Quarterly Journal* LII (1896) 308–19.

[15] W. A. Macfadyen, *Miocene Foraminifera from the Clysmic Area of Egypt and Sinai* (Cairo, 1931).

at intervals from Suez to Magharah and westward toward Siwah Oasis and Cyrenaica. The wood and cobbles were probably derived from the Oligocene (see p. 2), and the country where dominantly made of these materials may be marked as Oligocene. It is evident, however, that the Lower Miocene sea and Nile delta covered much of the northern part of Egypt and its deserts; hence Lower Miocene fossils may occur especially in the upper part of such concentrations of typically Oligocene material. In that event it appears to be a moot point whether Oligocene or Miocene better expresses the geology of a given locality, unless the presence of other Miocene rocks near by marks it as essentially a Miocene province.

The western side of the Delta near its apex seems to be essentially an Oligocene and Pliocene, not Miocene, terrain (cf. pp. 1 f.). In the country between Cairo and Suez, however, such coarse pebble and cobble material deposited by drainage from near-by land into the Miocene sea and coastal belt is a prominent feature in the vicinity of Wadi el-Gafraᵓ and thence along the broad valley which the Cairo–Suez road follows to Gebel ᶜUwaibid (Pl. II *B*), suggesting indeed that those great lines of drainage have been in operation at least since Middle Miocene times. Similarly traces of drainage into the Pliocene sea were found along the first 20 miles or so of the road eastward from ᶜAbbasiyyah. They may be regarded as Pliocene rather than Miocene (see p. 21), as they were marked by Barron.[16] Such traces rest on Oligocene rocks in the vicinity of Tower No. 3. In the drainage gravels there are abundant pebbles and (more rarely) rolled fossils of Upper Miocene age. In comparing published maps with the actual ground we concluded that certain gravels marked as Pliocene (cf. Gebel el-Humairah district) were Miocene.

3. The vicinity of Gebel ᶜUwaibid deserves some special reference. The gebel itself is a hogback of Middle Eocene limestones, severely faulted, and its rugged scenery is reminiscent of Upper Egypt, or more especially of Gebel Duwi, near el-Kusair. At its east end Miocene beds are indicated by an oyster bed about 20 feet thick banked against it, crowded with large and small shells of *Ostrea virleti*. Beyond is a sequence of limestones and fine calcareous beds, much folded, forming part of the great dome, of which Eocene rocks form the center. About half a mile northward from the oyster bed the limestones rest upon Oligocene sands, tough black sandstones, and ocherous beds, much disturbed (locally vertical) before the limestones were laid down. The latter are exposed northward to the abandoned track of the old Cairo–Suez railway line of 1858–69 (reconstruction of which has been undertaken in the last few years). The Miocene beds are largely *Pecten* limestone in which free-growing *Ostrea virleti* occurs with echinoderms. This is a succession such as is described in the Pliocene beds between the pyramids of Gizah and Abu Sir (pp. 13 ff.).

On the south side of Gebel ᶜUwaibid the Miocene beds are faulted. A strongly marked north–south fault, with cemented fault breccia, is also present, cutting across Wadi ᶜUwaibid; it is shown on the ground by canyons.

At Tower 12 and again about 3 kilometers west of it is some debatable ground. The Miocene seems to pass upward into a fossiliferous bed containing a species of *Mactra* which led Barron to consider it to be Pliocene.[17] But the bed is folded with the Miocene and in every way seems to be a part of it; it is overlain by gray to yellow clay, and locally by flint-pebble beds and calcareous sandy beds in which we found no fossils, and further searches in 1931 and 1932 produced no more satisfactory results. Near Tower 12 the gray and yellow clay is covered by at least 15 meters of flint gravel, forming a considerable area of low hills, and abounds with pebbles of Middle Miocene limestone. The lower 4 meters or so are fairly fine and consist in great measure of Miocene limestone pellets; in the upper part harder and large limestone peb-

[16] T. Barron, *The Topography and Geology of the District between Cairo and Suez* (Cairo, 1907) Pl. II.

[17] *Ibid.* pp. 52–54.

bles occur, and the gravel is coarse. The gravels may be of Pliocene age, the lower beds Miocene, probably Middle or Upper. Since Miocene beds, with small pieces of Eocene limestone washed from neighboring exposures, occur farther east (near kilometer 95 at Tower 13, on the Cairo–Suez road), and since Upper Miocene strata with corals and *Lithothamnium* north of the road near kilometer 79 (6 kilometers west of Tower 12) contain pebbles of and rolled fossils from Middle Miocene beds, we are the more inclined to transfer the whole of Barron's Pliocene beds near by to the Upper Miocene and to regard the series as indicative of a passage from marine to wadi-gravel conditions. The wadi was probably the forerunner of that followed by the Cairo–Suez road in this district, its further erosion being stopped by the piercing of the Miocene escarpment on the north by Wadi el-Gafraᵓ in Pliocene times.

4. North of the abandoned Cairo–Suez railway line there is a broad region of faulted and folded Oligocene rocks, forming broken sandstone country which sinks beneath the open plains of Plio-Pleistocene Nile gravels that slope gently to the Delta and to Wadi el-Tumilat (cf. Fig. 6). Beyond, to the north, is a further flat expanse of these gravels, the Tell el-Kabir "island," followed by the sand dunes and marshes of Lake Manzalah and by the alluvium of the eastern Delta. Along the line of the Suez Canal north of Great Bitter Lake Miocene beds sink beneath fresh-water limestones of Pliocene age and the Pleistocene to Recent gravels, sands, and clays that form the desolate country on both sides of the canal from Ismailia to Port Said. South of the lake, Miocene beds are exposed as far as Suez, with broad plains of Pleistocene and Recent deposits and superficial accumulations on the east side (Sinai) and, near the head of the gulf, on the west also, where they appear to have been left high and dry at no remote date. Living corals and reefs begin to fringe the shores of the gulf within a few miles of Suez. Huge detrital fans and torrent accumulations curtain the base of the cliffs of Gebel ᶜAtakah and other eminences (Pl. IX *B*).

FORMATIONS AND STRUCTURES REPRESENTED IN THE ERYTHREAN REGION BETWEEN SAFAGAH AND EL-KUSAIR

As already indicated in the Introduction, our contributions to the knowledge of the local geology of this region are limited to the later formations; it is not to be supposed that we should add substantially to official reports based on maps of the scale of 1:10,000 or 1:100,000.[18] Nevertheless the general account given here may serve to complete the reader's mental picture of the geology of prehuman times in the Nile Valley and of the events that controlled the relation of land and sea to the valley. It should be possible then to understand the changes that were taking place on the east side of the Red Sea Hills while the country west of them was stable, and to appreciate the relative values in discrepancies and similarities of altitudes and contents of the younger formations in the two geological provinces.

The dominant topographical feature of the inland region between Safagah and el-Kusair is the Archean metamorphic and plutonic complex of the Red Sea Hills, forming a seemingly impenetrable barrier when viewed from the coast and presenting a wild, rugged skyline from which certain peaks detach themselves when seen from some miles out at sea. Towering above the rest, northwest of Safagah is Gebel el-Shayib (2,184 m.), the highest mountain in Egypt.

[18] Cf. W. F. Hume, T. G. Madgwick, F. W. Moon, and H. Sadek, *Preliminary Geological Report on the Quseir–Safaga District, Particularly the Wadi Mureikha Area* (Egypt, Ministry of Finance, Petroleum Research, "Bulletin" No. 5 [Cairo, 1920]); Beadnell, *Report on the Geology of the Red Sea Coast between Qoseir and Wadi Ranga* (Petroleum Research, "Bulletin" No. 13 [Cairo, 1924]). See also Hume, *Report on the Oilfields Region of Egypt* (Cairo, 1916).

The original survey of the region was made by Barron and Cooke in 1897 and is included in Barron and Hume, *The Topography and Geology of the Eastern Desert of Egypt, Central Portion* ("Geological Survey Report" [Cairo, 1902]) pp. 2 and 60–82.

From this impressive eastern margin of Africa, which runs from the Gulf of Suez (it is continued in southern Sinai) to Abyssinia, enormous quantities of waste material have been washed out onto the maritime shelf to become interbedded locally with the growing corals of the Red Sea reefs. It will be realized that at least part of the range north of the latitude of el-Kusair has been elevated and laid bare from beneath great thicknesses of sedimentary rock since late Eocene or Oligocene times. The margins of the complex massif have a strongly marked north-northwest–south-southeast trend, which is even more clearly shown by the stripped edges of its former sedimentary cover on the west and in some measure also on the east side. This direction recalls the first system of faulting described by Sadek (p. 5), which is pre-Miocene, probably Oligocene, at the head of the Gulf of Suez late Oligocene.[19] Between the latitudes of Safagah and el-Kusair are several infolded and faulted sections of the sediments that are presumed to have covered the whole range. In all of them Nubian sandstone forms the lower member, covered by Cretaceous rocks which include valuable phosphatic deposits mined at Gebel Duwi, near el-Kusair, and in Wadi Safagah (Fig. 3). Lower Eocene rocks cover the Cretaceous beds on a grand scale in Gebel Duwi and in several other places. All these prominent hill groups and the less spectacular expanses of Nubian sandstone find their counterparts on the west side of the Red Sea Hills in the great plains and limestone plateaus that stretch to the Nile, which is itself intrenched within them, and constitute vast areas of the Libyan Desert, virtually unchanged in lithology, stratigraphy, or fauna. Similar outcrops may be seen north of Safagah and in the oil-producing districts of the Red Sea coast.

So it is deduced that an elevation of the fundamental complex took place along north-northwest–south-southeast lines, arching a formerly unbroken cover, while increased denudation broke that cover and drove the western edges back. The disposition of resistant and soft beds in the series led to the formation of scarps, also lowlands such as Wadi Kena, on the west side, while on the east the strata were folded into the border zone of the region of elevation and severely faulted. The greater part of the cover on the east side of the Red Sea Hills has subsequently been destroyed by denudation, and only the stumps of the more deeply involved sections survive. All the members of the sedimentary series are probably present over a large part of the Red Sea littoral, buried beneath Miocene and later accumulations. On this assumption depends much of the success or failure of oil prospecting along the coast.

It will be noticed that neither Middle or Upper Eocene nor Oligocene beds are preserved in any of these masses; nor do they occur within the same limits of latitude west of the Red Sea Hills. It is probable, then, that the ancient sea, the Tethys, had been retreating northward over the whole of Egypt independently of the elevation of this north-northwest–south-southeast anticlinal axis. This is a reversal of the later Paleozoic (Carboniferous) and Mesozoic movements which had allowed Carboniferous and Jurassic sediments to be laid down in the north (Wadi ʿArabah and northern Sinai) but not in the south, which had not become submerged until Cretaceous times.

But what of the Red Sea itself? At the head of the Gulf of Suez, as already shown above, Upper Eocene and Oligocene strata are involved in the pre-Miocene faulting. Farther south those rocks are not seen; they have been utterly destroyed or buried deeply out of sight or were never formed. By analogy with the geology of the same latitudes west of the Red Sea Hills it seems that the last is the most probable and that during those periods the Red Sea area was land, suffering slow depression while the hills on its west side were being elevated. The pre-Miocene folding and faulting beyond question allowed the Mediterranean to invade the region of the Isthmus of Suez. Lower Miocene rocks have not been definitely recognized in the north-

[19] *Op. cit.* pp. 118 and 67.

ern part of the Red Sea, though they may be hidden or be indistinguishable from the gravels that were piled up on the new shore line by wadies draining the hills in Middle Miocene and later times.

While these movements were in progress evidently the Red Sea was not connected with the

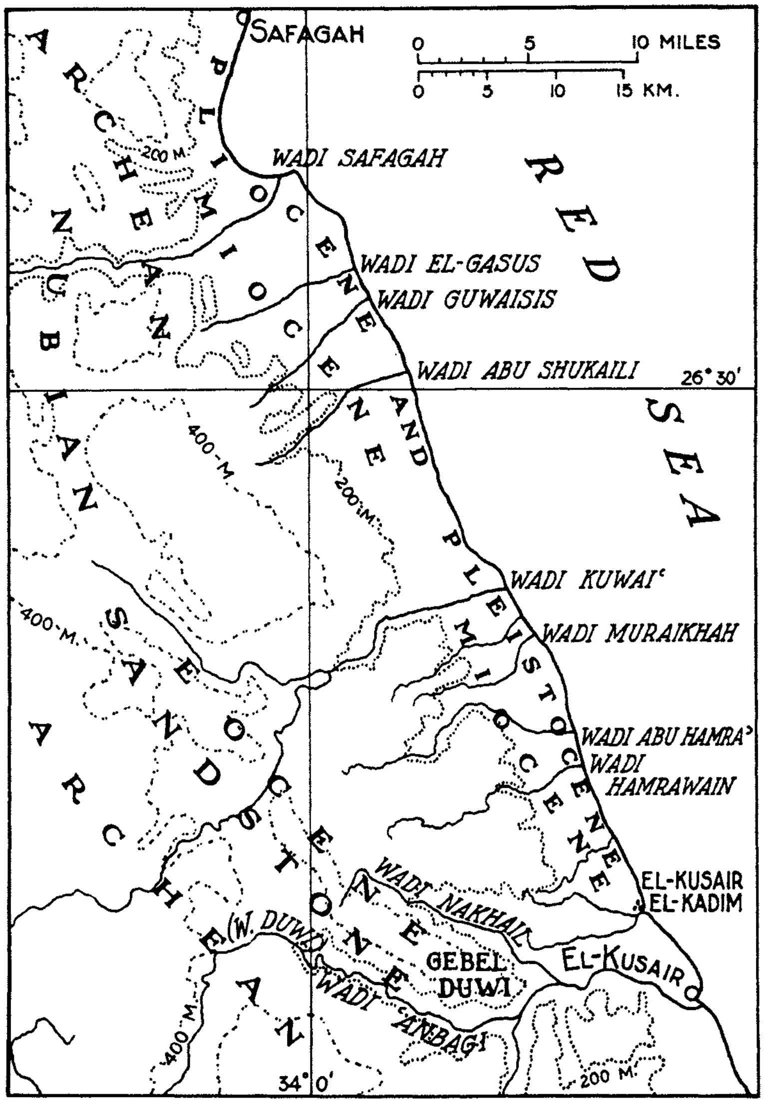

FIG. 3.—SKETCH MAP OF THE COUNTRY BETWEEN SAFAGAH AND EL-KUSAIR, SHOWING SITUATION OF MAJOR FEATURES MENTIONED IN THE TEXT

Indian Ocean, for the fauna of the latter does not appear until Upper Miocene[20] or Pliocene beds are reached. There is some question as to the position of the barrier which kept the Indian Ocean isolated from the Erythrean area of the Miocene Mediterranean; but Middle and Upper Miocene strata are now known through a considerable part of the Red Sea, and Macfadyen expresses the opinion that "there seems no reason not to believe that it reached to the southern land barrier at Perim Island."[21] According to C. Crossland, borings for water made two

[20] Beadnell, *Report on the Geology of the Red Sea Coast between Qoseir and Wadi Ranga*, p. 22.

[21] *Miocene Foraminifera from the Clysmic Area of Egypt and Sinai*, p. 16.

miles inland from Port Sudan show that alluvial gravel and sand from the hills extend downward as far as the borings, that is, to a depth of at least 1,000 meters.[22] This striking figure should serve as an indication of the amount of denudation suffered by the hills; it illustrates also the continued depression of the Red Sea area during Miocene times, with the formation of lagoons which were filled with clays and gypsum, typically developed between el-Kusair and Safagah. Here also there is some measure of the rate of denudation of the fundamental complex, since in Wadi Muraikhah (=Wadi Sudmain), near Wadi Kuwaiᶜ, the gravels contain "pebbles of Eocene limestones, flints, and fragments of metamorphic rocks, but, in this locality, apparently no granite."[23]

Beadnell[24] points out that the greatest concentrations and thicknesses of Miocene gravels, with flat terraced summits, occur opposite the main lines of drainage that debouch from the hills at the present day; that is, the main valleys have been in use at least since Miocene times. The same feature has already been noted on the Cairo–Suez road. Between the "tip heaps" of Miocene gravel and their deltas marine deposits of the time—lime grits, coral limestones, marls, etc.—were plastered directly upon the old coast of Archean–Lower Eocene rocks and around islands of these rocks (Pl. XVI). In almost every detail the Miocene shore line may be compared with that of today.

A late, post-Pliocene event was the creation of the many domal structures of the coast, many excellent examples occurring between Wadi Kuwaiᶜ and Safagah, where they are within a few hundred yards of the present coral lagoon. They show severe disturbance round the periphery, Miocene gypsum and other beds frequently approaching the vertical, with local faulting; they are usually somewhat flat-topped at about 250 feet above sea-level, with a diameter of a mile or less.

The explanation advanced in the bulletins to which reference has already been made is that the domes have been forced up by the elevation of protuberant parts of the Archean floor, a process recalling the type of folding met in the neighborhood of Suez; but Beadnell points out that the settling of soft deposits into hollows of ancient rocks would have much the same effect. Farther north, boring has revealed enormous thicknesses of salt below such domes, which are therefore assumed to have been forced up by its crystallization. In other words, boring or geophysical methods may be necessary to prove whether any dome is a salt dome or a surface indication of irregularity or faulting of the Archean floor.

The final movements of Pliocene (and perhaps Miocene), Plio-Pleistocene, and Pleistocene times, possibly still in operation, have been elevation of the land (with consequent tilting of littoral deposits seaward, usually at a very gentle angle) and contraction of the sea. It is possible also that the floor of the sea continued to be depressed.[25] Pleistocene benches and terraces traverse the coastal plain in a striking manner, the littoral and lagoon facies of some being clearly preserved. So far as can be ascertained, their levels are constant throughout the Gulf of Suez and the Red Sea. The Mediterranean Sea and the Indian Ocean might therefore have been united, had not deposits east of the Nile Delta and some local accumulation severed that connection which the Suez Canal has now reinstated, the interchange of marine fauna being thus re-established. In view of the stable conditions that evidently obtained along much of the Egyptian coast of the Red Sea, east and west of the Delta, and in the Nile Valley in Pleistocene times, it should be possible to find much in common among these widely separated areas.

[22] Linnean Society, Zoölogy, *Journal* XXXI (1907–15) 14.

[23] Hume *et al.*, *Preliminary Geological Report on the Quseir–Safaga District*, p. 10.

[24] *Op. cit.* p. 15.

[25] For recent work on the configuration of the sea floor see Crossland in *Nature* CXXXVII (Jan.–June, 1936) 712.

II

THE PLIOCENE PERIOD

THE NILE VALLEY

In the preceding volumes of this series the following conclusions have been reached concerning the events of Pliocene times in the Nile Valley:

Nubia and Upper Egypt[1]

1. The Nile Valley was cut to profound depth in Pontic times, that is, during the elevation that succeeded and in part accompanied the deposition of Miocene limestones from Cyrenaica to Suez and along the Gulf of Suez and the Red Sea.

2. In Pliocene times marine transgression led to the flooding of this deep gorge to a height of about 180 meters above present sea-level. The southern limits of the gulf thus formed were found in the vicinity of Kom Ombo. From all sides streams poured their load of bowlders, pebbles, sand, and mud into the gulf, the waters of which checked the flow and led to the deposition of great thicknesses of conglomerate near the valley sides. Fine material was laid down in regions of quieter water.

3. These accumulations wrap round the sides of enormous detached masses which slid away from the valley walls probably in Pontic times, but have not since moved.

4. Clean quartz sands were washed into the gulf by strong currents from the region of the Nubian sandstone. They occur here and there in Pliocene beds with indications of current action, and their thickness varies from 100 feet to a few feet or even inches within short distances.

5. The Pliocene deposits are locally covered with sands and gravels consisting of material derived from the Red Sea Hills (feldspar crystals, pebbles of granite and many igneous and metamorphic rocks) mixed with quartz sand from Nubian sandstone. These beds indicate considerable fluviatile action and are unconformable upon the "normal" gulf series. They were considered to be of Plio-Pleistocene age but to precede the formation of marked river terraces.

Upper and Middle Egypt[2]

1. Similar evidence of Pontic excavation and Pliocene transgression is seen on every side.

2. There is reason to suppose that the filling of the gulf took place in Middle and Upper Pliocene times; no Lower Pliocene beds are proved.

3. The relation of Pliocene deposits to slipped masses is the same as it is in the south.

4. The courses of tributary streams may be traced across the adjacent plateaus.

5. The Pliocene gulf entered considerable distances into embayments surrounded by Nubian sandstone hills; one such bay enabled the waters to approach close to the Red Sea Hills, from which a vast drainage system has brought material into the Nile Valley. In spite of this, however, feldspar and other igneous or metamorphic rocks are not found in the Pliocene deposits of the bay, and it is concluded that the Archean complex was still covered by sedimentary rocks of Cretaceous and (locally) of Eocene age. The irruption of material from the com-

[1] See *OIP* XVII 6–13 and 82 f. The Nile Valley in the northern Sudan was not eroded in the manner here described; see Sandford in the *Geographical Review* XXVI (1936) 67–70.

[2] See *OIP* XVIII 9–12 and 122.

plex into the Nile Valley is therefore considered with some reason to be a late or post-Pliocene event, as had been supposed from observations in the main valley.

6. Such clean quartz sands as are seen in the south[3] assume greater importance and in many places lie unconformably among Pliocene strata; locally they contain material derived from the underlying Pliocene rocks. They are thus considered to mark a considerable interruption in the formation of the gulf series, which may have accompanied a temporary regression of the marine flooding. This is coupled in the north with suggestions of unconformity of estuarine Upper Pliocene beds upon marine Middle Pliocene strata, both being fossiliferous.

7. The later Pliocene beds attain the full height of 180 meters, and 200 meters may be taken as a reasonable covering figure, which is perhaps exceeded locally by a few meters. In the northern part of Upper Egypt and in Middle Egypt massive travertines are associated with this phase, together with estuarine beds in the north. Pebble beds occur in the lower part and below the travertines.

8. A further period of locally deep erosion was followed by the piling up of great thicknesses of "Plio-Pleistocene" false-bedded sands, suggesting strong currents passing along the valley, scouring the Pliocene beds, and then filling the hollows and accumulating deposits to 200 meters or rather more above present sea-level. Since the sea does not seem to have been finally excluded at this stage, it may be considered to be the last phase of Pliocene times, though the material deposited is of "Plio-Pleistocene" type. The sands were followed by floods of coarse gravel with a high proportion of pebbles derived from the Archean complex of the Red Sea Hills. These were piled up to a great height, especially in the north, and subsequently re-deposited in an orderly succession of purely fluviatile Nilotic terraces which may be termed Plio-Pleistocene; but, if the terminology of the Mediterranean beaches is adopted, some of them become the highest and oldest stages of the Pleistocene succession.

The Nile-Faiyum Divide[4]

1. The evidence of Pontic excavation and Pliocene transgression is unchanged. A small embayment of the Middle Pliocene gulf extended over the southeast corner of the province of Faiyum.

2. Middle and Upper Pliocene marine and estuarine fossiliferous beds are identified, passing up into great thicknesses of cobble gravels. The marine stage includes typically *Pecten benedictus* and *Cardium subsociale; Ostrea cucullata* occurs in marginal deposits; *Melanopsis* is especially associated with the estuarine Upper Pliocene facies.

3. The deposits were banked round and locally overwhelmed slipped masses of Eocene rocks, some of which, of great size, had traveled astonishing distances over soft clays; the phase of landslips is remarkably well illustrated. In some places the slips have led to the preservation of higher zones of the Eocene succession than have survived subsequent denudation in this neighborhood.

4. "Fossil tributaries" of the Nile were first recognized in this district, their tumultuous contents of cobble gravels and of Eocene limestones and clays, cemented at depth into hard conglomerates, having survived subsequent denudation better than the broad expanses of surrounding country through which the rivers once flowed. Sinuous ridges may be traced across the country. Several such valleys, now hills, were mapped in detail.

5. The gravels of these ancient tributaries, where remote from the Nile, naturally mount high above the known height of the Pliocene transgression. Near the Nile the tributaries

[3] See *OIP* XVII 13. [4] See *OIP* X 11–23.

spread out their load into delta-like expanses of great thickness, especially during the Upper Pliocene estuarine phase, the more normal deposits of which were finally extinguished in a flood of coarse gravel and cobbles.

6. Clean quartz sands are identified in this region, as in the south, and locally expand to considerable thickness; southeast of the Faiyum they contain *Mactra subtruncata* var. *elongata* overlain by *Melanopsis* beds. Prominent patches of "Plio-Pleistocene" (feldspar-bearing) sands also appear, especially near Cairo (see p. 44).[5] Gravel terraces occur at heights much greater here than farther south and dominate the Western Desert in the neighborhood of the Nile. A vast amount of erosion has taken place since their deposition.

LOWER EGYPT

Deposits West of the Delta

THE APEX

The most northerly "fossil river" mentioned in *OIP* Volume X is that opening at the pyramids of Abu Sir. Its mouth is nearly 5 kilometers wide, but the distance to which it stretches inland is difficult to determine owing to its being masked by a sheet of Plio-Pleistocene terrace gravels. The mouth is filled entirely with false-bedded sands. Along the northern junction of these with the Eocene is cut a modern wadi such as has often been observed at the junction of Eocene and Pliocene; one side is formed of Eocene limestones and marls, the other of Pliocene sands. The general dip of the sands filling this ancient tributary mouth is as usual inward: northward at the south side, on the high ridge behind the Sakkarah step pyramid, where a *Pecten* bed (i.e., a Middle Pliocene marine bed) occurs at the base, and southward at the north side, where no fossils are present.

Beyond, along the cultivation edge between the pyramids of Abu Sir and those of Gizah, lies what may be regarded as the type locality of the Nile Valley Pliocene, the most often visited, the most written of, and by far the most fossiliferous outcrop of Pliocene rocks in Egypt. In it are situated the famous Wadi el-Mallahah, whence Mayer-Eymar obtained many species,[6] and the site called by the neighboring inhabitants Kom el-Shellul ("Shell Hill"), where numerous shells of the large sea urchin *Clypeaster aegyptiacus* were formerly obtained and sold to tourists at the pyramids. The side of the hill is covered with diggings, and only fragmentary specimens can now be found. Along this tract littoral deposits of the Pliocene gulf are banked steeply against the Upper Eocene, which they overlap with great unconformity at an average angle of about 10–20°. The remarkable abundance of fossils in the beds here as compared with those at the mouths of valleys rich in detrital material is instructive.

Wadies leading down from the high terrace behind have cut through the superficial covering of Pliocene into Eocene beds beneath, exposing along both sides continuous sections of the junction. The nature and relations of the Pliocene beds are thus particularly clearly shown. At Kom el-Shellul they are as in Figure 4. The section of this locality published by Fourtau[7] can only be described as fantastic. His "Miocene conglomerates," shown resting conformably on the Eocene, are in reality the basal conglomerate of the Pliocene, from which the wrong fossils were recorded; and it should be shown as cutting across the eroded edges of the Eocene. His two Pliocene strata are wrongly shown as banked against a vertical cliff, and, as

[5] See also *OIP* XVIII 47.

[6] See Karl Mayer-Eymar, "Systematisches Verzeichniss der Fauna des unteren Saharianum (marines Quartaer) der Umgegend von Kairo" (*Palaeontographica* XXX 2 [Stuttgart, 1883–1903] pp. 61–90). The Middle–Upper Pliocene fauna was monographed as Quaternary.

[7] Société géologique de France, *Bulletin*, 3. sér., XXVI (1898) 39–42.

a final inaccuracy, they have been inverted. To anyone who examines the *Clypeaster* bed it is obvious that it lies *above* the familiar *Ostrea cucullata* and *Pecten benedictus* beds, not below them as shown by Fourtau. *Ostrea cucullata* here occurs as an oyster bed, with a maximum thickness of 30 feet, at the base of the series, immediately followed, as in many places around the Faiyum, by 6 feet of beds crowded with *Pecten benedictus* and *Chlamys scabrella*. Upon this lies sandstone only 2 feet thick, full of remains of *Clypeaster aegyptiacus*, casts of large gastropods (*Strombus coronatus, Xenophora infundibulum, Cypraea fabagina*, etc.), the same Pectens as in the underlying bed, and many other fossils. Then follow up to 30 feet of yellow quartz sands and brown sandstones with large flint pebbles, apparently unfossiliferous. All the beds rise as the floor rises away from the cultivation edge, at the same time thinning out. The oft discussed fossil horizon with *Clypeaster* is therefore an integral part of the *Pecten benedictus* zone. The occurrence of this zone in Wadi el-Mallahah also, where 178 species (chiefly mollusca) have been recorded, indicates that its nearest equivalent in the succession of Pliocene beds described in the Faiyum is the *Cardium* beds.[8]

The Pliocene terminates south of the Sphinx in a north–south ridge crowned with a relic of the basal conglomerate breccia of large slipped and tumbled bowlders mixed with pebbles. Beyond comes the prominent plateau of Eocene limestones on which the pyramids of Gizah

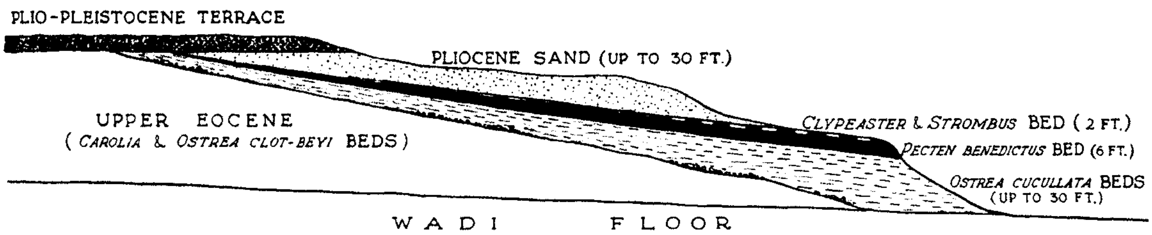

FIG. 4.—SECTION OF PLIOCENE BEDS IN THE SIDE OF A WADI AT KOM EL-SHELLUL. VERTICAL AND HORIZONTAL SCALES APPROXIMATELY EQUAL

stand, with the Sphinx carved out of a projecting mass at its foot. The Eocene rocks here overlook the cultivation in a steep cliff, leaving no room for Pliocene. Several curious misstatements have been published concerning this locality also; and, since they have been repeated and far-reaching deductions have been drawn from them by no less an authority than Eduard Suess, we cannot pass them by unnoticed. In Suess's great work, *Das Antlitz der Erde*, occurs the following passage:

> The first remarkable fact with which we are confronted is the relationship of the fauna, represented only by a small number of species, found in the sand deposits near the pyramids of Ghizeh, with that of the Red sea; this was first pointed out by Beyrich and subsequently recognized by T. Fuchs. These sand deposits form the cliff which bounds the desert towards the valley of the Nile. The Sphinx is carved out of their consolidated beds. . . . . The shells of *Ostrea Forskali*[9] and *Pecten erythraeus*, species which live in the Red sea, lie in this sand.
>
> Thus a district of the Erythraean type, or at least one which includes several species characteristic of the Red sea, occurs in the region of the present Mediterranean.[10]

The criticisms that must be made of this passage are that the Sphinx and the cliff which bounds the desert are composed not of Pliocene strata (as the fauna named would indicate)

[8] *OIP* X 13 and Fig. 3. The *Clypeaster* itself either does not occur or is very rare at Wadi el-Mallahah and elsewhere in Egypt has been found at Kom el-Shellul only. Such restricted occurrences of sea urchins, due to their colonial habits, are known in at least two localities in the Jurassic of England: in the Corallian of Calne, Wiltshire, and in the Cornbrash of Cirencester, Gloucestershire.

[9] Synonym of *O. cucullata* Born.

[10] Eduard Suess, *The Face of the Earth*, translated by Hertha B. C. Sollas under the direction of W. J. Sollas, I (Oxford, 1904) 379 f.

but of Eocene, while the records of Red Sea mollusca are not substantiated by the extensive collections of the Geological Survey at Cairo and elsewhere and have been since denied by the paleontologists most competent to form an opinion.

The common Pliocene *Pecten* of Kom el-Shellul and elsewhere was unfortunately confused with the living Red Sea form in an authoritative monograph by Depéret and Roman, who, following Beyrich, described it as *Pecten erythraeensis* Sowerby and said that the two were indistinguishable.[11] Dr. Blanckenhorn, however, immediately denied the identity and in an exhaustive discussion of the question proved from an overwhelming mass of material collected from all parts of Egypt that the Nile Valley *Pecten* showed every grade of variation to the typical *P. benedictus* Lamarck of the Plaisancian of Perpignan. At the same time he pointed out a number of characters by which the species differed from any collected in the Red Sea.[12] The distinctness of the Red Sea and Nile Valley forms has recently been attested again by Cox, who has re-examined the question in connection with the faunas of the two provinces as a whole and concludes that the evidence for any connection between the Red Sea and the Mediterranean since the Miocene is negligible.[13] We have made further collections from several localities in the Nile Valley and on the shores of the Gulf of Suez and would add our testimony to the conclusions of Blanckenhorn and Cox concerning the nature and distribution of the Pectens.

The northern face of the limestone plateau on which the Gizah pyramids stand (cf. p. 14) is riddled with borings[14] probably of the bivalve *Lithophaga*, as first noticed by Schweinfurth. The adjacent deep wadi is excavated along the junction of the Eocene limestones with another valley filled with Pliocene sands and clays and Plio-Pleistocene sands, extending from Mena House as far as the Cretaceous limestone headland of Gebel Abu Roash.

This mass of Pliocene beds consists of clays at the base, passing up into increasingly coarse quartz sands. In spite of the large area of outcrop which covers the center of the plunging anticline between Gebel el-Hikaf and the Giran el-Ful–Gizah pyramids ridge we were unsuccessful in finding any fossils, an indication that another river or large stream debouched here, bringing with it quantities of detrital materials inimical to the molluscan fauna. From the northern side of the hollowed anticline a great mass has slipped and stands isolated amid Pliocene and later deposits.

The detrital beds, which consist entirely of quartz and flint gravels derived from the vast reserves of the Oligocene to the west, can be traced up to the head of the Pliocene bay, where they terminate in a series of outlying mounds, conspicuously black against the white ground, a short distance to the west of the prominent ridge of Giran el-Ful. Beyond this point they have been removed by the Plio-Pleistocene Nile, which has planed off both soft rocks and hard at about 100 meters above sea, depositing across the top a level sheet of Nile gravel (the 320- to 265-foot terrace; see p. 43).

Outlying relics of the old Pliocene surface are still preserved, however, beneath cappings of still higher terraces, at the tops of the highest hills west of the Delta, Gebel el-Khashab and Karat (or Gebel) el-Haddadin (see folding map). Near the top of the eastern end of Gebel el-Khashab, below the 248-meter point, is preserved a channel of semicircular section cut in

[11] "Monographie des Pectinidés néogènes de l'Europe et des régions voisines" I (Société géologique de France, *Mémoires* X 1 [Paris, 1902]) 35–37.

[12] *Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie*, Beilage-Band XVII (1903) 177 ff.

[13] L. R. Cox in Malacological Society of London, *Proceedings* XVIII (1928–29) 166–73 and 185–87. Hume and Little (International Geographical Union, Commission on Pliocene and Pleistocene Terraces, *First Report*, p. 14) identify a Milazzian (Pleistocene) marine level in common between the Mediterranean and the Red Sea. The question is discussed more fully on our p. 68.

[14] See Beadnell, *The Cretaceous Region of Abu Roash*, p. 37.

Oligocene sandstone and filled with large cobbles. At the base is a mass of silicified tree trunks and sandstone blocks derived from the erosion of the Oligocene. This old channel is sealed above by a sheet of igneous gravel of the Gebel el-Khashab terrace, 765 feet above Nile (see p. 42 and Pl. III).

It is highly probable that this fragment was part of one of the Pliocene watercourses leading into the head of the bay near Giran el-Ful. Since the time when it was in use the intervening ground has been lowered by denudation to such an extent that Gebel el-Khashab and Gebel el-Haddadin are left standing as isolated hills. In all probability they were formerly backed by still higher ground, off which watercourses drained, as in the region of the Faiyum.

Beyond the Gebel Abu Roash headland there follows a gap of 10 kilometers from which all trace of Pliocene beds has been completely removed, but before reaching Gebel el-Mansuriyyah they return in force, forming the mass of that hill with an outcrop 7 kilometers wide. The south and southwest sides and the summit of Gebel el-Mansuriyyah are formed of coarse gravels like those of Gebel Dakakin and many other places in the Faiyum district. The highest point, at the southern edge, rises to 194 meters, but the gravels here are thin and were probably laid down on a steep land surface rising up to Karat el-Haddadin (233 m. above sea) and beyond. The top of Gebel el-Mansuriyyah is in general flat, at a level of about 180 meters above sea. We consider that it may indicate approximately the sea-level in Pliocene times, since we failed to find upon it any trace of igneous pebbles such as might show that it had been leveled subsequently by the Nile.

The Cretaceous headland (technically a dome) of Gebel Abu Roash undoubtedly formed the western gatepost of the Nile Valley in the Pliocene period. Beyond it no more is seen of the Nile Valley type of Pliocene, with its sands and clays containing shell banks composed of Pectens and oysters. Under Gebel el-Mansuriyyah the Pliocene shore line turns away to the west, indicating that the open Mediterranean has been reached, while at the same time the character of the marine deposits (excluding gravels) changes completely.

From Gebel el-Mansuriyyah onward to Wadi el-Natrun the characteristic rock of the Pliocene is a white porcelaneous limestone having the appearance of statuary marble and containing numerous layers of tabular flint. At the base of the Pliocene is always a well marked conglomerate, resting on a deeply eroded uneven surface of the underlying strata and incorporating rolled blocks of sandstone and silicified wood from them. At one point, near kilometer post 42 on the Cairo–Alexandria track, the conglomerate consists of pink limestone fragments, possibly derived from Miocene strata now totally destroyed.

Over the district between Gebel el-Mansuriyyah and Wadi el-Natrun fossils are surprisingly rare in the Pliocene limestone. We found them abundant at only one locality, namely the white hill called Gebel Hamzi (see folding map). The limestone series is here probably at least 100 feet thick, but we found fossils only at the summit, where a bed with tabular flints is full of the little gastropod *Pirenella conica* (Blainville). The altitude of the fossil bed at this point is 110 meters above sea, and it is near the top of the limestones, which contain interbedded patches of breccia with red-stained cement and at a level of about 130 meters pass up into coarse sandy beds and then gravels. It is therefore some 10 meters above the highest limit of *Ostrea cucullata* and *Pecten benedictus* in the Nile Valley and 40 meters above their more common limit, so we may conclude that it lies more probably on the horizon of the *Melanopsis* beds.

WADI EL-NATRUN

After a temporary break at the end of Wadi el-Farigh, Pliocene deposits reappear, striking at first due west, then west-northwest, the basal conglomerate standing out as a high ridge separating Wadi el-Farigh and Wadi el-Natrun. The summit points along the ridge rise consistently to heights between 90 and 118 meters, while the two wadies are excavated to below sea-level (see Fig. 2). The conglomerate at the base of the Pliocene and the plane of erosion on which it rests dip from the summit of the ridge steeply northward under Wadi el-Natrun. The northern slope of the ridge is largely formed by the dip-slope of the conglomerate; but farther down in the depression younger beds succeed, and it is the excavation of these, probably by wind, that has formed the depression (Pl. V *B*). Wadi el-Farigh, which is not so deep, reaching and falling below sea-level at only one point, lies south of the ridge and is excavated entirely in Lower Miocene or Oligocene sandstones and sands. The cause to which effective action of wind on the Pliocene beds of Wadi el-Natrun is to be attributed seems to be lateral passage of most of the white limestones into soft marls. The eastern end of the wadi is shut in by cliffs of hard white limestone, whereas within the wadi and on its other surrounding walls only thin beds of limestone and flint are to be found, intercalated in a thick series of soft marls and clays.

The Pliocene beds exposed in the floor of Wadi el-Natrun, below or just above sea-level, are different from any seen elsewhere, being estuarine in origin and containing a rich drifted fauna of vertebrates. The bones are abundant and in a beautiful state of preservation. They occur in bands of marl and soft white laminated limestone (a kind of lithographic stone) quarried for chemical purposes by the Egyptian Salt and Soda Company. Several expeditions have undertaken excavations to procure the bones, and numerous monographs and papers have been published on them.[15] The fauna comprises various kinds of fish, turtles, and crocodiles, as well as the dwarf hippopotamus (*H. hipponensis*), three species of otters, and a sea cow. The most interesting feature, however, is an extensive land fauna. It includes an early camel, giraffe (*Libytherium*), boar, an ancestral horse (*Hipparion*), rhinoceros, elephant, mastodon, hyena, *Machairodus*, and, most interesting of all, skull fragments of three cynopithecoid apes (*Libypithecus markgrafi*, *Aulaxinus libycus*, and *Papio* or *Cynocephalus* sp.).

Evidently such a fauna was collected and drifted down by a great river, which is readily identified as the Nile. Blanckenhorn, however, while believing that the deposits represent the delta of an ancient Nile, has always maintained that at the time when they were laid down the Nile flowed directly into Wadi el-Natrun by some unknown course across the Libyan Desert west of its present valley.[16] Such a supposition involves the revival of the old myth of a mysterious trans-Libyan river, the Ur-Nil—a myth for which there is no evidence and which has been recently set at rest by Ball.[17] Our geological investigation of the southern rim of Wadi el-Natrun revealed no trace of a river mouth nor any gap where one could have lain; a steep conglomerate-covered slope passes the whole way round the south side of the depression.

A consideration of the level at which the estuarine bone beds occur (below and just above sea-level) disposes of any difficulties as to their having been brought down the valley of the Nile, for they are lower by nearly 100 feet than any of the deposits seen in the Nile Valley or along the sides of the Delta between Wadi el-Natrun and Cairo. Even if similar beds were ever deposited within the Nile Valley, however, they need not be expected in borings, since they would probably have been cleared out in later times. Blanckenhorn's theory, on the other hand, involves the supposition that the Ur-Nil, after settling into its bed in the Miocene period and cutting the Nile Valley in Miocene to Pontic times, then left its course to find a new one across the Libyan Desert to Wadi el-Natrun, returning in the Pleistocene to its original bed. Such a supposition is clearly untenable. Blanckenhorn's view, in fact, depends on the now discredited theory that the Nile Valley owes its existence to comparatively recent faulting.

[15] Especially by Ernst Stromer in Deutsche geologische Gesellschaft, *Zeitschrift* LXV (1913) A 350–72, LXVI (1914) A 1–33 and B 420–25, and elsewhere.

[16] *Hdb.* pp. 131 f.

[17] *Geographical Journal* LXX (1927) 28–32.

If the excavation of the present valley by a Miocene and Pontic river is conceded, his theory has to be abandoned.

It may be presumed that the bone beds of Wadi el-Natrun are the only visible outcrop of the submerged delta of the Pontic Nile, formed during the first excavation of the valley.[18] The subsidence accompanying the transgression of the Third Mediterranean period, which carried the sea up the Nile Valley to form the gulf of Plaisancian-Astian times, submerged the products of erosion of the Pontic river far below sea-level, and they have not yet re-emerged. Only by the accident of wind erosion in the soft overlying strata of Wadi el-Natrun has a hole been excavated deep enough to give us a glimpse of the topmost layers of the ancient delta, in the strata of which lie entombed the rich vertebrate fauna of the African continent of Pliocene times.

At the opposite extremity of Lower Egypt the same beds may have been reached at and somewhat below sea-level in the cuttings of the Suez Canal. Fraas described a sand near el-Shallufah, resting on Miocene *Pecten* beds, containing crocodile teeth and bones and teeth of quadrupeds (notably hippopotamus), whales, and sharks.[19] This same bed was thought to have been the source of bones of *Phacochoerus* and *Halianassa* obtained at other points along the canal. Even Blanckenhorn remarked that these beds were strongly reminiscent of the bone beds of Wadi el-Natrun,[20] but any relationship with them would be difficult to account for on his hypothesis of a Nile flowing into the Mediterranean far to the west of its present mouth. On the other hand, the evident similarity strongly supports the view here taken that the mouth during Pliocene times was on the same longitude as it is at present.

It is not our purpose to discuss in detail the stratigraphy of the Pliocene beds of Wadi el-Natrun, which have been dealt with in at least an introductory manner by Lyons, Blanckenhorn, and others. Only a fraction of the area has been touched, however, all workers so far confining their attentions almost exclusively to the locality of Karat Muluk, where most of the bones have been found. An interesting task awaits the geologists who will eventually elucidate the stratigraphy of the wadi as a whole. We would call special attention, however, to the part played by lateral change of beds, especially limestone, along the south side and at the east end where thick limestone forms a bounding cliff. Limestone dies out laterally and in direction of dip, and the depression is deepest where the clays attain their maximum development.

The principal molluscan horizon is an oyster bed composed of very fragile shells of *Ostrea* aff. *cucullata* similar to but not identical with those in the Nile Valley. The differences, pointed out by Blanckenhorn,[21] afford additional evidence for assigning a somewhat earlier date to the bone beds of Wadi el-Natrun than that of the *O. cucullata* beds of the Nile Valley. Other beds contain shells of ostracods.

It is evident that the general dip of the Pliocene strata is not so steep as that of the basal conglomerate and that consequently the higher beds overlap the lower. This accounts for the absence of bone beds at the two extremities of the Wadi el-Natrun depression, where the excavation has not been carried so low as in the middle, although the basal conglomerate and overlapping beds are there equally well exposed (Fig. 5).

The western end of the depression is an interesting region owing to the abrupt oncoming of pink Middle Miocene (Helvetian) limestones, which extend westward into Cyrenaica. The Miocene escarpment faces south in a steep cliff at the foot of which was a short westerly exten-

[18] See *OIP* X 9 f.

[19] Oskar Fraas, "Geologisches aus dem Orient" (Verein für vaterländische Naturkunde in Württemberg, *Jahreshefte* XXIII [Stuttgart, 1867] 145–362) pp. 316 f.

[20] *Hdb.* p. 141.

[21] Deutsche geologische Gesellschaft, *Zeitschrift* LIII (1901) 315. Examples from Wadi el-Natrun have been figured by R. Bullen Newton in the *Geological Magazine*, new series, Decade IV, Vol. IV (1899) Pl. XIX 1–5 and pp. 404–6.

sion of the Pliocene shore line, but of dimensions inadequate to have brought the river postulated by Blanckenhorn for supplying the bone beds. The basal conglomerate of the Pliocene, here largely composed of pink limestone fragments, can be traced round the northern dip-slope of the Miocene and soon seems to become lost by overlap of the Plio-Pleistocene.

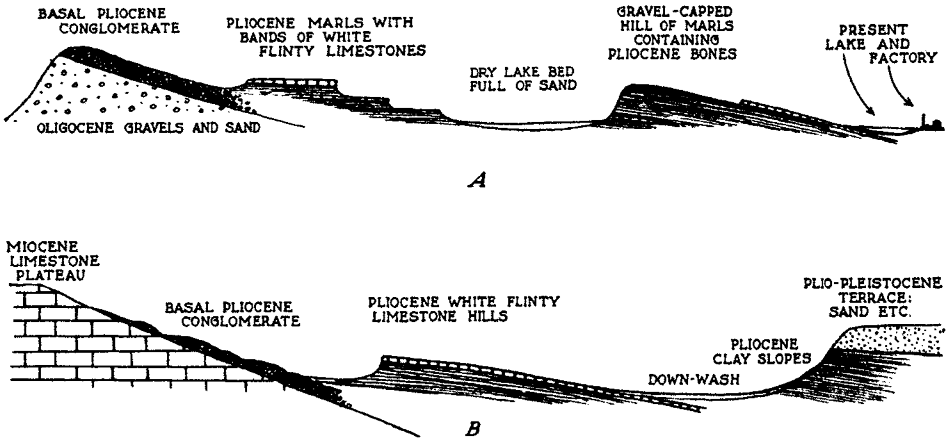

FIG. 5.—DIAGRAMMATIC SECTIONS OF PLIOCENE AND PLIO-PLEISTOCENE STRATA ACROSS WADI EL-NATRUN. *A*. SOUTHWEST OF THE SODA FACTORY. *B*. AT NORTHWEST END, SOUTHWEST FROM KILOMETER POST 140 ON THE CAIRO-ALEXANDRIA TRACK (20 KILOMETERS WEST OF NORTHWEST CORNER OF FOLDING MAP)

The western end of Wadi el-Natrun provides perhaps the best locality for observing the gradual upward passage of the Pliocene strata into the underwater equivalents of the Plio-Pleistocene terraces. The only criterion that can be relied on for indicating a line of demarcation is the first appearance of feldspar crystals. South of kilometer post 140 on the Cairo-Alexandria track we measured the following section:

Section Showing Passage from Pliocene to Plio-Pleistocene Strata

Bed		Feet
	PLIO-PLEISTOCENE (53½ FT.)	
16	Gray calcareous sandstone, weathering rubbly (forms top of plateau along which car track runs)	4
15	Fine gravel of quartz and feldspar	5
14	White calcareous sandstone pellets and sticklike concretions, passing up into the gravel	1
13	White sand	3
12	White concretionary sandstone	5
11	Papery, chalky white cement stone	2
10	Green clay	3
9	*Pirenella conica*[22] bed—a porous mass of hollow casts in gray sandy limestone	¼
8	Greenish and yellow sand	30
7	White concretionary sandstone with feldspar crystals	¼
	PLIOCENE	
6	Dark green, black, and brown clays	about 40
5	Gray, platy, laminated limestone with rare patches of comminuted shells	½
4	White chalky limestone	1
3	Soft dark green clays with selenite crystals	20+
2	Gray and white calcareous sandstone	?
1	Great thickness of clays and white limestone bands and calcareous sandstone pellets	?
	Bone-beds, overlapped	
	Basal conglomerate	

[22] Useless for correlation purposes, since it occurs from the Pliocene onward to the present day. It is highly improbable that the *Pirenella* bed here is of the same age as that at Gebel Hamzi (p. 16).

Deposits East of the Delta

The Pliocene strata at the foot of the Mukattam cliffs have been described by Schweinfurth and Blanckenhorn, and we have nothing to add to their accounts, for the exposures are now poor. The development is essentially the counterpart of that on the opposite side of the valley,[23] and many of the same fossils have been recorded, though the lists are not so long.

Since the Pliocene northeast of Cairo is virtually unknown and receives no mention even in Barron's memoir on the country between Cairo and Suez,[24] we set outselves the task of following its boundary out of the mouth of the Nile Valley. On rounding the corner of Gebel el-Ahmar it strikes away eastward with the same complete change in lithological and paleontological characters as was noted where it rounds Gebel Abu Roash in the west. Evidently the combined headland of Gebel el-Ahmar and the Mukattam heights formed the eastern gatepost, as it were, of the Pliocene gulf, corresponding to Gebel Abu Roash on the opposite side of the valley.

On the east side, however, although beds with *Pecten benedictus* and *Ostrea cucullata* are not met with and white and pink porcelaneous limestones such as are seen between Gebel el-Mansuriyyah and Wadi el-Natrun take their place, the Pliocene deposits form at first an extensive bay from east of Heliopolis to some 2 kilometers beyond Tower 3 on the road to Suez. There the boundary turns north and then west once more, and a faulted block of Miocene hills which builds the Gebel Umm Kamar group closes in to the cultivation edge at the sewage works of el-Khankah.

In this bay, which may be conveniently termed the Heliopolis bay, the principal rock is the highly characteristic pink and white limestone, containing a variable amount of large sand grains, such as we have become familiar with on the west side of the Delta. The limestone forms the bare hills east and northeast of the Heliopolis tramway depot, passing locally into highly porous rock indistinguishable from travertine, and is best exposed along the spurs on either side of a large wadi north of Tower 2 on the Suez road. Plio-Pleistocene feldspathic sands worked in pits northeast of the tramway depot contain pebbles and angular fragments of the limestone. Pliocene limestone with flint pebbles is exposed in the tramway cutting near by in variable layers of about 3 feet, interbedded with gray clays reminiscent of the Upper Egyptian facies to a visible thickness of about 20 feet.

A long ridge lying north of and almost parallel to the Suez road and extending from the sand pits toward Tower 3 is composed entirely of Pliocene beds. At a level of about 150 meters above sea limestones pass up into gravels (as on Gebel el-Mansuriyyah), and these form the rest of the ridge eastward. At the eastern end the limestones are entirely overlapped, and the gravels come to rest with a basal conglomerate on Lower Miocene (or Oligocene?) grits with basalt flows.

The relations of the beds are thus the same as in the ridge forming the southern boundary of Wadi el-Natrun, but here no such continuous ridge is formed owing to the subsequent dissection of the country by numberless wadies draining toward cultivation from the high ground on the southeast. The basal conglomerate of the Pliocene describes a zigzag outcrop, tonguing far down the wadies and up the long spurs but keeping a general direction parallel to and south of the Suez road for 12 kilometers and crossing it 2 kilometers west-southwest of Tower 3. At a few points on the extreme edge of the outcrop the gravels reach heights considerably above 180 meters, the highest points being 195 and 210 meters on the ridge behind Tower 3.

[23] E.g. in the deepest part of the gravel pits of ʿAbbasiyyah we noted pure quartz sand, typically Pliocene, below feldspar-bearing (Plio-Pleistocene) quartz sands with local conglomerate, the two sands separated by fine-bedded clay.

[24] *The Topography and Geology of the District between Cairo and Suez.* The more important places mentioned in this section are shown in our Fig. 10.

At these places, however, the gravel is very thin and, as is usual at heights above 180 meters, appears to have been formed on a land slope and therefore need not be taken into consideration in determining the Pliocene water level.

We were unable to spare sufficient time to determine how far up the valley followed by the old Suez railway of 1858–69 the Pliocene extends, but probably it continues to no great distance, the valley being in all probability of subsequent origin. Relics of watercourses which formerly drained into the Pliocene of the Heliopolis bay are numerous in the country traversed by the Suez road, taking the form of gravel mounds and ridges, now much dissected and disconnected. Their mapping, in such a broken country consisting largely of gravels, would require much detailed work; but it would be possible, for the Pliocene gravels can always be recognized with practice, by reason of their composition and geological relations.

The only fossils found in the Pliocene east of the Delta were indeterminate markings of reeds in a tufaceous stratum near the top of the limestones on the summit of a ridge 2 kilometers northeast of Tower 2.

North of the Heliopolis bay the relations of the Pliocene beds on the east of the Delta are much less clear than those on the west, owing to the broken nature of the country.

North of the sand dunes behind the sewage works of el-Khankah Miocene and Oligocene beds form high ground for some 15 kilometers; in that area are situated the extensive quarries worked by the convicts of the Abu Zaʿbal prison. The high ground is probably bounded on the north by faults, beyond which succeed vast plains of Nile gravel corresponding to those between the Delta and Wadi el-Natrun. Unfortunately there is no hollow like Wadi el-Natrun scooped out between the gravel terraces and the older rocks, and over most of the area the outcrop of the Pliocene is entirely concealed.

At the "corner" where the Nile terraces sweep round high ground eastward, about 20 kilometers southwest of Bilbais, the foothills are composed of an enormous thickness of coarse gravel made up of both Oligocene and Miocene materials. The same feature extends a considerable distance eastward along the margin of Gebel Umm Kamar. This gravel is obviously older than the Plio-Pleistocene terraces which it underlies, and the presence of pebbles of pink and mauve Miocene limestone in it dates it as Pliocene. It can be traced up the north face to the highest points of the Gebel Umm Kamar ridge; we recorded it in considerable thickness at a point marked on the map as 196 meters above sea, as an appreciable skimming at a point 209 meters, and as a scattering of pebbles to 211 meters—heights corresponding significantly with the maxima round the margin of the Heliopolis bay and elsewhere.

The presence of this Pliocene gravel in its present position throws an interesting side light on the amount of denudation that has affected the surrounding country since its accumulation, as compared with the trifling amount suffered by the Plio-Pleistocene terraces. The only satisfactory way of explaining its origin is to suppose it to be a down-wash fan carried by heavy rains from higher ground to the south, whence alone the Oligocene materials of which it is chiefly composed could have been derived. Far to the south the Oligocene outcrop, with the amount of fossil wood required to match the composition of the gravel, still rises to 395 meters at the eastern Gebel el-Khashab, the site of the fossil forest behind the Mukattam Hills. But since the materials were carried across the Miocene limestone outcrop to their present position the intervening valley utilized by the old Suez railway has been excavated, and the accumulation of any further gravels in such a position across the existing topography would be an impossibility (Fig. 6).

Evidently limestones equivalent to these gravels in age must be sought beneath the mantle of Plio-Pleistocene terraces to the north. Only occasionally are they visible, and then only along the southern margin of the terraces. The most easterly point at which we recorded the characteristic white and pink porcelaneous rock with scattered quartz grains was in the vicinity of ʿIlwat el-Ashgar, in longitude 31°53′ east, latitude 30°17′ north, or about 2′ east of the meridian of the ruined palace of ʿAbbas I near the Suez road and 16 kilometers north. Farther east we did not follow it, but Mr. Macfadyen kindly allows us to publish the information that

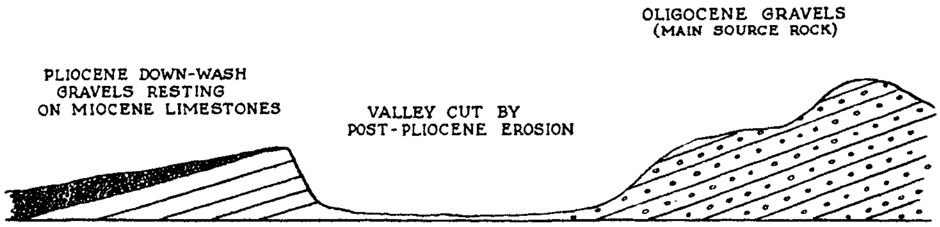

FIG. 6.—DIAGRAMMATIC SECTION ACROSS RELIC OF PLIOCENE DOWN-WASH FAN (EXTENDING UP TO 211 M. ABOVE SEA-LEVEL) BETWEEN CAIRO-SUEZ ROAD AND WADI EL-TUMILAT, SOUTH-SOUTHEAST OF BILBAIS

he found porcelaneous white and pink limestone north of the high ground near Gebel Shubra Wit, a short distance west of the north end of Great Bitter Lake, and again south of Ismailia close to the Suez Canal.

THE ERYTHREAN REGION

The newer Tertiary and Quaternary rocks of the Red Sea province present a series of problems entirely their own and in the main geological. In the last 20 years, chiefly owing to the discovery of petroleum in the Miocene strata, several memoirs on special areas have been published by the Geological Survey of Egypt, and for these areas much detailed information is thus available. The history of the region as a whole, however, and the linking of its chronology with that of the Nile Valley and the tracts on either side of the Delta still await attention by a geologist with experience and abundant time at his disposal. In the course of our Prehistoric Survey we made joint visits to the shores of the Red Sea and Gulf of Suez, and Sandford returned later. But these occasions did not afford opportunities of entering deeply enough into so vast a subject to make any very great advance over the conclusions formed by the geologists who had preceded us. Nevertheless, we feel that, in view of the new facts here set forth concerning the Pliocene deposits round the mouth of the Nile Valley and the sides of the Delta, a brief summary of what is known concerning that period in the Red Sea province should be included and that the present account would be incomplete without it. The information already obtained is to be found in scattered papers and memoirs, each of which to a great extent corrects and supersedes its predecessors.

PRE-PLIOCENE GEOLOGY

The problems of the Red Sea province are so entirely separate from those of the Nile Valley that the only method of treatment likely to yield results is separate analysis of the two regions, followed ultimately by tentative synthesis. Following this plan we must revert briefly to the periods before the Pliocene in order to bring the Red Sea area into line with the Lower Nile, the history of which during the Oligocene and Miocene epochs was outlined in our first volume.[25] In the Oligocene neither the Nile Valley nor the depression of the Red Sea with its extension, the Gulf and Isthmus of Suez, was in existence. That period therefore provides a common starting-point for tracing the divergent histories of the two regions.

[25] *OIP* X, chap. ii.

The great Oligocene river system, part of which has been pictured as flowing into the Mediterranean somewhere over the region of the present Faiyum, also poured its sands and gravels over the northern end of what is now the Red Sea Hills and the Gulf of Suez. They form much of the country between Cairo and Suez and, although deeply denuded subsequently and broken up into isolated patches by faulting, they can still be traced at intervals far down the coast, thus proving that they were brought to their present position before the elevation of the northern end of the Red Sea Hills.

During the widespread volcanic activity that marked the end of the Oligocene period thin sheets of dolerite and basalt were poured out at numerous points in northern Egypt. The Oligocene deltaic conditions were ended by the elevation of that area into a plateau, which caused a river to cut down into its bed and to begin carving out the great gorge through which the Nile still flows.

Between Cairo and Suez have been traced volcanic necks,[26] the fissures once occupied by geysers, which have silicified the surrounding sandstones. The best known instance of silicification by thermal waters is that of Gebel el-Ahmar, near Cairo.

As the upper portions of the fluviomarine sands and sandstones are traced eastward between Cairo and Suez they are found to contain an increasing number of marine fossils and limestone bands, until eventually they pass into pure white limestones with the full suite of Miocene fossils. At the same time an unconformity begins to be apparent between the Oligocene and the Miocene.

> Towards the west, denudation of the basalt had not proceeded very far before the latter was submerged and covered by the fluviomarine deposits of the Lower Miocene. Further to the east all the basalt, except on the flanks of the volcanic cones, was removed, while still further on, the Oligocene sands and gravels have been considerably denuded before they were covered by the Miocene. . . . . From Cairo eastward the Middle Miocene beds gradually pass from a gritty limestone into a pure white chalky rock of greater thickness, while the lower beds of sand, pebbles, and grits become gradually changed into impure limestones.[27]

These observations allow the deductions that the general elevation of the Egyptian plateau at the time of the volcanic outbreaks was followed by warping and subsidence along the northern margin and that this negative movement began earlier in the vicinity of the Nile mouth than it did farther to the east. The continuity of the fluviomarine type of sedimentation in the neighborhood of the Nile mouth points to the survival and persistent activity of the river, even if in diminished form.

Incidentally the evidence discovered by Barron for earlier submergence in the west than in the east lends strong support to the current view of the formation of the Red Sea and Gulf of Suez rifts. According to that view, which Sadek has admirably summarized, with the evidence on which it is based,[28] a wide anticlinal uplift with its axis along the center of the present Red Sea and Gulf of Suez began to take shape at the beginning of the Miocene or the end of the Oligocene period, while on either side shallow synclines or troughs were formed, their axes lying approximately along the Nile Valley and the middle of Arabia. Gradually the center of the anticline began to founder between long northwest–southeast faults, the northern end sinking first and letting in the waters of the Mediterranean.

Sadek shows[29] that the formation of the northwest–southeast faults preceded the ingress of the Miocene sea, thus supporting the conclusions of Blanckenhorn, in spite of Barron's strong opinion to the contrary.[30] We obtained in one locality, at the foot of the eastern extremity of

[26] Barron, *The Topography and Geology of the District between Cairo and Suez*, chap. iv.

[27] *Ibid.* p. 54.

[28] *The Geography and Geology of the District between Gebel ʿAtâqa and El-Galâla El-Baharîya*, pp. 117–20.

[29] *Ibid.* pp. 106–14. [30] Barron, *op. cit.* p. 111.

Gebel ʿUwaibid, incontestable evidence in support of Sadek's and Blanckenhorn's views, for we found an oyster bed composed of a mass of perfect specimens of the Miocene *Ostrea virleti*, growing upon the foot of a faulted cliff of Cretaceous strata tilted almost vertically.[31]

According to Sadek, the Mediterranean entered the rift to fill the Gulf of Suez, not only by the main channel across the present isthmus but also by a secondary passage west of Gebel ʿAtakah, over the depression of wadies Hagul and el-Baidaʾ.[32] It has left its fossiliferous deposits laid down during the maximum extension in the Helvetian or Second Mediterranean period along both sides of the Red Sea at least as far south as latitude 27°30′ north[33] (somewhat south of the extremity of the peninsula of Sinai), while intermittent coral reefs, lime grits, and other deposits probably referable to the same period have been mapped much farther south[34] and may be considered to extend at least to Raʾs Benas on latitude 24° north.[35]

The conditions prevailing in the Red Sea at that time have been graphically pictured by Beadnell,[36] who concludes that they differed in no essentials from those prevailing at the present time. The shore line lay only some 8 or 10 kilometers inland of the present coast, while along it were formed the same types of littoral deposits as those still in process of formation to this day.

Little has pointed out that feldspars and other igneous products of erosion were being washed into the sides of the Miocene sea throughout the period of sedimentation,[37] thus proving that since the Oligocene the Red Sea Hills, at any rate in the north, had been uplifted and their igneous core laid bare by denudation. At the base of the Miocene series there is nearly everywhere a conglomeratic torrent deposit or a coarse gravel. At Umm Fahm, in the Safagah district, this reaches its greatest development in a bowlder bed, described by Little, in which the bowlders are for the most part from 1 to 2 meters in diameter and sometimes reach 5 meters.[38] We are forcibly reminded of a bed of bowlders of comparable proportions at the base of the Pliocene beds in the Nile Valley.[39] It is possible that the two owe their formation to the same epoch of torrential denudation, the latter bed being perhaps a relic dating from the first cutting of the Nile Valley, covered after a long interval by Pliocene deposits when the sea rose in the Third Mediterranean period. Its counterpart on the Red Sea coast was submerged by Helvetian deposits in the Second Mediterranean period as the result of the rift faulting.

Along the Red Sea coast, from the Gulf of Suez to within 60 miles of Port Sudan, the Miocene period closed with the accumulation of a remarkable deposit, a mass of gypsum often from 500 to 1,000 meters thick and in places pierced by borings to nearly 2,000 meters. With the gypsum are interbedded dolomitic limestones, marls, and sandstones which merge near the mouths of drainage channels into gravelly detritus, showing that normal rainfall still continued. The conditions which gave rise to formation of the gypsum have caused many speculations. At the outset we are confronted with an anomaly. The formation of such a chemical deposit might be expected to be caused by evaporation in lagoon basins resulting from uplift of the land and shallowing and gradual contraction of the sea; yet the geological relations of the deposit to the underlying formations, all of which it overlaps unconformably, as well as

[31] Macfadyen has found evidence for pre-Miocene faulting of the Eocene beds at Gebel Gunaifah also (*Miocene Foraminifera from the Clysmic Area of Egypt and Sinai*, p. 15).

[32] *Op. cit.* pp. 118 f.

[33] Hume, *Report on the Oilfields Region of Egypt*, p. 20.

[34] Beadnell, *Report on the Geology of the Red Sea Coast between Qoseir and Wadi Ranga*.

[35] Macfadyen states that there seems no reason not to believe that they extend to Perim Island (*op. cit.* p. 16), but there seems to be as yet no evidence for the extreme south.

[36] *Op. cit.*

[37] Congrès géologique international, *Comptes rendus de la XIIIe session, en Belgique, 1922* (Liége, 1925) pp. 982–89.

[38] *Ibid.* p. 983.

[39] *OIP* X 15 and Pl. I.

its vast thickness, point to protracted subsidence and steady transgression of the sea. Moreover, any theory has to take into account the extension of similar gypsum, though possibly slightly earlier in date of formation, into Persia. Hume writes as follows:

> It seems to me that we cannot obtain a clear view of the probable conditions during this period of great chemical activity unless we admit the gradual formation of a depression in which the salts in solution were being deposited while material was still being brought down to it by streams from time to time.
>
> It should also not be forgotten that at this period even northern Europe was under tropical conditions, as indicated by the nature of its Miocene fauna and flora, so evaporation nearer the equator may have been far in excess of anything at present known in the tropics. . . . .
>
> To secure such continuous deposition, we must have a slowly sinking region in connection with a sea which remains at fairly constant level.[40]

Toward the northern end of the Gulf of Suez the gypsum becomes much thinner but is still present in attenuated form to within less than 20 miles of Suez on the east side.[41] On the west side of the head of the gulf, however, in the Miocene-filled bay south of Gebel ᶜAtakah, it is totally absent. Here highly fossiliferous Helvetian beds with the *Chlamys submalvinae* fauna are directly overlain by a thin series of chalky limestones and marls containing at the head of the bay a fresh-water fauna. Toward the open sea the fresh-water shells are mingled with a meager marine fauna of Mediterranean affinities, dated as Upper Miocene.[42] It is possible that these beds correspond to the gypsum and associated marls on the opposite side of the gulf.

However this may be, it would seem that the continuous subsidence giving rise to the formation of gypsum in the southern part of the Gulf of Suez and farther south was little felt in the north. The oil-field region seems to have been depressed some 5,000 feet or more relatively to the neighborhood of the Isthmus of Suez.

Pliocene Fauna and Sequence

Such differential movements as those described above provide an explanation for the next event in the history of the Erythrean region, an event of surpassing importance to paleogeography—the severance of its connection with the Mediterranean and the inflooding of the Indian Ocean, which brought with it a new fauna totally different from the old. With this event, which is regarded as having taken place some time in the Pliocene, the present era may be said to have begun. A few species have since died out, and others have migrated, but as a whole the existing population of the Gulf of Suez is descended from the stock which made its way in from the Indian Ocean at the end of the gypsum period. General conditions in the gulf and the Red Sea seem to have changed very little since, except that the sea stood considerably higher (how high is not yet known); but for the new fauna, moreover, the conditions might equally well be described as a renewal of those which prevailed before the gypsum era. Coral reefs flourished once more, as well as beds of shells, especially Pectens and oysters, and a rich assemblage of sea urchins.

The first fossiliferous beds to be laid down over the gypsum, marking the first marine invasion of the dead salt sea, are remarkably similar over the whole area, being characterized by limestones full of casts of mollusca and by oyster beds of the large *Ostrea gryphoides* Schlotheim (= *O. crassissima* = *O. gingensis* auctt.). The commonest fossil in the cast-beds is a small lamellibranch, *Metis papyracea* (Gmelin) (= *Tellina lacunosa* auctt.). This and the oyster occur both in the Indian Ocean province and in the Mediterranean. This fact has led to a general assumption that communication with the Mediterranean was still open, but recent examina-

[40] *Op. cit.* pp. 36 f.

[41] Moon and Sadek, *Topography and Geology of Northern Sinai* (Egypt, Ministry of Finance, Petroleum Research, "Bulletin" No. 10 [Cairo, 1921]) p. 28 and map.

[42] Sadek, *The Geography and Geology of the District between Gebel ᶜAtâqa and El-Galâla El-Baharîya*, pp. 76–81.

tion by Cox of further collections has shown that the importance of these forms has been overemphasized and that they are associated with a typical Indian Ocean assemblage.[43] Since no Erythrean forms escaped into the Mediterranean, we may assume that the connection with the Mediterranean was already cut off before the northern part of the Red Sea and the Gulf of Suez were invaded by the waters of the Indian Ocean.

Typically the cast-beds are succeeded by a variable thickness of littoral deposits, of facies similar to those formed in the Helvetian period, containing coral reefs, shell banks, and delta fans and called after the principal fossils *Clypeaster–Laganum* and *Pecten* beds. These and the underlying cast-beds have been known in the past as the Plio-Pleistocene and the Mio-Pliocene series respectively. They have now been shown by Cox on paleontological evidence to be a single indivisible series, constituting the Pliocene of the Red Sea and comparable with the Pliocene Upper Fars series of Persia and the Gwadar Stage of the Makran series of the Makran coast.[44]

The Pliocene beds, as described by Beadnell, Hume, Little, and other members of the Geological Survey of Egypt, appear to extend in typical development as far north as the oil-field region, on the Egyptian coast opposite the southerly extremity of the peninsula of Sinai. They are last seen with certainty in the north of the oil-field region, at Gebel Zait, in the form of a deposit of pseudo-oölite composed of white-coated quartz grains with *Clypeaster*, *Schizaster*, etc. overlying thin white marly limestone with Red Sea shells; at their base is the ubiquitous cast-bed. The pseudo-oölite may be the lateral equivalent of another deposit in the same area, a thick mantle of gravel rising up to and over the 60-meter contour but evidently laid down under water, as it contains rolled shells of *Pecten vasseli* and *P. fischeri* and has interbedded with it an oyster bed composed of thousands of *Ostrea gryphoides* (recorded as *Ostrea gingensis* var. *setensis* Blanck.).[45]

The extent of the northerly invasion of the Pliocene Red Sea up the Gulf of Suez is difficult to determine owing to changes in the character of the deposits which it left behind and to the amount of denudation which they have suffered. On the Egyptian side no more fossiliferous Pliocene rocks are found. The only deposits perhaps referable to the period are some flint and limestone gravels in the bay south of Gebel ᶜAtakah. Sadek describes them as

> a series of gravels of no great thickness, which follow on the Upper Miocene beds in many parts of the district, and differing from the alluvial and terrace gravels in the fact that they partake of the dip of the underlying beds and in some cases are even involved in the faulting. . . . . Though no fossils have been obtained from them, yet a Pliocene age is suggested on purely stratigraphical grounds.[46]

From the manner in which they form a mantle over the lower slopes of the topography and underlie the terrace gravels they recall the marine gravels with *Pecten vasseli* and *Ostrea gryphoides* in the Gebel Zait area. The unreliability of *Ostrea gryphoides* as an indicator of age is shown, however, by the fact that here a bed of the same oyster (recorded as *O. gingensis* var. *setensis* Blanck.) occurs at the base of the Upper Miocene deposits.[47]

On the Sinai side of the gulf siliceous limestones yielding a Pliocene sea urchin (*Clypeaster barthouxi*) and unconformably overlying highly tilted Miocene strata have been found to within 20 miles southeast of Suez. Northward unfossiliferous green marls predominate, with subordinate grits, still unconformably overlying the Miocene;[48] but no proof of their age has been obtained.

[43] *Geological Magazine* LXVIII (1931) 2.

[44] Malacological Society of London, *Proceedings* XVIII 168.

[45] Hume, Madgwick, Moon, and Sadek, *Preliminary Geological Report on South Zeit Area* (Petroleum Research, "Bulletin" No. 7 [Cairo, 1920]) pp. 6–8.

[46] *Op. cit.* pp. 101–3. [47] *Ibid.* p. 78. [48] Moon and Sadek, *Topography and Geology of Northern Sinai*, p. 27.

The Isthmus of Suez

The question of the existence of Pliocene beds in the immediate vicinity of Suez is a difficult one, and the supposed occurrences have been often discussed with varying conclusions. In the tip heaps thrown up from the canal between Suez and el-Shallufah numerous extinct Pectens and oysters are to be found. The low-lying situation from which these had come, below a muddy tract from which the sea appears to have not long ago retreated (certainly not before late Pleistocene times), was commented on with surprise by their first discoverer, who named the commonest *Pecten* after a certain Captain Vassel.[49] Later Fourtau visited the locality and by assuming that the materials thrown up on the tip heaps lay in the reverse order to that in which they were excavated arrived at the following sequence of beds cut through by the canal:

Top
3 Marly sands with *Ostrea cucullata* Born.
2 Marls with *Pecten vasseli* Fuchs and a rich Red Sea fauna, nearly all in the form of casts.
1 Sands with *Ostrea gryphoides* Schloth. (recorded as *O. crassissima*).[50]

The bed with *Ostrea cucullata* suggests correlation with that in the Nile Valley, but we found another bed of this oyster associated with undoubtedly Pleistocene raised coral reefs and beaches and conglomeratic material near the foot of Gebel ᶜAtakah, west of Suez.[51] Here the oysters are easily distinguishable both in form and in freshness of preservation from those collected in the Nile Valley or Wadi el-Natrun, while they agree with those still living and thrown up on the modern beach.

Cox, in his valuable work on the post-Miocene Pectens and oysters of the Red Sea region, regards these beds cut through by the canal as typical marine Pliocene[52] contemporaneous with the *Clypeaster–Laganum* series of the northern end of the Red Sea—a view which involves extension of the high-level Pliocene sea up the Gulf of Suez and across a large part of what is now the isthmus as far as the southern end of Great Bitter Lake. This conclusion is arrived at on purely paleontological grounds, the principal argument being that whereas both *Pecten vasseli* and *Ostrea gryphoides* typify the Pliocene beds, neither has been authentically recorded from a Pleistocene raised beach.

While admitting the validity of these deductions, we must call attention to a few records which seem to deprive the arguments of infallibility. In the first place, Fuchs himself recorded *Pecten vasseli* from apparently Pleistocene fluviomarine beds forming a plateau west of the Bitter Lakes at el-Kabrit.[53] In the second place, Macfadyen collected the species immediately north of the Anglo-Egyptian oil refinery west of Suez, from undoubtedly Pleistocene raised beach material.[54] In the third place, near el-Kusair we found a bed of *Ostrea gryphoides* associated with the living species *Anadara antiquata*, though the Pliocene or Pleistocene age of this oyster bed was not clear and was not at the time subjected to minute investigation.[55]

Cox would account for the presence of *Pecten vasseli* in the Pleistocene deposits of the Suez neighborhood by derivation from Pliocene strata.[56] On the other hand, if fossiliferous Pliocene strata ever existed at higher levels than those at which the fossils are now found, they have

[49] Theodor Fuchs in Kaiserliche Akademie der Wissenschaften, *Wien*, math.-naturwiss. Classe, *Denkschriften* XXXVIII 2 (1878) pp. 34 and 40.

[50] R. Fourtau in Association française pour l'avancement des sciences, *Compte rendu de la 31me session* (Montauban, 1902) 2. partie (Paris, 1903) pp. 487 f.

[51] Recorded at the same place by Fuchs also, as *O. forskali* (*op. cit.* p. 35).

[52] Malacological Society of London, *Proceedings* XVIII 189.

[53] *Op. cit.* p. 32.

[54] Not from older rock, as stated by Cox, *op. cit.* p. 188.

[55] W. J. Arkell in the *Journal of Ecology* XVI (1928) 145.

[56] *Op. cit.* p. 189.

been entirely removed, leaving no other trace behind, while the alternative explanation that the species lived on into Pleistocene times at the head of the gulf has yet to be disproved.

Beds with *Pecten vasseli* fringe the coast of East Africa, and Reck believes, on tectonic and stratigraphic grounds, that in Tanganyika they are of late Quaternary age; after an exhaustive discussion of the subject he states: "Der *Pecten vasseli* Fuchs der ostafrikanischen Küste kann also hier nicht nur jünger sein als altquartär, er muss es hier sogar sein."[57]

When such conflicting opinions are offered it is often safest to attach the most importance to the least dogmatic, and we shall not be falling foul of this principle in concluding that, although the matter still awaits final proof, the balance of evidence afforded by paleontology seems to indicate that in Pliocene times a narrow branch of the Red Sea extended up the site of the Gulf and the Isthmus of Suez at least as far as the southern end of Great Bitter Lake. Having once admitted the possibility of such an extension, we have the problem of picturing the configuration of the isthmus at that period; for we have already indicated (p. 22) the presence near the northern end of Great Bitter Lake of limestones laid down in a Mediterranean which stood probably at about 180 meters above present sea-level.

Other stratal evidence throwing light on the problem in the isthmus region is scanty. One very valuable locality in this connection, however, is Gebel Shubra Wit, forming the northeasterly corner of the hilly ground overlooking Great Bitter Lake and about 3 miles west of its southern end. Barron described as Older Pleistocene some 50 to 60 meters of conglomerates here overlying pebbly sands and clays.[58] Gebel Shubra Wit is a jagged hill of vertical and overfolded Cretaceous rocks protruding at the center of a sharp pericline through Tertiary covering and rising to a height of 225 meters above sea-level. The central peak of Cretaceous strata stands in a horseshoe-shaped amphitheater, surrounded except on the east by cliffs of Eocene and Miocene beds of lesser elevation. The conglomerates fill a portion of the amphitheater, being banked round the central hill of Gebel Shubra Wit and extending from its western side to form a separate ridge with a fairly level top, the highest point of which rises to 161 meters above sea-level. The pebbles and bowlders which extend to this height consist chiefly of rolled Eocene and Miocene limestones, with an admixture of Oligocene material, and their stratification proclaims that they were laid down under water. Their present situation is explicable only on the assumption that they originally filled the amphitheater from side to side to a level of at least 161 meters (allowing nothing for erosion from the top of the ridge, which is a narrow arête in process of rapid denudation). The materials, moreover, were derived from the Tertiary rocks forming the walls of the amphitheater, from which they are now separated by valleys at least 150 feet deep. Such erosion automatically relegates the formation of the conglomerates to a period long anterior to the Pleistocene as understood throughout this work and, taken in conjunction with the height of 161 meters, leaves little room for doubt that they were formed at the same time as the conglomerates and gravel fans of similar geological relations farther west, at Gebel Umm Kamar—in other words, that they correspond to the period of the Nile Valley Pliocene.

The occurrence at Gebel Shubra Wit affords an instructive analogue of the gravel-filled Pliocene valley between the Gizah pyramids and Gebel Abu Roash. Both accumulations of Pliocene detritus were laid down near the mouth of a valley excavated in the crest of a periclinal fold, exposing Cretaceous strata in the center; and both opened approximately east-

[57] Hans Reck in *Centralblatt für Mineralogie, Geologie und Paläontologie*, 1921, p. 535.

[58] *The Topography and Geology of the District between Cairo and Suez*, pp. 27 f.

ward.[59] The Gizah pyramids valley debouched into the mouth of the Nile Valley gulf, and it would appear that the Gebel Shubra Wit valley opened over the region now occupied by the northern part of Great Bitter Lake.

East of Gebel Shubra Wit, at the mouth of the valley or amphitheater, lower beds crop out. We did not see them in direct continuity with the conglomerate, but they are apparently conformable beneath it, dipping both inward and down the valley as though they were laid down within it, like the beds at the mouths of valleys opening into the Nile gulf. They consist of clays and some bands of buff-colored mudstone, which has been dug for salt, the whole of considerable thickness but unfossiliferous. Barron noted a section "at the foot of the Eocene cliff opposite Gebel Shabrawet" where he saw 4.8 meters of conglomerate and sand overlying 13 meters of brownish clay, the latter in turn covering 4 meters of sandy beds.[60]

How far south along the foot of Gebel Gunaifah these beds extend on passing out of the Gebel Shubra Wit valley we were unable to determine, owing to the masking effects of Pleistocene and Recent down-wash and the lack of time available for such purely geological matters not directly concerned with the era of Man. It is tempting to suppose that the clays may be continuous with some of the unfossiliferous clays with gypsum which underlie the Pleistocene shell beds northwest of Suez[61] or with the clays lying unconformably on the Miocene along the Sinai shore (see p. 26). The presence of salt and gypsum recalls Sadek's Upper Miocene beds south of Gebel ʿAtakah, which are perhaps in part the equivalent of the gypsum (see p. 25).

If we accept the *Pecten vasseli* beds at the southern end of Great Bitter Lake as Red Sea Pliocene and the Gebel Shubra Wit beds as Mediterranean Pliocene, we are left with nothing more than the frontage of Gebel Gunaifah, 10 miles long, in which to reconstruct the isthmus that prevented the faunas of the two regions from mingling.

This brings us face to face with the fundamental problem, as yet unsolved, of the relative ages of the series of beds which in the two areas are called Pliocene. Where no fossil is common to the two and the geological relations are as different as the faunas, it by no means follows that they are contemporaneous. A solution could be found only by a geologist working minutely over the ground on both sides of the Isthmus of Suez and the northern part of the gulf and acquiring a thorough knowledge of the various clays and marls involved, ranging in age from so-called "Schlier" (mid-Miocene) to Pleistocene.

One other recorded occurrence of beds attributed to the Pliocene must be mentioned, for, as it stands, the record adds serious complications to an already complex subject. Barron, in his memoir on the *Topography and Geology of the District between Cairo and Suez,* at the end of the chapter on the Miocene, added under the heading "Beds of Doubtful Age":

> Near House [i.e. Tower] 12 of the Old Post Road to Suez, a small area of sands, conglomerates and clays is met with. The following is the section of this formation:—

Top.	Flint conglomerate with calcareous cement	15 to 17 metres
2.	Falsebedded grit	0.5 "
3.	Saliferous clay or marl, greenish in colour, with a fossiliferous band	2 metres

The occurrence is a little east of the watershed in the valley through which the road passes, 17 miles from Suez. From the fossiliferous band were collected 29 species of fossils, "all re-

[59] It has often been pointed out that these two uplifts, exposing a Cretaceous substratum, lie on a long line of weakness extending from Magharah Oasis on the west-southwest to the Jurassic massif of Gebel el-Magharah in northern Sinai on the east-northeast.

[60] *Op. cit.* pp. 27 f.

[61] E.g. in a pit southwest of the Cairo road beyond the point where it branches off the road to Mahattat el-Kubri. All this area is mapped as Miocene by Macfadyen (*Miocene Foraminifera from the Clysmic Area of Egypt and Sinai).*

turned as of Helvetian [Middle Miocene] age by Dr. Blanckenhorn." On the evidence of one species, common in the Nile Valley Pliocene, *Mactra subtruncata*, Barron suggested that all the other fossils were derived from the Miocene and redeposited in a Pliocene sea. He was influenced also by the unconformity of the beds to the underlying Middle Miocene and the fact that "they have no affinity lithologically with the Miocene beds, the latter being limestone, undoubtedly of marine origin, while they are fluviomarine."[62] Blanckenhorn later accepted the Pliocene age as settled,[63] and the occurrence has been entered as a patch of Pliocene on Hume and Little's geological map (1928).[64]

When Barron and Blanckenhorn wrote, however, the fluviomarine Upper Miocene of the next "bay" to the south was unknown. From Sadek's description it is evident that the latter situation is similar to that on the Suez road, each area being at the head of a bay or wadi, one on either side of Gebel ᶜAtakah. Moreover, the beds are lithologically similar. A particularly suggestive section is one in Wadi Hagul, where "soft, salty, green marls" are succeeded by "false-bedded coarse sandstones" which in turn pass up into gravels[65]—a succession identical with that on the Suez road. The Upper Miocene also is unconformable to the marine Middle Miocene, so that Barron's chief reason for excluding beds on the Suez road from the Miocene is invalidated.

The doubtful beds on the Suez road cross the 300-meter contour, which is 120 meters above what is believed to have been the height of the Pliocene Mediterranean; and according to Sadek his Upper Miocene beds extend to a maximum height of 289 meters, or only 11 meters lower than the occurrence on the Suez road. The probability that the two occurrences are of the same age is therefore great on various grounds. We made a careful examination of the neighborhood of Tower 12 and formed a strong impression that, although the 15–17 meters of gravel at the top of the series might be Pliocene wadi gravel, the underlying beds were not of Pliocene age. Additional grounds for this conclusion are:

1. The beds beneath the gravels are involved in steep folding along with underlying Helvetian strata.
2. The beds beneath the gravels are cut by a fault, whereas the gravels cross the fault without interruption.[66]
3. The fossils are in an unsatisfactory state of preservation, and the single miniature lamellibranch identified as *Mactra subtruncata* could in the circumstances of its occurrence hardly be considered a satisfactory index fossil, even if its correct identification were beyond doubt. We obtained no confirmatory specimens.[67]
4. A few kilometers west of Tower 12 we found an outlying patch of the beds, resting unconformably on the Helvetian and containing large quantities of *Ostrea gryphoides*, as noted by Sadek[68] in the Upper Miocene of nearly all his localities on the other side of Gebel ᶜAtakah.

In concluding this attempt to reconstruct the history of events leading up to the Pleistocene period in northern Egypt, reference must be made to the evidence for faulting affecting Pliocene beds. We may say at once that in no single instance anywhere in the Nile Valley have we obtained definite evidence of Pliocene strata having been affected by a fault or involved in

[62] Barron, *op. cit.* pp. 52–54.

[63] *Hdb.* p. 141.

[64] Egypt, Survey Department, *Atlas of Egypt* (Giza, 1928) Pl. 8.

[65] *The Geography and Geology of the District between Gebel ᶜAtâqa and El-Galâla El-Baharîya*, pp. 94 ff., esp. p. 98.

[66] As noted by Barron (*loc. cit.*).

[67] The small bivalve of the Nile Valley Pliocene usually identified as *Mactra subtruncata* var. *elongata* bears little resemblance to the living *M. subtruncata* Da Costa (described in 1778) and is unlikely to be the same species.

[68] *Op. cit.* (called *O. gingensis*).

differential earth movements of any kind. Curious structures in beds regarded as Pliocene in the Kom Ombo plain[69] are explicable as due to peculiarities of deposition. The general uniformity in the maximum height of Pliocene strata in Upper Egypt is strong evidence in favor of tranquillity having reigned since they were laid down. Although in Lower Egypt the occurrences of Pliocene rocks are more scattered and give no comparably trustworthy indication of the water level during the time of their formation, the general agreement of the upward limits set to the occurrences testifies against their having been involved in differential movements of any great extent.

Along the northern fault scarp bounding the North Galalah Plateau, southwest of Suez, Sadek made the following observation: "Near the mouth of Wadi El-Abyad, where it issues from the Meneidra scarp, beds of gravels, composed of rounded flint pebbles in a pink sandy matrix, cover the Eocene limestones and are obviously involved in the faulting at the edge of the plateau."[70] The gravels in question were grouped by him with the Pliocene on grounds of general expediency, but there is no evidence for their age except that they are post-Eocene and pre-Pleistocene. The absence of limestone pebbles, which Sadek records as notable constituents of most of the other occurrences of such gravels, points to their being of a rather different age from the rest, and they may well be a subaerial accumulation formed during some part of the Miocene, before the east–west faulting had subsided. In the valley followed by the Cairo–Suez road the gravel containing Miocene limestone pebbles passes uninterruptedly over a north–south fault, as observed by Barron and remarked above (p. 30).

A glance at the geological maps by Barron, Sadek, and others suffices to show that the Helvetian (Middle Miocene) strata laid down during the Second Mediterranean period are cut by a series of east–west faults of great length and importance as well as by a series of lesser, north–south faults belonging to the same system and resulting, according to those who have studied them, from the same movements. This is the great system of east–west faults so conspicuous as a series of ridges and steps in the country between Cairo and Suez, and it is because of them that the Eastern Desert plateau breaks down to the north and gives place to gravel plains and the Nile Delta. Since the Pliocene beds are apparently unaffected by them, these faults now come to have definite meaning, for they can be connected with the major earth movements between the Second and Third Mediterranean periods—the interval when the deepest erosion of the first Nile Valley probably took place, during the maximum upheaval in the Pontic Pluvial period.

The West Side of the Red Sea

In the Nile Valley, in the Cairo–Suez area, and in a part of the Gulf of Suez faulting and differential movement of any importance were evidently at an end by the time of the Middle or Upper Pliocene transgression. The application of such a generalization to the Red Sea is doubtful for the following reasons:

1. The geology of the region is not yet thoroughly known.
2. In many places Pliocene strata have a marked seaward dip. This might be original bedding dip; but frequently it steepens inland, and the increase is not necessarily accompanied by any lithological change. The slight dip at the seaward margin causes projecting remnants of Pliocene reefs to simulate raised Pleistocene reefs.
3. In many localities Pliocene strata have been forced up into prominent domes; these may be claimed to be salt domes, but in many instances the hypothesis remains to be proved. Beadnell does not attribute them to the action of salt but "is inclined to ascribe the majority if

69 See *OIP* XVII 8–10. 70 *Op. cit.* p. 102.

not all of these occurrences as due to simple sagging and settlement of soft sediments over rigid underlying ridges of crystalline rocks during gradual vertical uplift, attended by extrusion of their water contents."[71] He cites[72] Hume's explanation[73] that marked dips may be due to simple monoclinal folding during uplift of the granite core and the carrying with it of a portion of the overlying beds.

4. Faults can be observed along the coast in Pliocene and Pleistocene beds (cf. pp. 35 and 64).

5. No definite summit level of Pliocene submergence can be recognized in the Red Sea; the Pliocene deposits along considerable stretches of both the west and the east coast have been elevated and to some extent deformed in post-Pliocene and Pleistocene times. The movements may still be in progress.[74]

Most of the characters of the Pliocene beds of the Red Sea may be observed along the coast between Safagah and el-Kusair (see Fig. 3). It will be remembered that parts of this littoral have been geologically surveyed in great detail by officials of the Egyptian Government. The following illustrative notes and sections were compiled in the field in 1931 for the purposes of this volume.

PORT SAFAGAH TO WADI SAFAGAH

The steep cliffs of igneous and metamorphic rocks that tower above the harbor reveal magnificent faults. Pliocene beds near their feet are tilted rather strongly to the northeast. A great fan of gravel lies on the north side of Wadi Safagah near its mouth. The gravel lies unconformably on Pliocene or Plio-Pleistocene sands, pebbly and shelly limestone, and corals, dipping 7°–10° to the northeast, similar to those near Port Safagah. On the south side of the dry watercourses of the wadi is an elevated region of deltaic sands and gravels, evidently shot into standing water. Nothing but detrital material is seen from top to bottom. The surface has been smoothed at a number of distinct terrace levels, each accompanied by several feet of coarse gravel, bowlders, and redeposited sands and gravel of the older delta. It seems probable that the whole of the deltaic material is the equivalent of the *Laganum–Clypeaster* series, that is, Pliocene to Pleistocene. The terraces are described on pages 62 f.

WADI SAFAGAH TO WADI EL-GASUS

A traverse from west to east about midway between the two wadies and parallel to them illustrates the nature and history of this part of the coast unusually well. The following notes apply to a section from about 4 miles inland to the present lagoon (Fig. 7): First a great mass

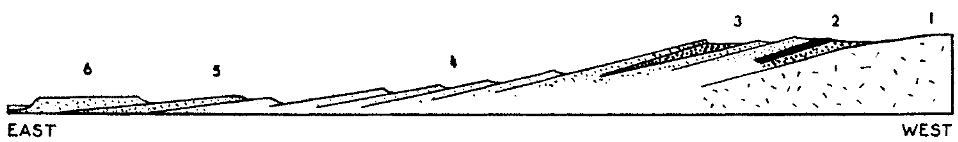

FIG. 7.—SECTION OF MIOCENE TO PLEISTOCENE BEDS OF THE RED SEA COAST BETWEEN WADI SAFAGAH AND WADI EL-GASUS. BASED ON FIELD SKETCHES MADE WITH VIEW FROM NORTH TO SOUTH

of hard yellow Miocene gypsum (1), like the side of a dome, rests in front of the intensely broken flanks of the main Red Sea Hills structural mass. Gravels (2) occur in a semicircle round the flanks of the gypsum and consist of pebbles and bowlders derived from the complex of the Red Sea Hills, interbedded with variegated sands, grits, and fine gravels. Thicknesses are

[71] *Report on the Geology of the Red Sea Coast between Qoseir and Wadi Ranga*, p. 32.

[72] *Ibid.* p. 33. [73] *Report on the Oilfields Region of Egypt*, p. 59.

[74] See Beadnell, *loc. cit.*, and Moon and Sadek, *Preliminary Geological Report on Wadi Gharandel Area* (Egypt, Ministry of Finance, Petroleum Research, "Bulletin" No. 12 [Cairo, 1923]).

difficult to gauge in these beds, especially as they dip on the whole steadily seaward; there is also some suggestion of faulting parallel to the coast and possible reduplication of beds resulting therefrom. Probably 100–200 feet is a conservative estimate of the thickness where visited. Coral-bearing yellow limestone (3) crowded with spines of sea urchins follows; this likewise contains gravels, rather lenticular, localized, as much as 40 feet thick, with seaward dip and evidently deposited in standing water. The same limestone reoccurs on top of such gravel banks. There follow about five 20-foot ridges of coral sand and clay (4), running parallel to the coast, the seaward dip becoming very slight, total thickness probably about 150 feet and width of outcrop about a mile. The last visible member of the succession is a yellow coral limestone (5) with rounded gray masses of *Lithothamnium* of about the size of a golf ball, the upper part of the limestone being of rather cavernous structure (with cast-beds). It dips locally at 7° to the east; at 25 feet above the sea it disappears beneath a massive Pleistocene coral reef (6) which can be traced in unbroken section below sea-level with living corals growing upon its seaward submarine or intertidal flank.[75] In such a traverse the alternation of coral growth, lagoon conditions, irruption of detritus from the high hills, and return of corals to grow on top of the gravel is plainly seen; moreover, beds of the general sequence may be represented by unfossiliferous gravels, as in the lower part of this sequence. In such instances, of which this traverse has purposely been selected as an example, it is difficult to determine where the Miocene ends and the Pliocene begins; probably here the division is between beds 2 and 3. In this section the contrast between beds 5 and 6 in dip and nature of the rock rather than in fauna serves to illustrate the opportunity in the field of distinguishing between Pliocene and Pleistocene. Many miles of similar outcrops may be passed over without further description or comment; it will be realized that such a sequence may have almost endless variations.

WADI EL-GASUS TO GEBEL ABU SHUKAILI

South of Wadi el-Gasus the country is similar to that just described, with Miocene or Pliocene gravels on the west.[76] The marine (coral etc.) facies of nearly all members of the Miocene–Pleistocene sequence then becomes dominant, and the present coastal plain narrows. In other words, the region was not influenced by the great drainage belt of Wadi Safagah, and, except locally, corals could flourish in clear water in later Tertiary and Quaternary times along the coast as far as the next great line of drainage, that is, Wadi Kuwaiᶜ.

GEBEL ABU SHUKAILI TO WADI KUWAIᶜ

Pliocene hills of structural origin, the greater number being small domes, occur as marked ridges at the back of a rather narrow and sloping marine platform with Pleistocene raised beaches. Pliocene strata are visible beneath the eroded beach surfaces with occasionally steep easterly dips on the flanks of the domes. Immediately north of Wadi Kuwaiᶜ enormous masses of Miocene gravel reappear, in crescentic form with occasional terrace-like upper limit, as may be seen at and near the majority of drainage channels from the Red Sea Hills. The Miocene gypsum, usually of great thickness, is thus locally reduced and may be entirely replaced by gravel.

WADI KUWAIᶜ TO WADI HAMRAWAIN[77]

Near the wadies are deltaic deposits of Pliocene age—laminated sandy clay overlain by sands, gravels, and, in upper levels, coarse bowlder beds. These are planed by terraces (Pl.

[75] The marine beaches cut across beds 5 and 6 are described on p. 63.

[76] Some interesting features of the Pleistocene series are described on pp. 63 f.

[77] Part of this area is included in Hume *et al.*, *Preliminary Geological Report of the Quseir-Safaga District* (see our p. 10).

XIV). There is evidence of settlement or faulting here in late times (see p. 64). The coastal region,[78] clear of this great line of drainage, returns to the type seen between Gebel Abu Shukaili and Wadi Kuwaiᶜ. Domal structure in lagoon deposits and coral-reef limestone is responsible for much of the topography, and Pleistocene marine platforms run along the seaward face.

WADI HAMRAWAIN (=WADI KUWAIR[79])

Wadi Hamrawain reintroduces the features of wadies Safagah and Kuwaiᶜ, and much interesting geology must be summarized. *Laganum–Clypeaster* limestones are particularly well dis-

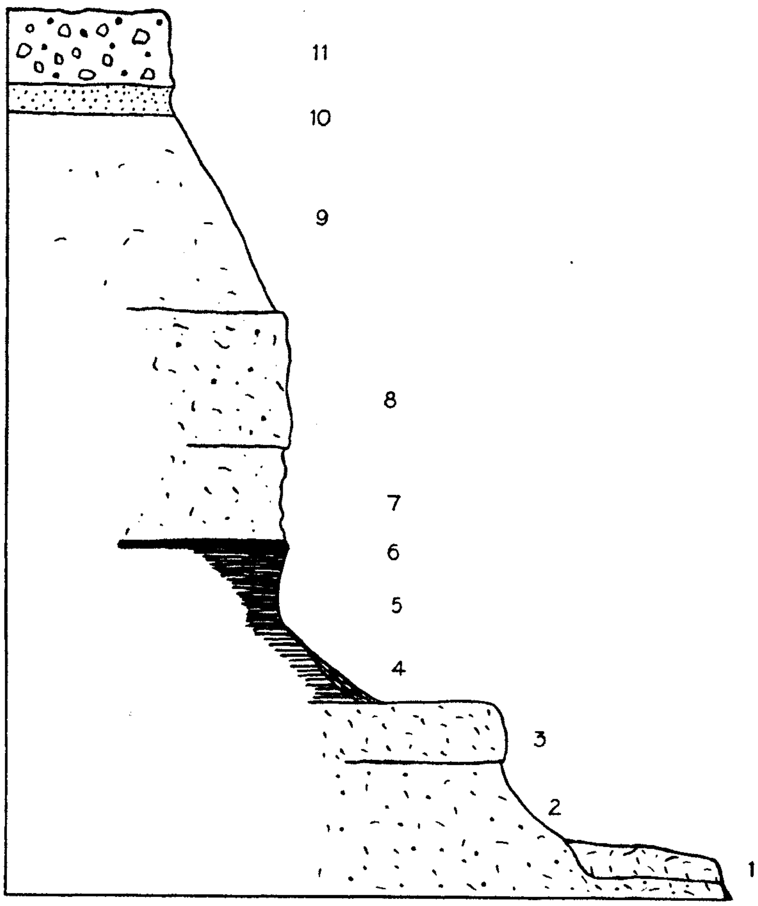

FIG. 8.—TYPICAL PLIOCENE AND PLIO-PLEISTOCENE CORAL-REEF SUCCESSION AT THE MOUTH OF WADI HAMRAWAIN

played both north and south of it in cliff sections, and acres of low ground are almost covered with sea-urchin spines. The beds are also well exposed in the dome that flanks the south side of the wadi and dominates the coastal plan southward of it; here again platforms are well developed (pp. 65 f.). This wadi was the farthest point reached from el-Kusair in our joint visit to the coast in 1927, but about a week was spent in it in 1931, and the following is taken from a considerable body of field notes. On the north side of the mouth of the wadi, about a

[78] Described in detail *ibid.*

[79] To be distinguished from Wadi Kuwaiᶜ.

kilometer from the sea, is a cliff section (Fig. 8) in a hill that rises (according to Abney level) to about 176 feet above sea:

Bed			Feet
(24)*	11	Bowlders and blocks, with shingle of Eocene and Red Sea Hills material, lime-cemented, passing under 10 feet of sandy and gritty coral to north	15
(23)	10	Coral sand, white with casts of *Laganum depressum*	6
(22)	9	Scree on white, partially decalcified coral	40
(21)	8	Red coralline rag and red marly beds with granite pebbles, *Laganum*, *Pecten*, etc.	25
(20)	7	As bed 8, but white, of variable thickness	20
(19)	6	*Pecten* bed	1
(18)	5	Green-gray clay, salt at surface	15
(17)	4	Scree, concealing 15 feet of salty clay	15
(16)	3	Coral reef; yellow, nullipore limestone, slaggy, partly decalcified	10
(15)	2	White and gray coral limestone with white *Lithothamnium;* locally and partially replaced by gravel from Red Sea Hills	15
	1	Pleistocene and living corals etc. growing on flank of bed 2, visible above sea-level	14
		Total	176

* Numbers in parentheses indicate position of bed in the succession as a whole, but it must be remembered that beds vary laterally within short distances.

This section may be traced inland, where belts of deposits for the greater part equivalent to it may be discerned. Belts of the following are seen to pass under bed 2 of the main section:

Bed			Feet
(14)	3	Buff sandy limestone and clay	30
(10–13?)	2	Hard coral	3
	1	*Lithothamnium* stone, passing to sandstone when traced laterally	50
		Total	83

Some local faulting, which seems to be of no great magnitude, breaks the sequence farther inland, and three belts of deposition may be noticed. The first is composed of

Bed			Feet
(14)	4	Buff sandstone	15
(13)	3	Gravel	10
(12)	2	Brown marl	2
(11)	1	Pebble grit	3
		Total	30

This belt is separated by a fault with downthrow of 10 feet from the section given above, the downthrow being on the east side of a north–south fault; that is, the buff sandy limestone and clay corresponds to the buff sandstone (in part), both passing below bed 2 of the main section. The deposits of the remaining two belts are not considered to be confused by the faulting observed between beds (6) and (5). The next belt to the west shows

Bed			Feet
(10)	5	Gritty white limestone, coralline at top	6
(9)	4	Clay with pebbles	2
(8)	3	Gray clay	1
(7)	2	Pebbles set in gray clay	2
(6)	1	Rubbly limestone passing into sandrock	3
		Total	14

The last belt takes us probably to the base of the Pliocene and into soft Miocene beds:

Bed			Feet
(5)	5	Gray limy clay, with kidney-shaped products of weathering	10
(4)	4	Variegated shales, red, green, fine-bedded	8
(3)	3	Rubbly coral and yellow clay	10
(2)	2	White to yellow coral rubble	15
(1)	1	Yellow marl	10
		Total	53

The total distance involved from the sea inland is about 3 miles. This section is considered worthy of inclusion because it shows with considerable clarity the inland passage from growing reef to lagoon clays, over which at intervals gravels are propelled by torrents issuing from the wadies of the Red Sea Hills complex and sedimentary rocks in the rear. It serves as a final illustration of the Pliocene coast.

WADI HAMRAWAIN TO EL-KUSAIR

A few short wadies, draining the Miocene rocks and coastal plain, break the succession between these two places; but in general it was a region of coral growth, lagoon formations, and marine conditions, as at the present day, with little interference from the land. In the vicinity of el-Kusair el-Kadim is a small inlet, behind which is a dry lagoon, probably an elevated part of the purely Pleistocene coral girdle (see p. 67). Near el-Kusair the great drainage line of Wadi ᶜAnbagi enters the coastal plain, with its vast accumulations of Miocene and later gravels with features already noted in Wadi Safagah, in Wadi Kuwaiᶜ, and to a less extent in Wadi Hamrawain.

CONCLUSIONS

In Lower Egypt the following conclusions seem to be justified:

1. The Lower Pliocene estuarine and littoral facies is revealed at and below present sea-level in Wadi el-Natrun, and analogous deposits may have been revealed in the cutting of the Suez Canal. Slipped masses occur where the rocks are of suitable character.

2. Middle Pliocene marine beds are strongly developed just inside the "gates" of the Delta (see pp. 16 and 20), that is, just south of Gebel Abu Roash and Gebel el-Ahmar.

3. Pliocene quartz sands occur and appear to have been deposited in hollows from which earlier beds had largely been removed. At ᶜAbbasiyyah they are covered by a few feet of clay, while not far away (on the ᶜAbbasiyyah-Heliopolis tramway line) are sections of limestone and interbedded clay recalling deposits of Upper Egypt (see pp. 11–13).[80] This series may probably be accepted as Blanckenhorn's *Melanopsis* beds.

4. The Pliocene Nile gulf expanded into the open sea north of the "gates" mentioned above. Upper Pliocene sandy and porcelaneous beds, with local porous travertine-like rocks, occur to a height of 130 or even 150 meters and there become increasingly charged with gravel, until all limestone disappears. Their altitude may be compared with the heights attained by the *Melanopsis* beds but not reached by the Middle Pliocene marine beds of the Nile Valley. Moreover, many hand-specimens are virtually indistinguishable from sandy limestone and travertine found on the west side of the Nile between the latitudes of Beni ᶜAdi and el-Minya at and above 100 meters above sea-level.[81] The nature of the sandy porcelaneous limestone seems to depend partly upon the constitution of the shore line in the gulf or outside it.

5. Throughout the gulf and the river mouth and the adjacent littoral from Wadi el-Natrun almost to Suez the uppermost part of the succession is occupied by gravels, attaining 180

[80] See also *OIP* XVII 13.

[81] See *OIP* XVIII.

meters and even surpassing 200 meters above sea-level; the highest levels may represent gravels piled up from the land above the actual height of submergence.

6. "Fossil tributaries" may be identified to the very gates of the gulf, and even drainage systems that discharged into the open sea from the high ground between Cairo and Suez and from the western plains of Gebel el-Khashab and Giran el-Ful.

7. "Plio-Pleistocene" (feldspar-bearing) sands occur in and among the Pliocene series, always with indications of erosion, incorporating bowlders of the porcelaneous and sandy limestone, though well below its level. Outside and inside the gulf coarser gravels, in terrace-like form, occur at great heights, the lower levels cutting independently across all Pliocene strata and the quartz-feldspar gravels themselves, as between the pyramids of Gizah and Abu Roash.

It may justly be claimed that every feature recognized in the Pontic to Pleistocene succession of Upper and Middle Egypt and of the approaches to Lower Egypt is represented between the Abu Sir pyramids and Wadi el-Natrun and between Hilwan and the Suez Canal.

The following comparisons may be made between the Pliocene strata of Lower Egypt and of the Erythrean region:

Mediterranean Pliocene sediments may be traced to Gebel Shubra Wit, and Red Sea Pliocene fossils to the Great Bitter Lake. A gap of only about 10 miles separates them, and detailed survey might lessen this distance. The fauna and geological relations of Mediterranean and Red Sea Pliocene are essentially dissimilar and so may be of dissimilar ages. But there seems no escape from the conclusion that an effective although very narrow barrier separated the two seas in Pliocene times.

In the Nile Valley and both west and east of the Delta deposits of the Pliocene transgression may be traced to about 200 meters above sea-level. There is no such clearly defined upper limit in that part of the Red Sea littoral which is discussed in this chapter, but the Pliocene sediments and coral reefs lie for the greater part below the 100-meter contour.

In the Nile Valley no major differential movements seem to have taken place since Pliocene gulf deposits were formed; in the clysmic area there is some indication of Pliocene or post-Pliocene faulting. Movement may still be in progress in the Red Sea, and local variation and domes are due to the action of salt and settling of deposits or to structural adjustments.

III

THE PLIO-PLEISTOCENE SERIES

INTRODUCTION

It has been shown in *OIP* Volume XVIII that the irruption of detritus into the Nile Valley from the Red Sea Hills heralded the close of Pliocene times and that some of the material was deposited in hollows in the Pliocene sediments in the form of clean feldspar-bearing sands, usually false-bedded toward the north. These are locally of great thickness and have the appearance of having been deposited in a sheet of water. Since their lower limit falls from south to north, it has been suggested (*ibid.*) that they were laid down after a period of subaerial erosion during a subsequent phase of drowning. So far as the evidence permits an opinion to be formed, they are, however, everywhere older than the high gravel terraces that were laid down by the Nile during its final emergence; the vertical interval between the sands and the terraces renders improbable the suggestion that the sands are underwater deposits contemporary with those terraces.

The situation at the mouth of the Nile, in its ancient delta, and in the submarine banks which accumulated in front of the delta in the waters of the Mediterranean is instructive. The high-level terraces of the Nile turn west and east along the African coast line, where they may be traced laterally, ultimately passing into Mediterranean beaches for the most part obscured or destroyed along the north coast of Egypt. The material of any one terrace when traced northward below the sea-level obtaining at the time of its accumulation thickens appreciably and becomes of finer grain. Within a comparatively short distance submarine sandy limestones are therefore encountered, and the slopes from Wadi el-Natrun or from the featureless country between the hills of the Cairo–Suez road and Wadi el-Tumilat to the present coastal dunes and marshes are in great measure the underwater profile of the ancient delta.

When correlation is attempted it is soon realized that some of the terraces here retained under the title of Plio-Pleistocene are embraced in the earlier Pleistocene stages of the Mediterranean, notably the Sicilian and Milazzian (see Fig. 9), while others are above the Sicilian beach and may therefore be retained as strictly Plio-Pleistocene. The term thus serves its purpose of linking known Pliocene to known Pleistocene horizons, with a certain amount of overlap at older and younger limits.

Finally, attention should be called to the fact that some of the terraces near the apex of the Delta (see p. 47) are higher than any preserved in the Nile Valley. For this no entirely satisfactory explanation can be offered. It appears improbable that deposits of the higher stages have been utterly destroyed in the Nile Valley, since the summit level of Pliocene submergence could hardly have been so perfectly preserved if denudation had wrought such havoc at somewhat higher levels. It may be suggested that the scouring of the valley in the early stages of final emergence led to aggradation near its mouth, surplus material being piled up faster than the sea could wash it away. There are obvious criticisms to such a hypothesis. The probability of local depression near the head of the Delta naturally occurs, especially in view of the movements that were then taking place at the head of the Gulf of Suez (though these were elevations, not depressions). But some of the stages agree, so far as altitude is concerned, with those more generally known in the Mediterranean (Fig. 9); if there had been localized and uniform movement there would not be such concurrence of levels.[1] The problem will be reconsidered after the field evidence has been given. The presence of these high terraces gives a

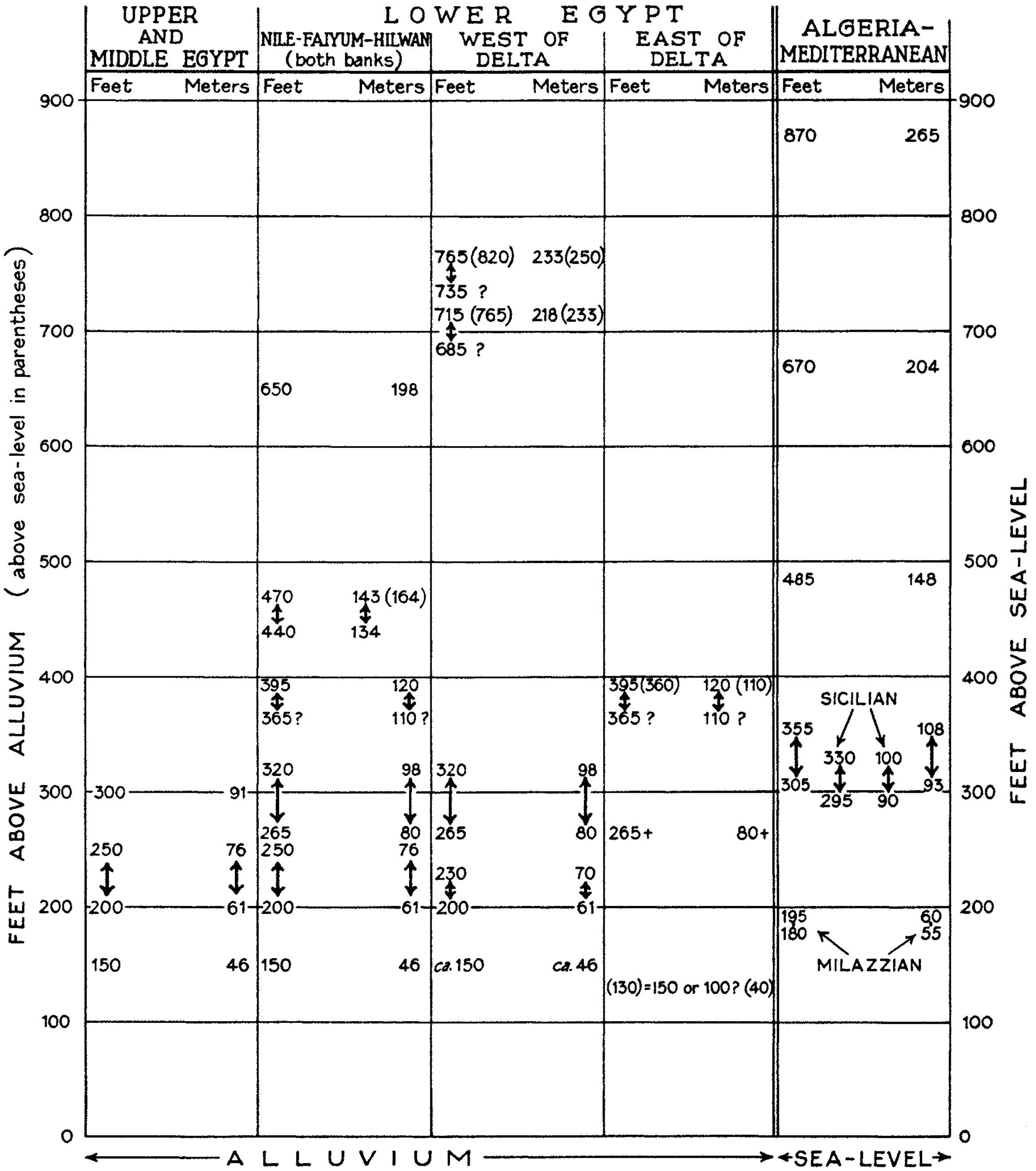

FIG. 9.—PLIO-PLEISTOCENE TERRACES OF THE NILE AND MEDITERRANEAN LEVELS

vivid illustration of the almost incredible amount of denudation that has taken place west of the Nile since their formation.

[1] Some of the problems of the high levels of erosion surfaces on the Mediterranean coasts have been discussed recently, with special reference to the central plateau of France, by Henri Baulig, *The Changing Sea Level* (The Institute of British Geographers, "Publication" No. 3 [London, 1935]).

The following factors must be borne in mind in assessing the altitudes of the terraces:

1. In the open plains west of the Delta and in the country adjacent to Wadi el-Tumilat, especially the Tell el-Kabir "island," wind action has removed the sand from the upper parts of gravels. The larger material has thus been concentrated. In extreme examples a thin gravel has evidently been produced at the surface of a sand with disseminated pebbles as a result of this selective process. The summit level of the gravel may be below the average for the terrace in question.

2. The country east of the Delta is subject to considerable showers and storms, even at the present day. These, striking the high ground between Cairo and Suez, give rise to much erosion in the hills and spread sand, gravel, and loose detritus at their feet. In the past—and the process continues—sheets of local material have been spread out from the high ground toward the southeast corner of the Delta as well as northward and toward Suez and the Bitter Lakes (Pl. VI *A*). The Plio-Pleistocene terrace gravels of the Nile, especially the highest stages, which are naturally nearest the hills, have been submerged by the local flow. Over wide areas no trace of Nilotic material is visible on the surface or in shallow excavations; it is thrown out, however, from well-diggings and similar artificial exposures and occasionally is seen in wadi sections, under local rubble. For this reason the terraces on the east side of the Delta and south of Wadi el-Tumilat, though actually present, are little seen and impossible to survey in detail.

3. The question of measurement of terrace altitudes naturally arises. Are they to be measured in the vicinity of the Delta above sea-level or above alluvium? South of Cairo naturally alluvium surface is the level of reference, but in dealing with older and higher terraces one might assume that the influence of the open sea was felt nearer the site of Cairo than it is at the present day. This is only partially true; in the country west of the Delta there is no insuperable difficulty, after a little experience, in deciding whether a gravel was laid down by the flowing river or beneath the sea-level of its time. Gravels laid down by the river are coarse and ungraded, of measurable thickness, with an outer margin resting against slopes or small cliffs of Tertiary rocks, the surface sloping gently toward the present Delta and cut off in a sharp terrace feature by the next succeeding group of gravels. If deposition was in the deltaic zone influenced by the sea or in the sea itself, the deposits are found to be graded, false-bedded; sandy limestones soon appear in the sequence; they form enormous and utterly featureless areas of country; their base is never seen; younger deposits lap onto them insensibly but at slightly lower levels. If this type of deposit is traced southward it becomes coarser but remains bedded, and the passage to its parent river gravels is relatively sharp. Traced northward its material becomes fine and dusty, with blue or white limestones which may be quite pure and hard; but the level sinks imperceptibly till identical deposits, probably of a younger stage, pass under the coastal sand dunes or the Recent deltaic muds. It has been found possible therefore to define the position of the sea in general terms by studying the deposits themselves. Through the earlier and higher stages of the Plio-Pleistocene terraces the sea was probably between the latitudes of Cairo and Wadi el-Natrun. By the time the 320- to 265-foot[2] stage was reached the coast was on the latitude of Wadi el-Natrun itself, and it was probably over the latitude of Wadi el-Tumilat until the dawn of Paleolithic times (Fig. 10).

It is well known that great accumulations of silt have taken place in the present Delta, their height defined by the flood level of the Nile near Cairo and by sea-level. The present altitude of the cultivated land at the apex of the Delta is a little below 20 meters; that is, the gross difference between alluvium and sea-level as a datum is less than 65 feet. By determining the

[2] Such terms imply the known top and bottom levels of a single terrace gravel.

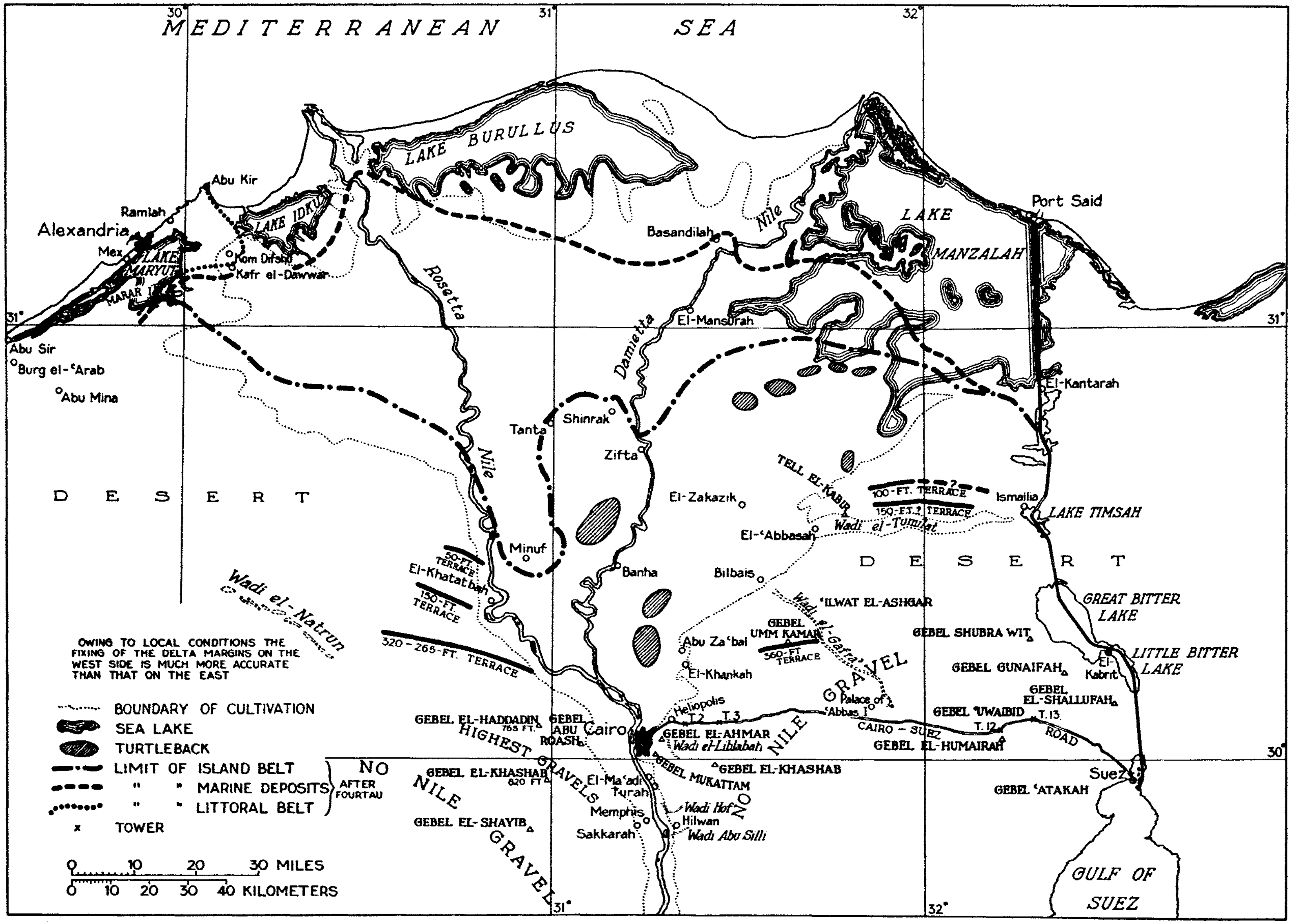

FIG. 10.—SKETCH MAP SHOWING APPROXIMATE LIMITS OF RIVER GRAVELS AND ASSOCIATED FEATURES OF THE NILE DELTAS OF PLIO-PLEISTOCENE AND LATER TIMES

position of the coast for a given terrace, as outlined above, it is possible to determine its correct stage. Fortunately at least one of the terraces, at 320–265 feet, can be traced almost without a break, from the Nile Valley near Sakkarah along the west side of the Delta until its subaqueous deposits are met approximately between el-Khatatbah and the eastern end of Wadi el-Natrun (see p. 43). This terrace serves as an additional datum. When all available information is thus used the determination of relative altitude ceases to be a matter of real difficulty or error.

LOWER EGYPT

Deposits West of the Delta

SANDS

By far the best exposure of feldspar-bearing sands is to be seen in a pit about half a mile north of Mena House (Pl. IV *B*). Here the sand is well washed, even polished, and false-bedding toward the north is very strongly marked, broken halfway up the section by a horizontal band that contains ferruginous concretions. Since the pit was being actively worked when last visited (April, 1931), the total thickness of the sand was not easy to gauge; it is probably not less than 50 feet. The sand is capped by Nile gravel, probably washed down from above. Small pink feldspar crystals seem to occur throughout, though on the occasions of earlier visits they were not found in the lowest sands then exposed.

Pliocene sands between the pyramids of Abu Sir and the north corner of Abu Roash are not well displayed, but numerous conspicuous patches not excavated for commercial enterprise, often covered by gravel washed down from above, may be observed in the Abu Roash–Giran el-Ful district. They are prominent in the denuded anticlinal structure at the Nileward end and are clearly displayed under Abu Roash itself, resting on Pliocene clays which rise from beneath them. In one exposure Plio-Pleistocene sands are banked against Pliocene sands.

TERRACES AND THEIR SUBMARINE DEPOSITS

Terrace gravels are well displayed on the west bank (Fig. 11). The greatest height at which they have yet been found is 250 meters (820 ft.) above sea-level (765 ft. above Nile), on the

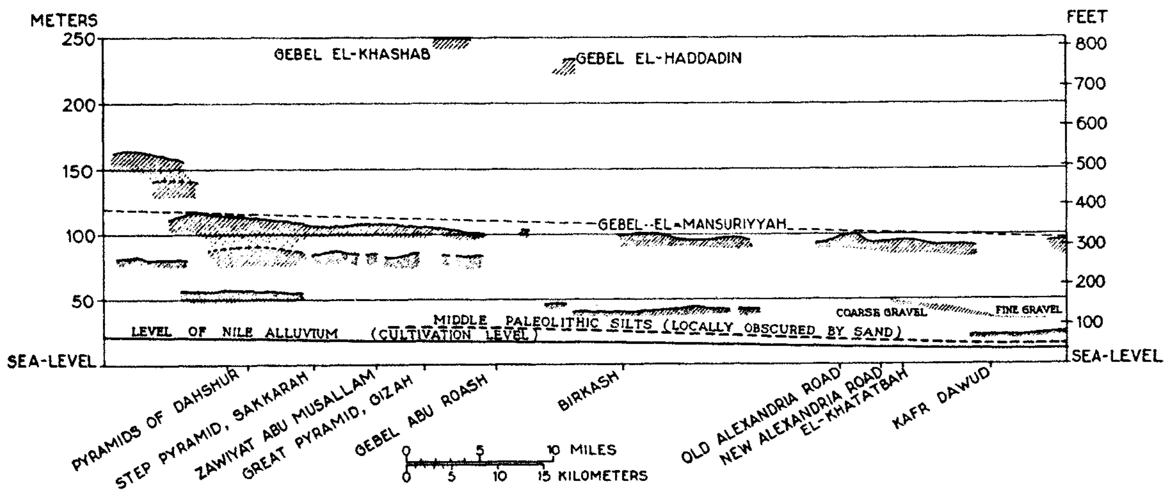

Fig. 11.—Plio-Pleistocene and Pleistocene Gravels West of the Delta

flat summits of Gebel el-Khashab (Pl. III). There typical Nile gravel, with abundant pebbles of granites and metamorphic rocks of the Red Sea Hills, is clearly defined. It seemed to be about 30 feet thick. This was admittedly a great surprise and led to a search of the ground farther afield, to Gebel el-Shayib. But none was found, except in the vicinity of Gebel el-Khashab. From this fragment of river gravel, for such rather than a deltaic deposit it seems to be, one may survey a great area, the whole of it at a decidedly lower level, and gain some impression of the scale of subsequent denudation. The entire desert area has been lowered several hundred feet; the Faiyum and Wadi el-Natrun have been excavated below sea-level. From Gebel el-Shayib also the part played by water erosion in the neighboring deserts can be vividly seen; much of the drainage has been away from the Nile toward depressions such as Wadi el-Farigh.

The second stage also is found in an isolated area. Gebel el-Haddadin, northwest of Abu Roash, bears large pebbles of Nile gravel to a height of 233 meters (765 ft.) above sea-level (715 ft. above alluvium), resting, as at Gebel el-Khashab, on Oligocene gravels (also limestone at the latter) with Pliocene rocks near by. At neither place was it possible to determine the thickness of the gravels with complete satisfaction, as they are mixed with older rocks on the screes and slopes, but in each 30 feet seemed to be a fair estimate.[3]

Along the Nile-Faiyum divide we recognized gravel spreads which possessed terrace features and mapped them as 470–440 feet and 395–?365 feet above alluvium;[4] neither of these is recognized farther north.

The next stage, 320–265 feet above alluvium, was traced from Sakkarah to Abu Roash, where the river was deflected eastward round the headland; but the terrace reappears and may be followed to el-Khatatbah (Pl. VII). Its coarse Nilotic gravels are beautifully displayed along the northern part of the route from the Gizah pyramids to Wadi el-Natrun, notably in the region of kilometer posts 54–56, where they form a well marked bank, a typical marginal deposit, while slightly higher ground west of the route is devoid of Nilotic gravel. A little south of the el-Khatatbah–Wadi el-Natrun railway the terrace changes sharply in character to a submarine or deltaic pebbly sand, which soon (but imperceptibly) sinks below 180 feet above sea-level. North of the railway sandy limestone appears, and the submarine elements merge into a featureless plain. This underwater stage may be traced also along the railway westward, and it forms the northern wall of almost the entire length of Wadi el-Natrun. Its deposits are included in Figures 2, 5, and 11. Low limestone ridges project from the sandy plain some miles to the north along the whole of this country. Thus the 320- to 265-foot terrace and its underwater deposits virtually dominate the country west of the Delta and north of Gebel el-Haddadin, with the site of Wadi el-Natrun as a margin now deeply excavated. The surface levels fall from south to north, and westward along the north side of Wadi el-Natrun, as the deposits become finer-grained.

A terrace not clearly differentiated in the country south of Sakkarah[5] is locally prominent (see folding map) and is defined as the 230- to 200-foot stage. It is seen between the pyramids of Abu Sir and Gizah and occurs southwest of Kirdasah and at the east end of Abu Roash, where the hard rocks are planed. Beyond there it is followed by a lower terrace lying along the margin of the 320- to 265-foot gravels, and the change from fluviatile to deltaic facies has thus been obscured or lost.

In the neighborhood of el-Khatatbah there is another well marked terrace, falling from 50 to 30 meters (164–98 ft.) above sea-level, which can be traced from marginal (fluviatile) to underwater facies from south to north. Near el-Khatatbah the gravels are coarse from bottom

[3] Although these high gravels suggest fluviatile deposition, their positions, both geographical and with relation to the Pliocene shore west of the Delta (cf. folding map), leave little doubt that each was not far from the shore line of its time. For that reason the figures above sea-level are in their case considered to be more accurate than those above Nile.

[4] *OIP* X 24.

[5] Cf. *OIP* XVIII 50.

to top, constituting a clearly marginal river terrace; north of the railway from el-Khatatbah to Wadi el-Natrun the upper part of the deposit becomes gritty, then sandy, and the large pebbles disappear progressively northward in lower and lower levels till near the *deir* of Sidi Abu Nabbut the stage is represented solely by a sandy, gritty plain with a few low hillocks of sandy limestone. This feature is approximately bounded by the 30-meter contour on the Survey Department's 1:100,000 map. The gravels near the southern end at 50 meters are clearly referable to river-level, not sea-level, and therefore suggest a reduced remnant of a 150-foot terrace (Pl. VII). The passage to the marine stage may be placed a little north of the railway.

Of special interest in the sector north of the railway is a lower terrace which remains a true marginal river gravel, banked against the edge of the deposits just described, sometimes with a wadi between the two, almost as far as Sidi Abu Nabbut, where it likewise passes into a gritty submarine deposit and merges into the general featureless plain. The evidence of maintenance of fluviatile deposition farther and farther north as the terrace stages descend is well illustrated by this example, which we term the "Kafr Dawud terrace" (see folding map). It is 45 feet above flood plain at its western margin and sinks eastward to about 33 feet. It is certainly of Pleistocene age, and in turn old Nile silts are banked against it above the present alluvium.

Traces of a terrace with summit level at about 150 feet above alluvium are seen farther south, for example at the ends of spurs between the pyramids of Gizah and Sakkarah.

Deposits East of the Delta

SANDS

False-bedded feldspar-bearing sands are well developed in the Cairo district, especially between ʿAbbasiyyah and Heliopolis (Pl. IV *A*), and thin patches are seen here and there southward to Hilwan, beyond which they attain greater development. From time to time these

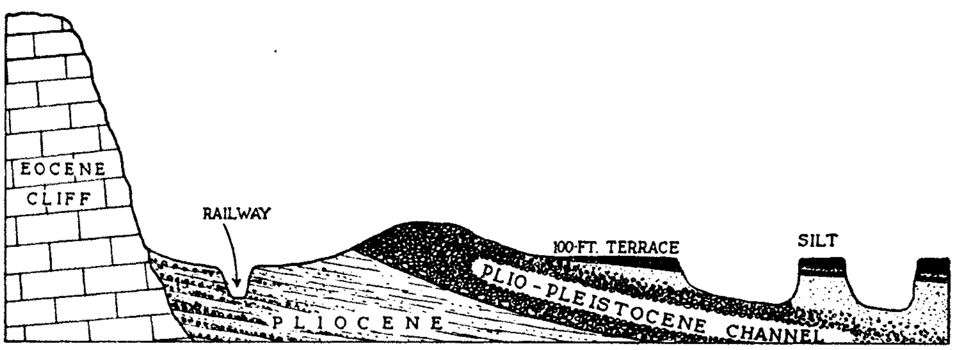

Fig. 12.—Diagrammatic Section across the ʿAbbasiyyah Gravel Pits from Ancient Cliffs to the Northeast (Not to Scale)

estuarine sands are exposed in the deepest excavations at the ʿAbbasiyyah gravel pits, where in the spring of 1929 we saw them to a thickness of about 50 feet, beautifully false-bedded and containing sticklike concretions of sand. They rest on a remarkably coarse conglomerate with subangular bowlders of Oligocene sandstone and Eocene limestone as much as 3 feet in length washed from neighboring cliffs, mixed with pebbles of granite and metamorphic rocks of Nilotic origin (Fig. 12 and Pl. VIII *A*, lower part). The conglomerate rests upon Pliocene clays and sands. A little farther north, land and fresh-water shells have been found in the upper part of the sands.[6] At Heliopolis the tramway depot buildings are situated on an outcrop of Plio-Pleistocene sands capped with gravel and resting upon Pliocene beds. Not far away is a very

[6] See *OIP* XVIII 42.

large sand pit, near the Suez road, exposing 30 feet of loose false-bedded quartz-feldspar sands, with small pebbles of igneous and metamorphic rocks, capped by about 8 feet of Nilotic gravel.

Another notable occurrence of similar sands is in the Tell el-Kabir "island." Especially at its west end, near el-ᶜAbbasah, they are commonly seen in small pits, invariably covered by gravel forming a terrace-like feature which immediately catches the eye of any observer in the train from Port Said to Cairo. Concentration of the gravel by aeolian removal of sand particles is very clearly seen over the whole of this district.

These few descriptions will serve to define the widespread development of Plio-Pleistocene sands on the east bank.

TERRACES AND THEIR SUBMARINE DEPOSITS

The Plio-Pleistocene terraces are poorly represented east of the Nile (see p. 40). Isolated high-level occurrences south of Hilwan, at 650 and 380 feet above alluvium, have already been noted.[7] The highest gravels recorded in the region east of the Nile form extensive rolling country between the Miocene hills of the Cairo–Suez road and Wadi el-Tumilat, where they were traced to 360 feet (110 m.) above sea-level on ᶜIlwat el-Ashgar. Northward of this point they fall steadily, thicken (30 ft. of gravel were seen on the flanks of ᶜIlwat el-Ashgar), and become finer and more sandy—a counterpart of the change already observed west of the Delta (pp. 43 f.). It is reasonable to suppose that these gravels represent in their upper part the 395- to ?365-foot stage.

Above the sand pit near the Heliopolis tramway depot there is a flatness covered with Nilotic gravel; at its west end the gravel may be but a down-wash or a surface concentration on the sands, but when traced eastward it seems to form a terrace at 265 feet above alluvium, that is, at the lower limit of the 320- to 265-foot stage.

Between Heliopolis and Wadi el-Tumilat the high gravels are present, but hidden under local down-wash, for the greater part of the distance. They emerge again on both sides of Wadi el-Tumilat, but on its south side may be no more than the submarine portion of higher stages. On the north side, that is, on the Tell el-Kabir "island," the surface concentration of fairly coarse gravel is not fully explained by the size of pebble in the underlying Plio-Pleistocene sands. The remarkable flatness also is significant, and the altitude, generally 130 feet above sea-level, rather more than 100 feet above alluvium, may indicate the presence of the lowest gravel considered in this chapter, the 150-foot terrace. On the other hand, some of the gravels may have been rewashed at the stage of the 100-foot terrace (see Fig. 14 and pp. 52 f.).

No Plio-Pleistocene deposits were identified in the ground investigated around Suez.

THE ERYTHREAN REGION BETWEEN SAFAGAH AND EL-KUSAIR

There is no clear-cut Plio-Pleistocene interval; certain gravels which were already accumulating in Pliocene times continued to do so until the Pleistocene period was well advanced, and coral reefs continued to grow. It is more convenient, therefore, to consider the deposits of this area in the chapters devoted to the Pliocene period (pp. 31–36) and the Middle Paleolithic stage of the Pleistocene (pp. 65–68). Beadnell suggests association of the Pleistocene raised

[7] *OIP* XVIII 50, where they are referred to as east of Wastah.

beaches with the Milazzian stage but points out that there are reasons for supposing that positive movement of the land is still continuing at the present day.[8] Hume and Little also suggest that the Milazzian stage may be recognized in the Red Sea beaches (cf. p. 68).[9]

CONCLUSIONS AND COMPARISON WITH THE MEDITERRANEAN SUCCESSION

The relationship between the Plio-Pleistocene sands and the Pliocene deposits of the valley confirms the impression gained in Upper and Middle Egypt that a period of intense erosion followed the completion of the Upper Pliocene deposits and that resubmergence led to the piling up of great thicknesses of feldspar-bearing sands, false-bedded toward the open sea. These may be locally fresh-water, estuarine, or marine.

A succession of river terraces may be traced seaward into intimately associated submarine deposits at the mouths of the ancient deltas, the nature of the formations rendering possible estimates of the progressive northward shift of the coastline and delta.

There is a fairly close connection between the altitudes of many of those terraces and the levels generally accepted along the Mediterranean littoral (Fig. 9).[10] The 765- and 650-foot (233- and 198-m. stages) above alluvium recall the high terraces of Algeria at 870 and 670 feet (265 and 204 m.) above sea, and the 470- to 440-foot stage (143–134 m.) is paralleled by the 485-foot (148-m.) level. It will be noticed that each Nile stage is somewhat below its supposed Algerian equivalent.

Another group is centered round the 100-meter level, that is, at 395–?365 feet (120–?110[11] m.) and 320–265 feet (98–80 m.), recalling the Algerian stage of 355–305 feet (108–93 m.) and the generalized Mediterranean stage of 100–90 meters, the Sicilian or oldest Pleistocene stage of Depéret's classification. If this identification is accepted, the Plio-Pleistocene interval may be deemed to have ended at this point. The higher of these two stages is a little above the Algerian figure, the lower some 10 meters below the general figure for the Mediterranean. There is a marked terrace west of the Delta at 230–200 (in Upper and Middle Egypt 250–200) feet (70–61 and 76–61 m.), which field work has shown to be distinct from the 320- to 265-foot stage, in spite of the close approach of extreme lower and upper figures (265 and 250 ft. or 80 and 76 m.). The extremes are in fact liberal allowances, to make certain that no false sense of precision should be implied, and the stages are far more distinct as physical features of the landscape than is implied by the figures. The Nilotic terrace of 150 feet (46 m.) also is recognized west of the Delta but is not generally distinguished in the Mediterranean, where with the higher terrace of 250- or 230–200 feet it forms a group around the Milazzian stage of 195–180 feet (60–55 m.) or indicates a continued fall in level to the next succeeding, 100-foot (30-m.) or Tyrrhenian, stage (see chap. iv). The record thus seems to be one of progressive degradation and terrace formation, with halts that resemble those generally adopted for the Mediterranean but with more detail than is usually taken into account.

Fortunately the 100-foot or 30-meter stage forms a lower datum in the Nile, its age fixed by Paleolithic implements.

In most of the stages here included in the Plio-Pleistocene, therefore, some of them referable to Pleistocene times, a tendency to fall below Mediterranean and especially Algerian levels will be noted. Some differential movement may be indicated, but it is small and not uniform.

[8] *Report on the Geology of the Red Sea Coast between Qoseir and Wadi Ranga*, p. 26.

[9] International Geographical Union, Committee on Pliocene and Pleistocene Terraces, *First Report*, p. 14.

[10] Cf. references in *OIP* X 26 and *OIP* XVIII 43.

[11] 365 ft. is equivalent to 111.25 m., but 110 is adopted for convenience here as in *OIP* X and XVIII.

It is thus necessary to reject local depression and re-elevation of the whole series as a complete explanation of the highest levels, which are known in the Mediterranean but unknown in the Nile south of Beni Suef. Since in the south there is indeed no sign of either piling up or subsequent denudation of gravels above the known height of Pliocene submergence, there is the more reason to view this as a phenomenon of the vicinity of the Delta. But the only known source of the igneous and metamorphic rocks is the Red Sea Hills, via Wadi Kena and the Lakitah plains.[12] If a gradient similar to that of the whole sequence of terraces and of the present Nile is allowed, that material may be calculated to have entered the valley at a height of about 310 meters above sea-level, that is, 110 meters above the height attributed to Pliocene submergence and 130 meters above the general upper limit of Pliocene deposits in Upper Egypt. No positive or negative evidence in Middle and Upper Egypt is available to support any such hypothesis, for every observation there points to 200 meters above present level as the maximum height of all Nilotic deposits from Middle Pliocene times to the present day, including the 300-foot terrace of Upper Egypt, which seems to develop into thick gravels (320–265 ft.) near the Delta. It seems easier, therefore, to account for gravels about 50 meters above the Pliocene level of submergence by invoking local changes than to consider them as a general feature, since the latter view would necessitate accounting for more than 100 meters of rocks which are supposed to have disappeared from the valley.

Depéret has had the same difficulty. He quotes stages recorded by De Lamothe in Algeria and Tunis (325, 265, 204, 148, 100, etc. m.) and says: "et d'autant plus anciennes qu'elles sont plus élevées au-dessus de la mer actuelle"; he mentions also stages found by Gignoux in Sicily (200, 155 m.), Otranto (200, 149, 115 m.), Capri (200 m.), and Gibraltar (200 m.).[13] In the absence of satisfactory paleontological evidence Depéret attributes all levels above 100 meters to the Upper Pliocene unless evidence of earth movements[14] (e.g. in the Calabrian area) shows that the sequence as a whole or in parts has been elevated. It will be observed, moreover, that even among these extreme altitudes all save three are at or below the 200-meter line, the covering figure adopted for the height of Pliocene submergence.

The highest levels in Egypt occur near the apex of the Delta (see pp. 42 f.), and the altitudes descend from north to south until concordance, beginning with the approach of the pre-Sicilian levels of the Delta and along the Nile-Faiyum divide, becomes universal throughout the river in the Sicilian or first Pleistocene stage. It is reasonable therefore to suspect not elevation of the whole series but depression of the region in the early stages and re-elevation before Sicilian times. The same may well apply to the high levels of Algeria, and this correspondence within reasonable limits may be fortuitous. The still higher levels noted by De Lamothe but omitted by Depéret may fall into the same class.

If the detecting of such temporary change of levels in the region of the apex of the Delta, perhaps contemporary with the end of known movement at the head of the Gulf of Suez, is correct, the vertical range of terraces falls below the maximum of Pliocene marine submergence.

[12] The watershed of Wadi el-Tarfah, which enters the Nile from the east near Samalut, is in the Nubian sandstone, in close juxtaposition to the Archean rocks, as well as in the south side of the South Galalah Hills; no trace of igneous or metamorphic pebbles could be found near its mouth, and there is no evidence that it supplied such material to the Nile in the past.

[13] See Académie des sciences, *Comptes rendus hebdomadaires des séances* CLXVI (Paris, 1918) 481–83. Since the completion of the text of the present volume there has been a noticeable tendency among European geologists to cast serious doubts once more on some of Depéret's and De Lamothe's stages, though such criticisms have not yet found their way fully into print. At present it is unnecessary to interfere with the analogies, purely tentative, drawn in this and later chapters between the stages of the Nile and those of Depéret's scheme. See Postscript for further information.

[14] Cf. W. J. Sollas, *Ancient Hunters* (3d ed. rev.; New York, 1924) p. 30, n. 25.

The problem is then brought back to the filling of the Nile gulf in the final stages with feldspar-bearing sands and with pebbles and gravels gradually following after the sands until the gulf was completely filled. To some extent the gulf may have been overburdened with gravels a little above the Pliocene level of submergence, but not to the extent of 100 or even 50 meters.

Owing to the fragmentary condition of the highest remaining gravels and their localized distribution it is unlikely that the problems they raise can be solved absolutely in the region of the Delta of the Nile. The foregoing is offered as a possible solution and as a working hypothesis which does not confuse or conflict with the known facts of Pliocene or Pleistocene geology. It is not claimed to be an entirely satisfactory or proved explanation. In the Erythrean region there is little evidence of a clear-cut Plio-Pleistocene interval.

IV

THE LOWER PALEOLITHIC STAGE OF THE PLEISTOCENE IN LOWER EGYPT

INTRODUCTION

The earlier stages in the general classification of Quaternary time in the Mediterranean basin—the Sicilian and Milazzian —have already been discussed in chapter iii. Here the deposits which contain the oldest Paleolithic implements yet found in Egypt in stratified deposits will be considered. Their discovery in such circumstances near Cairo is due to the perception and long-sustained efforts of Père Paul Bovier-Lapierre.[1]

Two gravel terraces containing Lower Paleolithic implements have been traced from the Second Cataract northward to Hilwan.[2] The higher or 100-foot terrace has been shown to be of Chellean age, but its gravels contain a mixture of old and young Chellean types and even some that suggest the oncoming Acheulean technique. The lower or 50-foot terrace contains typical Acheulean implements, including some of advanced type which show that the period of that culture was nearing its end. The higher terrace can be traced without difficulty through this great length of river valley, and only in the neighborhood of the Nile-Faiyum divide is its margin found to some 85 feet instead of 100 feet.[3] The lower terrace is to be seen as far north as Maghaghah, and tributary gravels of the same height have been noted as near the region described in the present volume as el-Saff; on the whole, however, the stage is difficult to recognize in the north. Along the Nile-Faiyum divide its gravels are evidently embodied in the lower part of the cross-section of the river channel of the 100-foot terrace, exposed from Sidmant el-Gebel northward to the pyramids of Lisht. The center of the channel of the 100-foot stage reaches to the level of modern alluvium at several places between the Second Cataract and Cairo.[4]

North of Sakkarah and Hilwan the higher terrace is readily recognized and the lower virtually absent. A level of about 70 feet is prominent in the wadi deposits and raised beaches of the head of the Gulf of Suez and in the Safagah-el-Kusair region, but in the Nile Valley it is unknown as a marginal level north of Dihmit (near Aswan).[5]

In the northern part of Lower Egypt, as already seen in the study of the Plio-Pleistocene series, most of the lower terrace features merge into featureless slopes, fine deposits, and marine limestones and clays (see pp. 40 and 44). In these it is usually impossible to make any distinctions of age. In this connection there may be noted especially the well known fresh-water limestones and shelly beds, rich in Nilotic sand and gravel, that are thrown across the Isthmus of Suez, especially from Lake Timsah northward, the ultimate term of the ancient delta, which served to separate the Mediterranean and the Gulf of Suez after the disappearance of any structural barrier such as had been brought into being at the end of Miocene times. The fresh-water deposits, exposed at their best in the excavation of the Suez Canal, lie on marine or estuarine

[1] See *L'Anthropologie* XXXV (1925) 37–46 and Institut d'Égypte, *Bulletin* VIII (1926) 257–75. See also Union géographique internationale, Congrès international de géographie, Le Caire—avril 1925, *Compte rendu* IV (Le Caire, 1926) 298–308.

[2] See *OIP* XVII and XVIII.

[3] See *OIP* X 28 ff.

[4] See *OIP* XVIII 53 ff.

[5] See *OIP* XVII 29 f.

beds which, if judged by their fauna, are likewise Pleistocene. Neither of these formations can be attributed to a definite stage of the Pleistocene period, but it will be shown that an arm of the Nile probably flowed eastward from el-Zakazik or Bilbais to Ismailia at the time of the 100-foot terrace. The old river course is marked by Wadi el-Tumilat, which was subsequently flooded with silt and cut off from Lake Timsah by a bar of washed-down gravel and sand. The subsequent history of the wadi is discussed on pages 56–58, where it is seen to have certain features in common with the Faiyum.

On the west side of the Delta no equivalent feature was produced, but in post-Sicilian times the overlap of the gravels of that stage upon Pliocene and earlier deposits, running approximately northwest–southeast, was first picked out by subaerial denuding agents, and Wadi el-Natrun was initiated. If wind has been the chief agent in digging this great hollow, which, bounded by high ground, has evidently had no surface connection with the Nile or the Mediterranean since Sicilian times, a cursory inspection of its southern side and of the adjoining Wadi el-Farigh shows how intense has been surface transport by water. On all sides are down-washes, runnels, and watercourses; there has been a prolonged movement of coarse material by water down the slopes toward the deepening floor. Only the finer pebbles of flint and limestone, grit and sand seem to reach the floor, the material being reduced as it proceeds fitfully with occasional heavy rains. At no period, so far as any geologist has yet discovered, did surface water form deep or extensive lakes on the floors of Wadi el-Natrun or Wadi el-Farigh; the porous nature of the whole of the rocks save the seams of Lower Pliocene clay prevented any such accumulation. At the present day the depth of the water table aids the rapid passage of any surface water into the thirsty ground.[6] From almost every aspect, then, save depth and the presence of Pliocene and Plio-Pleistocene or Pleistocene gravels along one side, Wadi el-Natrun is dissimilar from the Faiyum.

It is impossible to judge the time at which the wadi attained the rough outline of its present size and shape. Apart from implements obviously washed down the flanks we found only one Lower Paleolithic specimen, of local tabular Lower Pliocene flint, that probably had been dropped in antiquity where we found it in the middle of the depression on Pliocene clays. This implement is probably of rather early Acheulean type. The original is in the Musée des Antiquités at Cairo, and the photograph (Pl. XXII 7) is from an excellent plaster cast made in the museum. Although it is impossible to draw a conclusion from one specimen, the evidence, such as it is, does in fact suggest that the depression was already formed in Lower Paleolithic times. Man seems to have shunned it, except to get natron and salt, until monasteries which still survive (and others long since destroyed) were established here in early Christian times.[7]

The discussion of Wadi el-Natrun introduces for the first time the question of the past climate of the regions described in the present volume, a subject frequently provocative of discussion. At the present day winter brings fierce storms and the certainty of rain annually over most of Lower Egypt. In such circumstances it is inevitable that in deposits of all ages so near the Mediterranean there will be evidence of severe wind action in the sand-and-gravel country, combined with torrential run-off as the result of sporadic showers especially on the high ground between Cairo and Suez. In the Gulf of Suez and the Red Sea the climate, as shown by deposits, seems to have been on the whole similar to that of the present day throughout post-Miocene times: hot and dry, with irresistible flooding of wadies at variable intervals of months, years, or decades, the product of cloudbursts in the Red Sea Hills and high ground adjacent to the Gulf of Suez.

[6] See John Ball's papers in the *Geographical Journal* LXX 21–38, 105–28, 209–24 and LXXXII (1933) 289–314.

[7] See E. H. Sawyer, "The first monasteries" (*Antiquity* IV [1930] 316–26).

One has but to spend a winter in tents in the desert and semidesert country between Suez and the Delta and between Cairo and Burg el-ᶜArab to realize how destructive are the winds and rains of the bitter Mediterranean storms that sweep over this ground. In the remote past they may or may not have brought more rain; but within the limits of this introductory note it can be said, with little probability of contradiction based on actual knowledge, that the climate has altered but little since Pleistocene times. Certain evidence of change in specific instances will be mentioned in due course.

Though the climate of Lower Egypt has remained more or less unchanged, the nature of the deposits formed by the Nile has been profoundly modified. Until the end of Lower Paleolithic times coarse gravels were brought northward by the river along a graded course no more severe than that of today. Thereafter only fine gravel, sand, and predominantly silt arrived in the Delta. It may fairly be assumed therefore that the supply of water and of material had changed radically in the south.[8]

THE 100-FOOT TERRACE

On the west side of the Nile gravels of the 100-foot stage are well exposed from the south northward as far as Sakkarah. Since the bed of the river was on the east side of the valley between Hilwan and Turah and between the Citadel in Cairo and ᶜAbbasiyyah, gravels are not prominent on the west bank opposite these places. Having negotiated the headland of Abu Roash, however, the river, or probably one branch of it, cut strongly into the edge of the Western Desert, and a smooth surface, associated with gravels at and below 100 feet above alluvium, may be seen for most of the distance between el-Mansuriyyah and Abu Ghalib. Lower Paleolithic implements occur on the surface but were not found in the gravels, which are excavated for ballast on a modest scale. The same branch of the Nile cut a meander immediately south of el-Khatatbah (Pl. VII), where a bay marks the desert edge,[9] but local downwash has incumbered the ground. In both instances the river cut below Sicilian gravels, and underlying later Tertiary strata are exposed. North of el-Khatatbah (at Kafr Dawud) the river cut into the west bank at the 50-foot stage, and no transition of the 100-foot gravels from fluviatile to sandy facies can be observed.

East of the Nile the deposits of the 100-foot stage are strongly developed and of special interest. First, in and near Wadi Abu Silli, a few miles south of Hilwan, a section of the channel is exposed; it may be seen again between Hilwan and the mouth of Wadi Hof. In both places Nilotic gravel and silt are truncated by later deposits of purely local origin derived from the wadies. In the Wadi Abu Silli district these later deposits occur at a clearly defined height of 30 feet above wadi floor (see p. 56) and above alluvium at the Nileward end. Lower Paleolithic (Chelleo-Acheulean) implements may be found *in situ* rarely at the northern exposure (Pl. X *B*).

At ᶜAbbasiyyah are the gravels made famous by Père Bovier-Lapierre (Pl. VIII). From quarries there the following have already been mentioned: (1) Pliocene clays and sands (p. 20), (2) Plio-Pleistocene conglomerate and feldspar-bearing false-bedded sands (p. 44). Of the essentially Pleistocene strata are differentiated (1) purely Nilotic gravels, a section of the main river bed, (2) outwash from a branch of Wadi el-Liblabah which drains the high plateau and the Oligocene country of the eastern Gebel el-Khashab. There is another such detrital cone between this site and the Citadel, and the material spread out farther and farther as the Nile withdrew westward across its valley. It appears to be late Middle Paleolithic (see p. 56).

[8] See *OIP* XVII–XVIII.

[9] This is shown on the folding map, but no exposure of the 100-ft. terrace can be marked.

The purely Nilotic gravels and interbedded sands are as much as 30 feet thick and rest unconformably upon the quartz-feldspar sands. As a result of a number of visits to the pits, sometimes with the advantage of Père Bovier-Lapierre's company, we have concluded that each of the three groups of sand and gravel into which he divides the beds outcrops separately at the margin. In other words, at the eastern edge of the gravel pits only the oldest stratum is exposed (replaced by "fawn sand" in Fig. 13); this falls in the direction of the Nile. The featheredge of the middle group, met as the traverse is continued westward, also falls. The third group is met in similar fashion. All three, together with Nile silt covering the uppermost group, are covered indifferently by the detrital outwash from Wadi el-Liblabah, which gives a false appearance of conformity upon the third group and its overlying silt.

It follows therefore that these groups were deposited by a falling river. Careful leveling from a Survey Department bench mark elicited the fact that the highest point of the implementiferous gravels, at the margin of the oldest group, is 104 feet above adjacent alluvium,

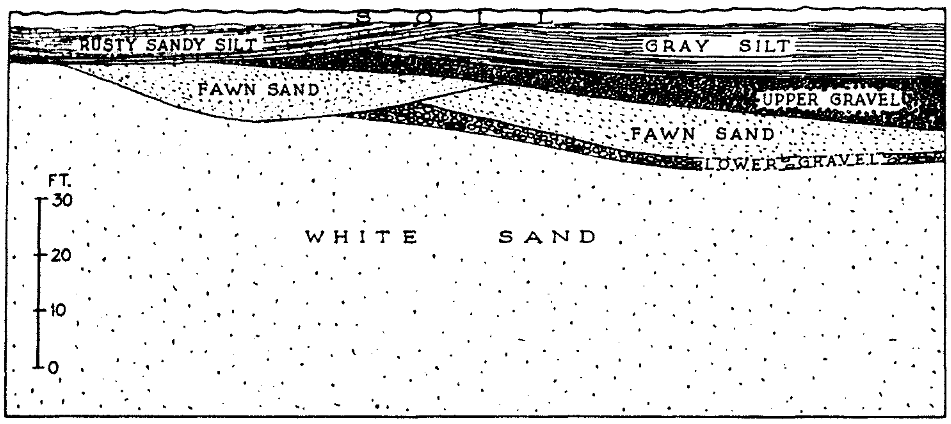

Fig. 13.—Section Exposed in 1930 in the Southwest Wall of the Deepest Pit at the Southwest End of the Group at ʿAbbasiyyah, Showing Channel Bedding of Pleistocene Deposits over Plio-Pleistocene White Sands. Implements Were Found *in situ* in Both Lower and Upper Gravels. The Stratigraphy Is of the Deeper Part of the Gravels Rather Than of the Margin

a satisfactory approximation to the 100-foot terrace. Since the levels fall and the sequence is truncated by modern alluvium, it is difficult to fix precise altitudes for the higher groups in the series, which fell below the 104-foot level as the river "sideslipped" westward. We are convinced, however, of a general 100-foot level for the oldest and middle groups, of Chellean age; the third or Acheulean group may be judged to start as high as 70 feet above alluvium in the numerous exposures, but this is indeed an approximation that may be modified as year by year the great pits are excavated. Père Bovier-Lapierre and his friends have found isolated vertebrate remains in the pits, and it is greatly to be hoped that at no distant date a list of these remains will be available together with precise knowledge as to their horizons in the succession.

Little is seen of the 100-foot terrace east of the Delta until Wadi el-Tumilat (Fig. 14) is reached. This is a furrow from the Delta to the Isthmus of Suez between Plio-Pleistocene sands and gravels, concealed on the south side by sand and material washed from higher ground. The bulk of the material of the Tell el-Kabir "island" (e.g. the sands) was probably deposited under water; the surface gravel is partly a concentrate from the sands and partly coarser than any pebbles found below its own level. It is suggested (p. 45) that the higher parts of this flat-topped region are the surviving remnants of 150-foot terrace gravels at 130 feet above sea-level; that is, by analogy with the sands and gravels north of el-Khatatbah (see p. 44) they indicate the gradation from fluviatile to marine facies. But there is a considerable amount of coarse gravel on the flank adjacent to Wadi el-Tumilat and on the west and north which is dissociated from the Plio-Pleistocene sands; here and there are marked suggestions of a bench (cf. Gebel Umm Tabak) of which the higher parts, at about the 40-meter contour (i.e., about 130 ft. above sea-level), are probably Plio-Pleistocene, whereas the long slopes below the bench or break in contour rise to about 90 feet. The "island" as a whole is a Plio-Pleistocene relic; but especially its southern side, which is a flank of Wadi el-Tumilat, is fluviatile and of later origin. The evidence therefore suggests that the wadi marks a course of part of the Nile at the 100-foot and later stages. The wadi was not cut after the 100-foot stage; the height of its flanks and its cross-section also indicate its formation at that stage. The marine facies of the 100-foot gravels is probably to be recognized in the vicinity of Ismailia.

THE 50-FOOT TERRACE

No terrace is widely developed at this altitude, nor have implements been found in such gravels as occur at 50 feet above alluvium or local datum. Nevertheless there are sufficient indications that this stage was once well represented and that, as in the country south of Hilwan, it has been reduced to small and often unrecognizable fragments. First, a terrace is developed at 50 feet above present wadi floor in certain tributaries, notably Wadi Hof in the Hilwan district, and calcareous cement has kept the pebbles bound together. Elsewhere the ubiquitous flint gravels have for the greater part been broken up or covered by washes along the desert edge. There are traces of similar wadi gravels in the western part of the hills above Cairo and Heliopolis, but these are poor examples. The Chelleo-Acheulean and Acheulean gravels at ᶜAbbasiyyah are not seen as a marginal deposit as low as 50 feet above alluvium.

Traces of a 50-foot terrace of the Nile appear at about the same latitude on both sides of the Delta, between el-Khatatbah (the "Kafr Dawud terrace") and the *deir* of Sidi Abu Nabbut (see folding map) and at el-ᶜAbbasah, near the west end of Wadi el-Tumilat. The "Kafr Dawud terrace," a very clearly defined marginal gravel seen to a thickness of about 10 feet and thickening toward the Delta, runs for some few miles with summit at about 45 feet above alluvium, being banked against the eroded edge of the submarine deposits of a much higher terrace (see p. 44); the contrast between the two is hard to exaggerate. At the *deir* of Sidi Abu Nabbut, however, the local gravels in turn sink down into sandy beds and become indistinguishable in the open plain. At el-ᶜAbbasah is a noticeably beveled surface, but little gravel can be attributed to this surface, which is a little more than 40 feet above alluvium. The evidence, so far as it goes, supports what is already known in the south but would otherwise be entirely inconclusive; under the circumstances it can be assumed that the 50-foot stage is probably represented in Lower Egypt.

CONCLUSIONS

The Tyrrhenian stage of the Mediterranean (35–30 m., 115–100 ft.) is represented on the Nile by the 100-foot terrace from the borders of the Sudan to the Delta, and Chellean and Chelleo-Acheulean implements are found together in it. It is the first of the descending series of Nile terraces in which humanly fashioned implements occur. The higher group of the Monastirian stage (20–18 m., 65–60 ft.) is presumably recorded in the Nile throughout the same part of its course by the 50-foot Acheulean terrace, which is also preserved, though poorly, in Lower Egypt.

The interesting and important series of raised beaches and terraces of the Gulf of Suez and of the Red Sea is considered as a whole in chapter v.

V

THE MIDDLE PALEOLITHIC STAGE

INTRODUCTION

In the course of Middle Paleolithic times the Nile Valley north of Sakkarah, the Delta, and the Egyptian coasts of the Gulf of Suez and the Red Sea almost acquired their present shape; thereafter changes of level of sea and river with relation to land (or of land to sea) have been considerable but temporary. At the present day the Nile is engaged in regaining the altitude that it had attained near the close of the Middle Paleolithic stage of its development, having in the interval fallen far below it. Drastic changes of level are evident in Upper and Middle Egypt and in the Faiyum. The main movements were two in number, the first of Middle Paleolithic age, the second at the extreme end of that period and continuing into the late and probably post-Paleolithic stages, from which recovery has lasted since Neolithic times.

The changes that took part in the first of these movements are recorded in a number of ways, apparently unrelated but nevertheless leading to the same conclusions. The evidence is provided by the following: (1) height, thickness, nature, and distribution of Nilotic deposits; (2) types of flint implements in these strata; (3) nature, disposition, and contents of deposits in tributary streams. In the Erythrean area the height to which coral grew and the altitudes of raised beaches and wadi deposits and the flint implements found in them also provide useful data.

Since the completion of this text in 1935 the term "Middle Paleolithic" has become a subject of debate, notably at the meeting of the British Association for the Advancement of Science in 1938. The term has been used in this series of volumes in a broad sense, and its application to Egyptian prehistory continues to serve for the present. By the inaccurate but convenient term "Middle Paleolithic times" is implied the time interval occupied by the development of a group of industries in the region; the use has a geological significance within the area similar to that imparted by zone fossils.

LOWER EGYPT

Deposits West of the Delta

At the mouth of the Nileward end of the Hawarah Channel, the connecting link between the Nile and the Faiyum, are fine gravels containing an abundance of a rather advanced type of Middle Paleolithic implement.[1] We traced these deposits northward and southward along the Nile-Faiyum divide and discovered that, instead of being but a few feet or meters thick and resting upon a surface of some older rock or gravel, they were of unknown thickness (cf. p. 99). They were clearly seen to pass below the present surface of the alluvium, and their upper limit mounted to about 25 feet above flood plain. Their connection with older gravels in Upper Egypt has been traced;[2] they were shown to continue the sequence of those gravels, which disappear when followed northward. The older implement types found in them have nowhere been found *in situ* in Nilotic deposits in the region now under review. The younger types, those of the Nile-Faiyum divide, have been so found in a corner of the Western Desert edge opposite Zawiyat Abu Musallam midway between the pyramids of Abu Sir and Gizah

[1] Cf. *OIP* X 37 and 45. [2] See *OIP* XVIII 66–69.

(Pl. X *A*). There, in a small re-entrant cut in Eocene clay, is a mass of Nilotic silt which has accumulated to a height of 30 feet (with surface wash 33 ft.) above alluvium. The bedding suggests that the silt has been piled steadily into the hollow by the Nile, with bands and strings of local rubble, including lumps of mud, washed in the opposite direction. The mass has subsequently slipped on the underlying clay and has been unevenly tilted; the original bedding is nevertheless perfectly clear. At all levels throughout this mass, bedded in the silts and lying horizontally, we found numerous implements of the younger types mentioned above (Pls. XXIII–XXIV). The silt has indubitably been accumulated by the level of deposition creeping up the shelving floor of the hollow; its connection with lower levels has been more or less broken only by later (and present-day) erosion along the edge of the alluvium which is still forming. This site gives a precise replica of the sands and gravels of the Nile-Faiyum divide, the level of its summit having risen a few feet in the interval with reference to present flood plain. It will be shown that the height of 30 feet above alluvium applies to similar sandy silts along both margins of the Delta, the exposure at Zawiyat Abu Musallam being no isolated occurrence but representative of a widespread deposit.

Similar silt, with pebbles washed into it from the high banks, forms many miles of the Western Desert edge from el-Mansuriyyah to the *deir* of Sidi Abu Nabbut, well to the north of el-Khatatbah. It can be clearly seen from the railway line that follows the Rosetta branch of the Nile from the Delta Barrage. Unfortunately wind-borne sand has accumulated upon it for long distances, emphasizing its presence but obscuring its actual surface from close inspection. Nevertheless implements of the type found at Zawiyat Abu Musallam occur on the surface in the sand and figure in the collection made by Junker and others from their excavations of Neolithic and associated sites located on this surface in the Abu Ghalib–Beni Salamah district.[3] The silts are less incumbered with drifting sand in the vicinity of Kafr Dawud and Sidi Abu Nabbut's *deir* and are clearly seen to mount over the low surface and to rest along the flanks of gravel associated with the 50-foot ("Kafr Dawud") terrace. They rise to 5 meters above alluvium, here about 10 meters above sea-level; that is, they are seen to a little less than 20 feet above flood plain. Implements of the type already associated with them, that is, like those found at Zawiyat Abu Musallam, notably the "double-ended" type of core (see p. 90), are found on the surface.

This long stretch of rich silt was the site some years ago of a number of attempts at high-level cultivation by means of pumps and deep wells. Since in almost every instance drifting sand brought ruin to the enterprises, derelict equipment and remains of buildings and irrigation ditches may be seen at many points. Water lies in hollows of the sand in the winter; and the descending levels of these pools, marked also by dust blown from the cultivated land of the Delta and deposited in layers and films of mud, mark the presence of the underlying silt. The water is evaporated or, for the greater part, is absorbed into the sand.

The commercial disasters served one good purpose: they provided some knowledge of the strata below the visible layers of silt. In this area the beds might be expected to be thick if the Rosetta branch of the Nile had retained the position along the west side of the Delta which it had occupied at any rate since early Pleistocene times. Such proved to be the fact. A bore at Abu Ghalib, which was situated on the silt, passed through 29 meters (95 ft.) of Nilotic sands and clays and then entered quartz sands and clayey sands (probably Plio-Pleistocene).[4]

[3] See Kaiserliche Akademie der Wissenschaften, *Wien*, philos.-hist. Klasse, *Denkschriften*, 68. Bd., 3. Abh. (1928); *idem*, *Anzeiger* for 1929, pp. 156–249; 1930, pp. 21–83; and 1932, pp. 36–100.

[4] See *OIP* XVIII 80.

There are many other records of deep borings to which we shall refer in detail later, but the greater number were situated on modern alluvium, not on ancient deposits of known age.

The recorded data west of the Delta show unmistakably that the fine gravels and silts known in Middle Egypt as the 25-foot aggradation gravels[5] (1) rise a few more feet above present alluvium, that is, to about 30 feet, (2) contain similar implements, and (3) were preceded by profound erosion of the order of 100 feet below present alluvium.

Deposits East of the Delta

A prominent feature in the tributary wadies north and south of Hilwan is a terrace 30 feet above present wadi floors (see p. 51). At some distance from the Nile it consists of less than 10 feet of coarse locally derived pebbles and bowlders resting on an eroded surface of Eocene or other rocks. Near the Nile the full visible thickness of 30 feet may consist of local gravel. There is a lower and similar step at 10 feet above wadi floor. No surface excavations in the typical wadi floor, except near its head, reveal solid rock; near the Nile local deposits descend to great depth.[6] It might be suggested that the terrace at 30 feet is the long-sought representative of the older Middle Paleolithic stages of Upper Egypt.[7] So indeed it might be; but it has provided no implements, so common in the south, and it falls directly within the range of the 30-foot aggradation silts and gravels found west of the Delta (pp. 54–56). In the absence of any contrary evidence it seems more probable that it is associated with that aggradation, and the lower level with subsequent re-excavation of the valley.

This opinion—it is no more—fortunately receives confirmation at Père Bovier-Lapierre's sites at ᶜAbbasiyyah. Here, as already described (p. 51), the local outwash of a detrital cone from the high plateau spread out over Lower Paleolithic sands and gravels and followed the river as it swung away from the locality. Old river silts such as occur in the lower parts of the channel of the 100-foot stage were likewise overwhelmed by the local outwash, covered by it, and partly incorporated or redeposited with it. This upper material contains Middle Paleolithic implements of late type, such as those at Zawiyat Abu Musallam (see p. 55), together with some beautiful examples of types not found at that site. The implements are to be attributed to the outwash gravels, to the surfaces below them, and also to working-floors on gravel hummocks, from which they became incorporated. They occur also in the silt below the outwash, but experience shows that specimens found in this lie at high angles of inclination at the bottoms of visible cracks caused by the drying of the muddy material; that is, they have dropped into the silt, which is probably an integral part of the Lower Paleolithic deposits (Pl. VIII *B*, top).

On the east side of the Delta the silts and fine gravels attain their most interesting development in Wadi el-Tumilat (Fig. 14). They are last seen in recognizable form at the east end of the wadi, at a French farm close to el-Wasifiyyah station between Ismailia and Abu Suwair, where irrigation ditches expose porous white fresh-water limestone of Pleistocene age similar to that along the Suez Canal, and silt is seen in railway cuts near by. Thence westward of Abu Suwair the silt becomes prominent with surface at 14 meters above sea-level, that is, 20 feet above the alluvium of the Delta near el-ᶜAbbasah. It is prominent at the same level again near el-Kassasin, and along the south side of the wadi are banks of fine gravel to 15 meters above sea-level (26 ft. above alluvium). Near the French farm the silt is unconformable upon the fresh-water limestone; from Abu Suwair to el-Kassasin it is seen in section to rest upon and against the gravel flanks of the wadi itself, that is, to be filling a pre-existing valley, and is

[5] Cf. *ibid.* pp. 69, 79, and 83.

[6] See *OIP* XVIII 79 f. The 30-ft. gravels of the Wadi Abu ᶜAbbud–Wadi Abu Silli district lie unconformably across the denuded silts and gravels of the Nile channel of the 100-ft. stage which crosses the valley from west to east.

[7] *OIP* XVIII 72–76.

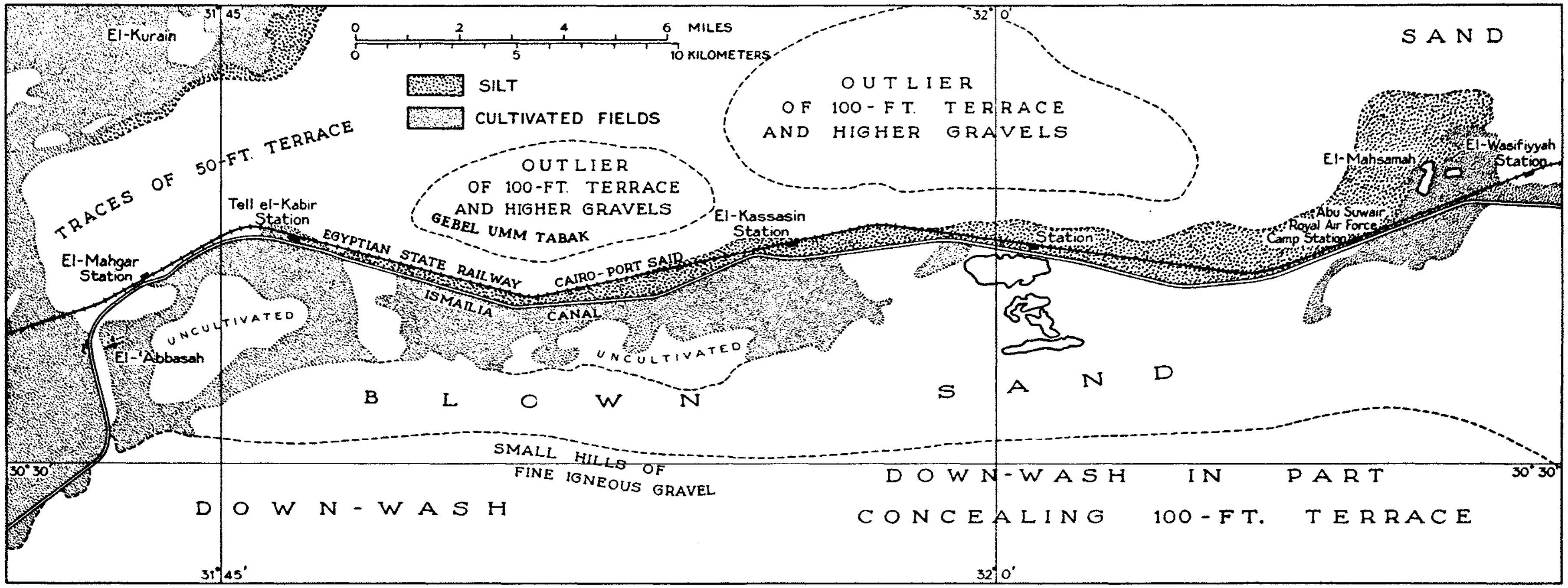

Fig. 14.—Sketch Map of Wadi el-Tumilat, Showing Position of Middle Paleolithic Silt Described in the Text. Probably the Silt also Underlies Low Patches of Uncultivated Ground and Salt Marshes South of the Canal

invariably covered by a down-wash of gravel and sand from the Tell el-Kabir "island." In the railway cut adjacent to the French farm this down-wash, 3 feet thick, was found to contain fresh and unrolled implements of late Paleolithic (post-Middle Paleolithic) type (see pp. 70, 90). The evidence so far as the position of the silt in the succession is concerned is thus fairly clearly defined. It lies in a valley section cut by the Nile at the 100-foot stage; its upper limit is the same as that of silt along the west side of the Delta and at Zawiyat Abu Musallam (see p. 54); and it is covered by washes of post-Middle Paleolithic age. North of el-ᶜAbbasah, at el-Kurain, silt is banked against sands and gravel to 11 meters (15 ft. above alluvium) and contains small white calcareous pellets such as occur in some exposures in Wadi el-Tumilat.

The history of Wadi el-Tumilat now calls for attention (cf. Figs. 21–22). Evidently it was the course of an old branch of the Nile and no doubt helped to spread Nilotic sand and fine gravel over a wide area between Port Said and Suez. In Middle Paleolithic times it may for a time have continued to do so, but now the Ismailia Canal[8] negotiates the last part of its course toward Ismailia between banks of older sands and gravels, limy beds, and down-wash, with surviving patches of silt at intervals. Moreover, the contours of the wadi floor give the impression of widening westward, toward the Delta; so also does the exposure of Middle Paleolithic silt. The surface upon which the silt rests is well defined gravel, limestone, or Plio-Pleistocene sands. In other words, the silt in the wadi is not thick, as at Abu Ghalib, but is filling a hollow which broadens and deepens westward.

The corollary of this state of affairs is that the Delta at one time drained into Wadi el-Tumilat, through which waters passed eastward; but before the accumulation of the late Middle Paleolithic sands and silts the wadi had been carrying local drainage in the opposite direction, that is, into the Delta, when that region had been cut to lower levels. When the action was reversed, silts accumulated to an even height from end to end of the wadi. Subsequently, however, they have been denuded and covered with down-wash, and a hollow has been cleared below the present height of alluvium, for example at el-Zakazik. That trench is only now being filled with alluvium as the height of the Delta increases. At the present day there is no eastern outlet to the wadi, save for the waters of the canal. Nile alluvium stands at 8 meters above sea-level near el-Zakazik, 7 near el-ᶜAbbasah (at the mouth of the wadi), 4 near el-Kassasin. It will be seen that this is the history of the Faiyum in miniature.[9]

Comparison with Upper and Middle Egypt and the Mediterranean

Although the evidence based on implements found *in situ* is somewhat scanty, it is fortunately distributed and is supported by considerable length of exposed deposits with concordant upper limit; it is also of defined character. Concordance of upper limit and of nature of deposit embraces the whole of the Nilotic deposits on both sides of the river and of its Delta north of Zawiyat Abu Musallam, including also Wadi el-Tumilat. Conclusions that may be made from tributary deposits and their contents are confirmatory and not contradictory. Where Middle Paleolithic implements occur *in situ*, they are of the types identified in Middle and Upper Egypt and have evidently been included in unworn condition as deposits accumulated along the sides of the main valley. Where implements of younger industries overlie sandy silt and fine gravels, they are scattered upon the surface or included in surface washes that rest unconformably upon older deposits. There is therefore good reason for regarding all silts that rise to about 30 feet above the present alluvium of the Delta as of common age and

[8] This sweet-water canal leaves the Nile at Cairo and skirts the eastern edge of the Delta, flows through the wadi, and then supplies the drinking water from Port Said to Suez.

[9] Cf. *OIP* X and Postscript to the present volume.

origin. Here and there borings show that they were built up from a considerable depth, of the order of 100 feet or more, below present flood plain.[10]

In Upper Egypt the terrace gravels that contain the oldest type of Middle Paleolithic implement occur at 30 feet above flood plain or wadi floor. When traced into Middle Egypt they become fragmentary, and in Lower Egypt they cannot be identified. This does not mean that they were never formed in the north, but if they were, as is reasonably probable, they have been destroyed or are no longer recognizable. The same change is seen in only slightly smaller degree in the 50-foot terrace. Many similar indications have been given that denudation of young deposits, in many instances manifestly by water erosion, becomes far more severe the nearer the approach to the Mediterranean.[11] It is a fair conclusion, and in the field an obvious one, that rainfall has remained considerable in the north while it has failed in the south.

In Upper Egypt a well developed Middle Paleolithic stage has been recognized in the wadies at 10–15 feet above their floors, the gravels thickening toward the Nile until at the edge of alluvium their base is below present flood plain; equivalent Nilotic gravels have been almost entirely destroyed or hidden. Northward through Middle Egypt to the mouth of the Faiyum such Nilotic deposits gradually emerge from beneath the alluvium, and tributary gravels thicken accordingly, until some 25 feet of gravel become visible above alluvium, the base being hidden. These deposits contain Middle Paleolithic implements more recent on the whole than those of the 10- to 15-foot gravels of Upper Egypt but with some types in common. Again it seems reasonable to suppose that the older types would be found *in situ* in the deeper parts of the gravels now hidden beneath the flood plain. Now, in the Delta, deposits of the same stage occur with the same implements mounting to 30 feet above flood plain, and, in the wide expanse of Lower Egypt, with current checked, the gravels pass to silt, sandy silt, and fine gravel. There is also evidence of their considerable depth below flood plain. There need be no hesitation therefore in including the whole of these deposits from Upper to Lower Egypt in a common group and in concluding that they were united in a common change which was wrought upon the Nile by the lowering of its ultimate base level, the Mediterranean, or by the raising of the level of the land with reference to the sea, with consequent regrading of the river from the sea upstream and subsequent aggradation in the same direction as the base level was again raised.

How far is such evidence in common with general conclusions formed by observers in the Mediterranean basin? The Tyrrhenian stage is already recognized in the Lower Paleolithic stage of the Nile (see p. 53). There remains the Monastirian. Depéret recognizes two levels of this stage: the main level at 20–18 and a later level at 8–6 meters (65–60 and 25–20 ft.).[12] The former may be identified with the 50-foot terrace of the Nile, which is for the most part Acheulean, including highly evolved forms, with some implements that seem to herald the close of that industry (see *OIP* XVIII 114).

Depéret identifies recessions of the Mediterranean between the stages of his classification, but De Lamothe was possibly even more impressed. Thus Depéret states: "M. de Lamothe s'est efforcé de montrer que chacune de ces lignes de rivage est le résultat d'un mouvement d'abaissement ou *négatif* de la surface marine (parfois jusqu'au-dessous du niveau actuel), suivi d'un mouvement d'élévation ou *positif* de la mer, ayant eu pour conséquence un remblaiement dont chaque ligne de rivage observée représente la phase terminale."[13] Special at-

[10] It cannot be assumed that the marginal deposits were completely reduced to this depth; the Rosetta branch of the Nile passes along the Western Desert edge, and the bores there may have penetrated the central part of its old bed.

[11] See *OIP* XVIII 95 f.

[12] Académie des sciences, *Comptes rendus hebdomadaires des séances* CLXVI 480–86.

[13] *Ibid.* p. 482.

tention may be given to the statement in parentheses and to the final words of the sentence. Of the later level Depéret says: "Après l'étage Monastirien, les lignes de rivage de la Méditerranée se sont abaissées jusqu'au niveau actuel, avec un stationnement temporaire à la hauteur de 6^{m} à 8^{m}, dont j'ai trouvé de nombreuses traces sur la côte française, mais qui ne me paraît pas assez important pour constituer une unité stratigraphique distincte."[14] Since this was written the level of 6–8 meters has attracted considerable attention. It will be observed that Depéret does not specify a regression between the higher and lower levels of his Monastirian, of which the latter in all probability is represented by the 30-foot silts of the Delta. The evidence that has been set out in the present volume and in *OIP* Volume XVIII suggests that there was some such regression and that it fell below the present level of the base level at the mouth of the Nile or was imposed upon the river by movement of the land. If the greater depths of Nilotic silt and sand met in bores along the Western Desert edge, for example at Abu Ghalib, represent in fact deposits of the central part of the Rosetta branch during such a regression (see p. 55), there is no need to assume that the flood plain was reduced to some 100 feet below its present level (see p. 99). On the other hand, the reduction may have been as much as this and even more; at any rate the flood plain was distinctly below present alluvium at Luxor and was deeper thence northward.

RAISED BEACHES, CORAL REEFS, AND WADI TERRACES OF THE ERYTHREAN REGION

Suez

At the present day corals make their most northerly appearance in the northwest corner of the Gulf of Suez, first in small colonies below tide level, then rapidly increasing to form a continuous platform near the shore, and finally passing into a normal reef with lagoon, within a

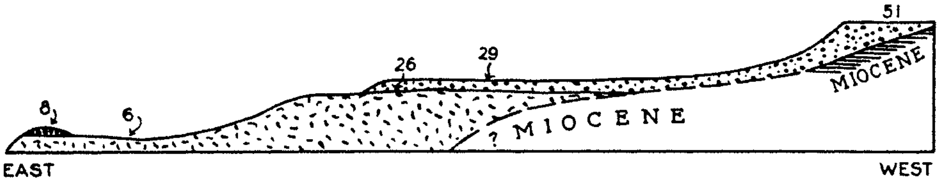

Fig. 15.—Section of Pleistocene Beaches and Coral Reefs in the Northwest Corner of the Gulf of Suez. Figures Represent Heights in Feet above Sea-Level

few miles. At the point of their first appearance, under the great cliffs of Gebel ʿAtakah, they may be traced above present sea-level. At the outset, then, the question of former relative level of land and sea introduces itself. In this respect corals are of unusual value, since they can form only at sea-level and below. Thus the often difficult problem of deciding whether a formation is of marine or fluviatile origin does not arise.

As a result of careful leveling we found in this locality that coral rises to 26 feet above sea-level, with a lower platform at 6 feet above sea. The higher limit recalls the 25- to 30-foot aggradation already noticed in Lower Egypt (see pp. 54–60), but it is not justifiable to suggest an association without further evidence. A detailed section found in this district is shown in Figure 15. First, above high-tide mark, with a small cliff to show its position, is an old storm beach rising to 8 feet above sea, made almost entirely of shells and sinking slightly inland. If followed away from wadies this is seen to pass into a broad and perfectly flat plain of shells, salt incrustation, sand, and clay about 6 feet above sea. Traced seaward where locally the

[14] *Ibid.* p. 485. See also Postscript to the present volume.

normal storm beach is missing, the 6-foot flat ends in a coral cliff above the present strand line. On the landward side it ends sharply. Secondly, behind the 6-foot flat there is a rise to a second platform at 23 feet. A section through this shows 7 feet of shingle and shells resting on a platform of corals at 16 feet above sea (not shown in Fig. 15); the corals may be traced to 26 feet, covered at that height by 3 feet of washed-down rubble (without shells) from Gebel ᶜAtakah. Another, rather gentle rise leads to a third flatness at 60 feet, part of a prominent platform that may be followed round the northeast side of Gebel ᶜAtakah. This consists of coarse local débris from the hills, which at 51 feet above sea gives place very sharply indeed to fine shingle and rubble crowded with marine shells, essentially Pleistocene or Recent. This seems to be a true beach, with summit at 51 feet. At and above 60 feet sections show about 7 feet of rubble on ocherous sandy limestone (Miocene); below 50 feet sections show only shelly shingle with local concentrations of rolled shells of *Ostrea cucullata*. All the shells are of species still living on the beach below. Here, then, we have clear evidence of marine beaches at 51 and 26 feet, corals at 26 feet, with flats behind them, and again at 6 feet.[15]

The records of streams are less satisfactory. As the Cairo–Suez road falls from the high country through a valley on the south side of Gebel ᶜUwaibid and passes Tower 12, it enters the region where the drainage lines curve eastward toward the head of the Gulf of Suez. A great amount of deposition and erosion has taken place, and a prominent series of terraces results (Pl. IX). Eastward from Tower 12 the road falls rapidly, and various terrace features were observed between kilometer posts 95[16] and 100. The levels of these features were accurately determined with reference to the present wadi floor at their feet. Tops of terrace gravels occur at 72, 55, 28, 16, and 6 feet. The gravels of the first two terraces were about 12 feet thick, so far as could be seen in the few clean sections, and of the next pair 7 feet, in all of them coarse bowlder gravel being interbedded with fine gravel and sand. The terrace gravels may be followed almost continuously along the sides of the wadi, which curves eastward and finally southward to Suez. In the middle of its course measurements were taken in several places, and terrace gravel tops were identified at 70, 40, 10, and 6 feet above wadi floor, the 16-foot surface being traced into the 10-foot level. At the shore the 10-foot level becomes a wide plain of fine superficial material on (Miocene) clays, with the present wadi course sunk 10 feet below it, and, together with the 6-foot step, noticeable throughout the wadi, merges, so far as could be determined, into the 6-foot flat with its hosts of shells. The general surface of the flat may be traced upward over a broad expanse of country into surfaces first without shells, then sandy, gravelly, and finally strewn with cobbles and passing in unbroken slope into the wadi fan of 10–15 feet, with a minor 6-foot level below in the now deeply marked stream course. As already stated above, near the shore the shelly flat is surmounted by shingle and old storm beach, and underwater slopes may be seen passing under the waters of the gulf.

The levels of *surfaces* may be tabulated as follows (in ft.):

Wadi terrace gravels	72	55	28	16-10-6
Marine beaches	..	51	26	8 (storm beach)
Coral surfaces	..	..	26	6

Unfortunately no flint implements could be found. It will be noticed that, although the drainage lines just studied sweep well northeastward toward the Bitter Lakes before turning southward to Suez, there is no reason to suppose that the isthmus was a strait. It is demonstrated, however, that the land had been severely reduced in level in this critical area, but not quite low enough to restore that connection between the Mediterranean and the Gulf of Suez

[15] Shells of the large *Tridacna* are found on the surface at any height, having been carried away; they are not *in situ*.

[16] Situated close to Tower 13.

which had been broken in Upper Miocene times. Denudation on a vast scale by torrents passing off Gebel ᶜAtakah had swept away the land that had kept the Pliocene seas apart before the higher of the terraces was formed.

So far as the terraces are concerned, no connection between the Gulf of Suez and the Mediterranean can be proved; but along the Red Sea marine platforms occur more than 51 feet above sea-level (cf. p. 67). The heights of these old beaches would suggest that the isthmus was then a strait unless there was some high ground, now lacking; for the present height of land in the isthmus is in fact only 52 feet. It must be assumed therefore that considerable denudation has taken place, since the faunal evidence will not allow of any marine connection in Pleistocene times. Before the terraces were formed fluviomarine deposits and limestones were laid down in the district of Ismailia (see p. 56). They may be traced to the head of the Gulf of Suez, where they pass into marine deposits,[17] and also north of Ismailia. Their fauna suggests Plio-Pleistocene or Pleistocene age. We may regard them as a Nilotic delta spreading out between the Mediterranean and the Gulf of Suez and keeping the two apart. This they evidently did; but they must formerly have been much thicker or higher than they now are to achieve this function, which at reduced level they continued to perform until De Lesseps cut his canal.

Port Safagah to Wadi Safagah

Under the towering mountain side that dominates this district less than a mile from the sea few orderly traces of deposition might be expected to survive. It was a surprise therefore to find defined levels of consecutive denudation in the steep alluvial fans as they flatten near sea-level. Traces of level surfaces are plainly visible at 50 feet above the present torrent beds, with a lower step at 25 feet, truncated in turn at the seaward edge by an old sea cliff, broken by the modern watercourse with fans of its own spread in front of the cliff on the shore. Near Safagah at the shore there is a platform 15 feet above sea consisting of 5 feet of gravel and an exposed cliff of 10 feet of yellow sandy clay. The living corals are greatly reduced under the cliffs and mountain side, sand and silt with *Arca* and similar shells taking their place. Nevertheless offshore reefs are growing actively.

On the north side of Wadi Safagah is a great fan of gravel in which certain stages are recognizable, but they are more clearly defined on the south side of the occasionally powerful torrent. In Wadi Safagah itself there is a feature that is universal in the main lines of drainage on this coast: the deep sections consist of gravel from top to bottom. Sometimes an eroded surface shows clearly that 10 feet or even less near the top are true terrace gravels, the remainder being similar deposits of the same wadi formed during its Tertiary history. Sometimes the Pleistocene terrace gravels rest on detrital material that is clearly deltaic, and the distinction is then obvious. It must be remembered, however, that these great wadies have been in operation at least since Miocene times. Wadi Safagah near its mouth is flanked for several miles by a level surface 50 feet above its bed, with a sharply truncated cliff face that indicates the severity of local bed erosion since the higher platform was abandoned. When traced up the wadi to the edge of the higher hills the 50-foot platform is found to be augmented by material piled on it from local, minor wadies. These lesser courses have also cut deeply through the combined and involved mass of detritus. This means that for obvious reasons reliance can be placed only upon altitudes of terraces and platforms in the coastal plain and in wide valleys within the hills, where the action of tributary floods is clearly defined.

A lower terrace feature at 25 feet and another at 10 feet may be found a few miles up

[17] For summary see Hume and Little in International Geographical Union, Commission on Pliocene and Pleistocene Terraces, *First Report*, pp. 9–15.

the wadi, the latter being banked against a cliff of which the summit is the 50-foot platform. In such districts, at the back of Miocene and later reef zones, redeposition of material to a new base level frequently results in the production of a continuous slope from 75 feet, for example, to 25 feet with reference to the adjacent main wadi. The redeposition in such instances has been made *toward* the main wadi at its new level, not parallel to it. Reference to a wrong datum in these involved slopes would obviously cause much confusion.

In this district, then, there are considerable indications of platforms at 70, 50, 25, and 10 feet above the adjacent main wadi; and at the last two levels, referred to the height above sea, there are signs also of sea cliffs.

Wadi Safagah to Wadi el-Gasus

On the south side of the mouth of Wadi Safagah mud has been spread over the broad coral lagoon; but the reef is still alive at its seaward edge, especially toward the south, where the lagoon itself also becomes clean again. In the muddy region the "false mangrove" (*Avicennia officinalis*) is colonizing the reef and lagoon, and scattered bushes have established themselves between tide marks.

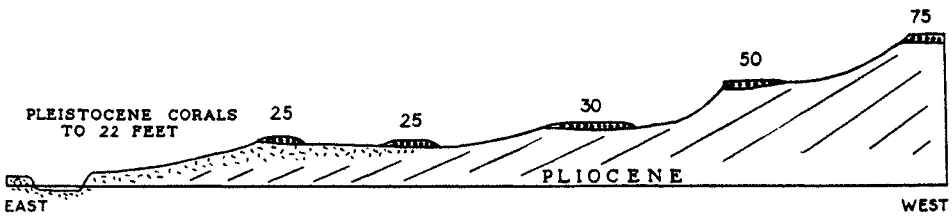

Fig. 16.—Section of Pleistocene Beaches and Coral Reefs on the Red Sea Coast between Safagah and Wadi el-Gasus

On the land *Laganum–Clypeaster* beds dip seaward and are overlain by a new series of corals ending 22 feet above sea-level. A series of marine beaches follows above this line, and in 1931 several days were devoted to obtaining with accuracy their levels and mutual relations (Fig. 16). The corals end at 22 feet and are covered with 3 feet of fine gravel. Similar flat surfaces cut in the dipping *Laganum–Clypeaster* series were found at 30, 50, and 75 feet above sea. In a branch of Wadi el-Gasus rubbly coral limestone 4 feet thick was found below the 75-foot platform resting horizontally upon the dipping (Pliocene) beds (cf. Fig. 7). There is a possibility, then, of finding coral contemporary with the 75-foot beach. This district thus provides evidence of marine platforms at 75, 50, 30, and 25 feet, with corals to 22 and apparently 70 feet.

Wadi el-Gasus to Gebel Abu Shukaili

In this area corals and gravels of the "25-foot stage" are widely developed, and some interesting features may be observed. The coral forms a prominent platform up to 20 feet above sea, with a cliff at its seaward end and the present lagoon at its foot. In Wadi Guwaisis (between Wadi el-Gasus and Gebel Abu Shukaili) about 14 feet of this old coral rest on gravel, lime-cemented with included corals, seen to a thickness of 3 feet and continued below sea-level; the coral is also capped by lime-cemented gravel. This is a fairly normal illustration of local changes, vertical and horizontal, in the Pleistocene and present reefs. Another section, on the north side of a small wadi immediately to the north of Gebel Abu Shukaili, illustrates an arrangement everywhere visible in the present lagoons of this coast: the strong southward current that surges along the inside of a lagoon deposits longshore gravel near the growing margin of the reef but sweeps clear the landward margin of the lagoon. Frequently therefore there is bare coral near the land and gravel at the outer margin of the lagoon, and such a bare hollow is the first to receive any wadi-washed gravel brought in by a flood from the adjacent land. The two gravels, longshore lagoon gravel and local material rapidly shot in, are always readily distinguishable. Where both can be recognized, as in the present example, there is no doubt

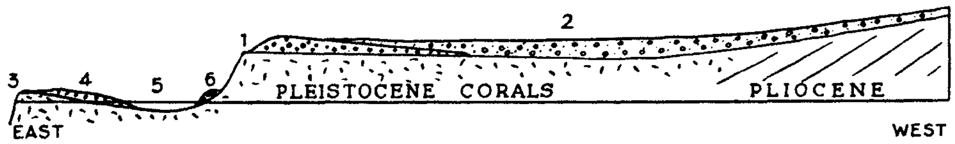

Fig. 17.—Section on the North Side of Gebel Abu Shukaili (cf. Fig. 3 for Location)

6 Storm beach in process of formation
5 Gravel-free part of lagoon scoured by currents
4 Longshore gravel on outer margin of lagoon (as at low tide)
3 Present edge of reef
2 Wadi gravels, filling lagoon and tapering out on longshore gravel
1 Longshore gravel deposited in lagoon of coral reef now raised 20 feet

that a lagoon was fully developed at that place and height; that is, the flat coral surface cannot be regarded as a feature of erosion. At the mouth of the wadi here noted coral grew 20 feet higher than its present level, and longshore gravel covered it to a thickness of about 3 feet. Local wadi gravel was then built out over this feature, first filling the landward hollow and then tapering out to form a featheredge on the outer margin of the longshore gravel. The "25-foot stage" in coral, beach, and wadi is thus united in a common section (Fig. 17).

Gebel Abu Shukaili to Wadi Kuwaiᶜ

The narrow marine plain south of Gebel Abu Shukaili is covered with sloping gravel terraces at 100 (especially marked near the gebel), 50, and 25 feet. The 50-foot terrace everywhere (as also north of the gebel) seems to slope down to the 25-foot marine platform. The 75-foot level so common farther south is but little seen on this part of the coast.

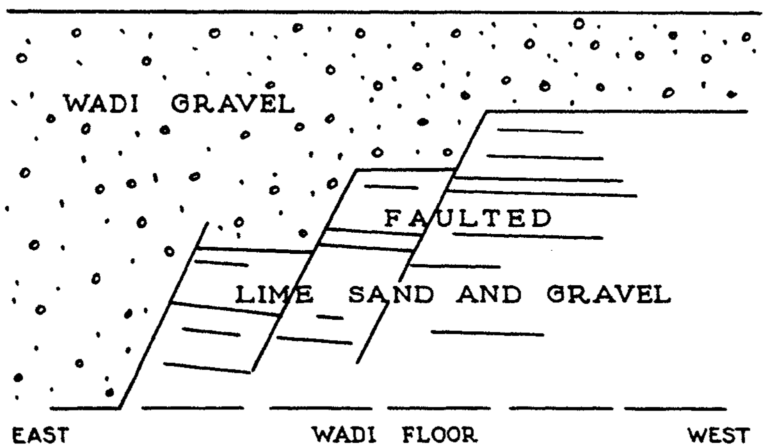

Fig. 18.—Faults at Biʾr Kuwaiᶜ, near the Mouth of Wadi Kuwaiᶜ

On the north side of Wadi Kuwaiᶜ a 50-foot wadi gravel is very strongly developed, its gravels in general being not more than 10 feet thick (Pl. XIV). Outside the wadi itself, on the marine plain, these gravels slope steadily down until they rest upon the 25-foot beach. On the south side of the wadi the 50-foot wadi gravels are again well exposed, and 50 yards west of Biʾr Kuwaiᶜ (dry in 1931) the gravels of the wadi are faulted (Fig. 18). The surface of the gravel does not conform to the faulting, such irregularities of surface as are present being due probably to later denudation. The gravels thicken seaward in a series of steps; first they are about 10 feet thick, then, in slices, 16, 25, and 40 feet thick. It seems that the lime sand (*Laganum–Clypeaster*) and gravel on which the wadi deposits formed settled during their accumulation and that the resulting hollows were filled more or less contemporaneously. Nearby wadi terraces may be seen in short lengths at 30 feet (10 ft. thick on lime sands and gravel) and at the normal 25 feet, which toward the sea consists of 15 feet of wadi gravel on at least 5 feet of longshore gravel.

The tendency in this district for the 50-foot wadi gravels to cease on the coastal plain at that height and to slope down to the 25-foot coral platform is a little difficult to explain. It suggests that the sea remained for a considerable period at the lower level and that the coastal slopes were regraded. It might also be suggested that coral did not have time everywhere to grow to the 50-foot sea-level before readjustment to the 25-foot level took place. The higher stage is most prominent on land (i.e., in wadies), the lower in lagoons.

Wadi Kuwaiᶜ to Wadi Hamrawain

There are traces of a 100-foot marine platform, and in this district a platform at 75 feet is widespread and well marked. A 50-foot stage is prominent neither on the coast nor in the short wadies. Again the 25-foot raised reef and beach are clearly seen with gravel-free area on the landward side of the old coastwise drifted gravels with pebbles of igneous and metamorphic rocks. About a mile north of Wadi Hamrawain this gravel-free plain of the ancient coral lagoon is a quarter of a mile wide.

Wadi Hamrawain (=Wadi Kuwair)

This is a very important district. Paleolithic implements were found here in 1931, as they had been in the gravels below Gebel Duwi inland from el-Kusair in 1927. Inland, in the drainage area of the wadi, nearly every surface is planed off at 50 feet above the main drainage line with great uniformity. "Islands" capped with a few feet of wadi gravel appear in this territory at about 100 feet above the main watercourse nearest to them, but the 50-foot terrace is remarkably constant in the hills, with 25- and 10-foot gravel surfaces below it locally, each with a few feet of gravel and remarkably even upper surface. In the gravels of the 10-foot terrace a few primitive Middle Paleolithic implements were found. They were seen sparsely upon the surface of the 50-foot terrace also, but not waterworn or incorporated in gravel. At the mouth of the wadi the 25-foot terrace on the south side passes to raised beach with a small and negligible gap, the two being abundantly shown to be associated one with the other.

The 50-foot terrace, preserved unbroken throughout the drainage basin, falls steadily on leaving the hills until it coincides with the 25-foot beach. This curious behavior, already observed farther north (p. 64), is extremely well displayed here on the north and south sides and in some low hills in the center of the mouth of the wadi. Again it seems that the wadies that conformed to a sea-level relatively 50 feet higher than it is today shot their material onto a sloping submarine plain that was not built up with coral to sea-level. In view of the amount of denudation since the 50-foot wadi terrace was abandoned, it seems unreasonable to suggest that in this district regrading of the old levels had started at the coast plain and yet cut sharply down through the gravels immediately behind that plain. Nowhere in this survey have reefs or lagoons been found definitely attributable to a 50-foot sea-level. Everywhere wadi gravels of that stage seem to have been shot out onto a coral-free submarine slope, upon the flanks of which corals grew to sea-level at the later, 25-foot stage. From this explanation must be excluded the many exposures of old *Laganum–Clypeaster* corals that are seen at the landward side in the lagoons, with seaward dip that gives a false impression of a raised reef, or covered by more recent growth (see Figs. 8 and 19). No doubt it will be correctly argued that corals could not grow in the turbid waters at the mouth of a great wadi—a condition that obtains today at the mouths of many of the important lines of drainage along the Red Sea coast. The living coral at and near the mouth of Wadi Hamrawain itself is obviously young and lacks opportunity for unbroken growth. But the lack of coral at such wadi mouths, even

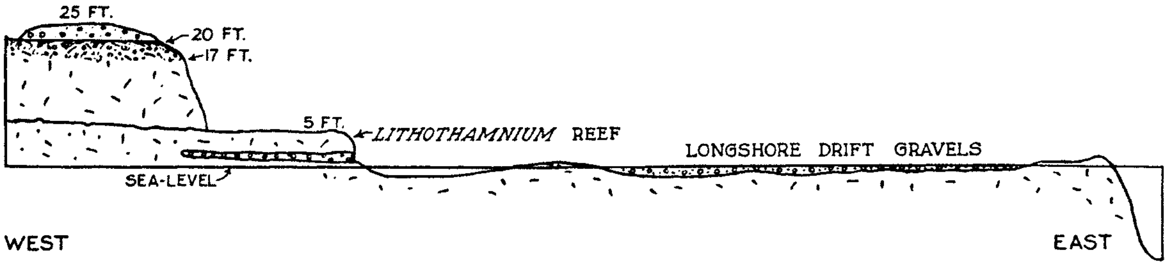

FIG. 19.—SECTION OF LAGOON AND RAISED REEF ON THE SOUTH SIDE OF THE MOUTH OF WADI HAMRAWAIN. THE PLEISTOCENE CORALS REST ON OLD REEFS OF THE PLIO-PLEISTOCENE AND PLIOCENE SERIES

if it indicated greater activity in the land drainage in the past, should be compensated along the great stretches of coast that are free of such interruption. So far as the 50-foot stage is concerned, it is impossible to point to such coral growth with certainty.

Immediately on the south side of the mouth of Wadi Hamrawain coral is found to 17 feet above sea, with a 5-foot step at its foot and 3 feet of lime rock and cemented gravel at the top. This is crowned by 5 feet of longshore gravel and by bare slopes on the landward side and may be traced along the coast southward (Fig. 19).

WADI HAMRAWAIN TO EL-KUSAIR

A prominent dome occurs a few miles south of Wadi Hamrawain, and upon its seaward flanks beaches are cut in *Laganum–Clypeaster* reef and *Lithothamnium* limestone, both of which dip seaward. The landward margin of each step shown in Figure 20 was measured. Within a foot

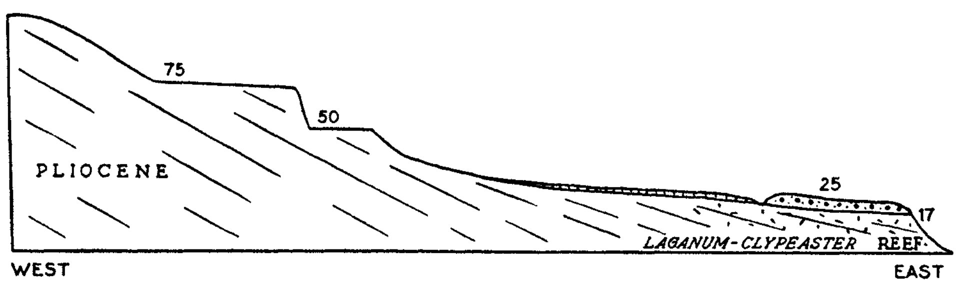

FIG. 20.—MARINE BEACHES AND CORAL REEFS ON THE COAST IMMEDIATELY SOUTH OF WADI HAMRAWAIN

the levels were 75 and 50 feet, with a long seaward slope below a cliffed margin of the 50-foot rock platform covered with fine washed-down rubble (Pl. XV). At the lower end of this slope, separated from the surface rubble by bare ground, is a longshore gravel bank rising to 25 feet, with lower margin at 17 feet, where *Laganum–Clypeaster* coral is exposed; that is, the whole series is one of coastal erosion without contemporary reef. The 50-foot platform is well marked as a coastal feature here.

These platforms may be seen at intervals southward along the coast; a leveled section was taken in 1931 at the headland a little north of el-Kusair el-Kadim, with resulting figures 76, 46, and 21 feet above sea, with the seaward margin of the sloping platform below 21 feet cut back to form a cliff 5 to 10 feet high. In this neighborhood there are also traces of a platform at 90 feet above sea.

A few hundred yards south of el-Kusair el-Kadim is an embayment of the living reef (the port of the adjacent ruined and long abandoned town). Breaking through the gap with considerable force upon the shore, waves have built up a storm beach, on the landward side of which is a salt marsh evidently marking a local channel of greater age, that is, of the 25-foot stage. The submarine deposits of quiet water are to be seen here with faunal associations of considerable interest.[18] The perpetuation of features along the coast, not only in outline but in small detail, from stage to stage and from Tertiary to Quaternary is remarkable.

The 70- and 25-foot platforms dominate the foreshore to el-Kusair and beyond it southward for long distances. At this town a route to the Nile Valley leaves the coast and winds up Wadi ʿAnbagi into the Red Sea Hills. In the lower part of the wadi, east of Biʾr ʿAnbagi, terrace gravels attain a magnificent development. Traverses made across them in 1927 showed the following levels (Pl. XVI): 90–95, 70, 25–30 feet above wadi floor and, half a mile farther east, 70, 50, 20–25 feet, with a low feature of 10–15 feet in both places. The 70-foot terrace is the dominating feature. Some miles farther up the wadi, close to the phosphate mines, are prominent gravels, 10–15 feet above the surface level, in which we found Middle Paleolithic implements.

From the foregoing survey it may be concluded that between Safagah and el-Kusair certain features appear with regularity, and in none of them can be traced more than local differential warping or faulting of the upper surfaces (heights given in ft.):

Wadi terraces	90–100	70	50	25–30	10–15*
Marine beaches	90	70	50	25	10?
Coral surfaces	......	70?	....	25	......?

* Early Middle Paleolithic.

CONCLUSIONS

There need be little hesitation in regarding the stages of the Suez and Safagah–el-Kusair districts as of common age and nature. In other words, they seem to have been controlled by uniform movements of land or sea or both. There is no sign in them of major coastal warping, faulting, or folding such as had taken place before their construction (e.g. the disposal of *Laganum–Clypeaster* series in domes).

With local gaps in the series wadi and beach levels of 90–100, 70, 50, and 25 feet may be identified, the important 10- to 15-foot gravels being represented on the coast by a 6-foot bench at Suez and by features farther south that form no general and clear-cut bench which may not have been modified by modern coastal erosion, storm beach, or down-wash. In other words, little change that is visible on the surface seems to have taken place since early Middle Paleolithic times. On the other hand, the gravels of the present wadi floors appear to be of great depth, and it is probable that great changes have been made good by deposition and by growth of coral reef, which in many places gives the impression of youth.

In considering the Erythrean area as a whole, Hume and Little conclude: "The study of the northern portion of the Red Sea area in recent years has emphasized the importance of the raised beach at an average of 15–20 metres. Higher beaches are indicated locally, but are not uniformly distributed throughout the area."[19] The final statement might be applied to all

[18] See Arkell in the *Journal of Ecology* XVI 134–49.

[19] International Geographical Union, Committee on Pliocene and Pleistocene Terraces, *First Report*, p. 14.

platforms above 25 feet. Hume and Little repeat Beadnell's suggestion[20] that the Pleistocene raised beaches along the coast from el-Kusair southward to Wadi Ranga correspond to the Milazzian shore line of 55–60 meters (180–197 ft.) above the present Mediterranean.[21] These figures are not identifiable near Suez, nor between Safagah and el-Kusair. In view of the many and varied altitudes quoted by Hume and Little, the repetition of the same features in Miocene, Pliocene, and Pleistocene times, the difficulty of determining age in the field, and the ease of assuming a Pleistocene age for a Miocene gravel, it is felt that any generalization in regard to the Erythrean area is unwise until many uncertainties are dispelled.

Nevertheless, correlations between the Erythrean area and the Nile Valley naturally suggest themselves; but they are based solely on altitudes, save for the 10- to 15-foot gravels, which contain older Middle Paleolithic implements between the same latitudes on the Red Sea and on the Nile. The higher levels of the Red Sea coast are familiar in the Nile Valley, but implements are still to be found to complete the series. On the whole, the 25-foot stage in the Erythrean area appears to be older than the 10- to 15-foot stage, not younger. A 70-foot stage of the coast is absent in the Nile Valley save locally in Nubia. Correlations based on altitude alone are open to grave errors, and only prolonged search for implements in the deposits east of the Red Sea Hills can bring definite results. Implements are common upon the mountain surfaces in certain circumscribed regions between the latitudes of Safagah and el-Kusair, and it is probably only a matter of time before the age of the terrace series in their vicinity can be completely fixed by discovery of implements in the gravels.

A comparison of the Middle Paleolithic deposits of Lower Egypt with those of Upper and Middle Egypt and of the Mediterranean is made on pages 58–60.

[20] *Report on the Geology of the Red Sea Coast between Qoseir and Wadi Ranga*, p. 26.

[21] Hume and Little, *loc. cit.*

VI

THE DELTA OF THE NILE

INTRODUCTION

It is already clear that on the surface of the Delta there is visible no Nilotic deposit that falls between the age of Middle Paleolithic silts (rising to 30 ft. above present flood plain) and the alluvium that is accumulating at the present day. The only features that stand above the monotonous miles of rich fields are "turtlebacks" (see p. 74), sandy and silty islands in a sea

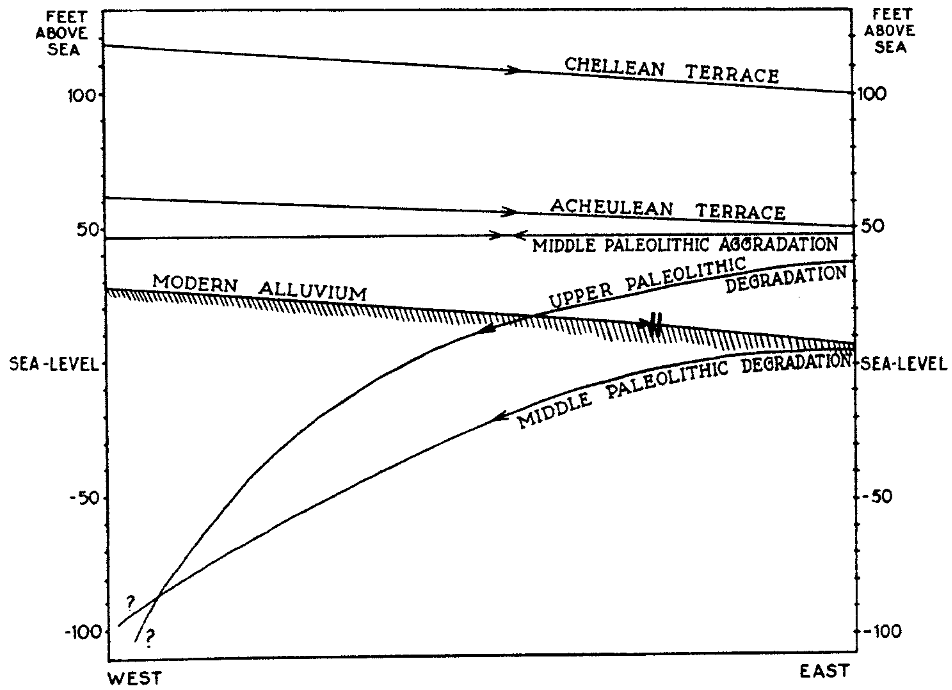

FIG. 21.—DIAGRAM SHOWING THE PLEISTOCENE TO RECENT HISTORY OF WADI EL-TUMILAT AND THE COUNTRY EAST OF THE DELTA BETWEEN EL-ZAKAZIK AND ISMAILIA. THE "SOLID" ROCKS HERE ARE PLIO-PLEISTOCENE AND PLEISTOCENE SANDS, GRAVELS, AND LIMESTONES. ARROWS INDICATE DIRECTION OF FLOW; OPPOSED ARROWS SHOW STABILIZED DEPOSITION; AND ARROW WITH TWO VERTICAL LINES REPRESENTS PRESENT INFLOW OF SILT WITHOUT ESCAPE AT THE EAST END (NOW MODIFIED BY ISMAILIA CANAL)

of cultivated land. That this would probably be so was indicated by work in the Faiyum[1] and in Middle Egypt,[2] where the younger strata were seen to lie below the level of Nile alluvium and to sink northward to deeper and deeper levels along the course of the river itself.

Since all such deposits are thus hidden from view, it is possible to add little to the information concerning them. Implements of the type that might be expected to occur in them have been found *in situ* in only a few places; these occurrences are indicative of people living on the plains adjacent to the Delta. If the alluvium of those times had been at or above the level of

[1] See *OIP* X 52–69.

[2] See *OIP* XVIII, chap. viii.

present-day alluvium, probably it would have been found together with its proper implements. The sites are:

1. The implementiferous surface washes of the east end of Wadi el-Tumilat (see p. 58) resting unevenly upon Middle Paleolithic silts. These silts have subsequently been denuded by water running in the reverse direction westward along the wadi, deepening a channel toward the Delta which is still in process of being filled by alluvium as the level of the Delta rises. The wadi is still very incompletely filled with alluvium, of which the level is some 3 to 4 meters lower at the eastern end than at its western contact with the open Delta (Fig. 21).

2. The lower part of a great belt of sand dunes near Ismailia containing similar implements. The dunes may have been coastal dunes before the more recent seaward extension of the Delta (see p. 88).

3. The well known sites south of Cairo, at Hilwan, containing implements of very late or post-Paleolithic type which seem nevertheless to be pre-Neolithic.[3] Such implements have not yet been found *in situ* in a Nilotic deposit.

4. Surface sites (actually upon and near the sand-covered surface of Middle Paleolithic silts) on the western edge of the Delta containing late but pre-Neolithic implements of a type found *in situ* in the deposits of one of the lowest lake margins of the Faiyum.[4]

It is probable, then, that the later Paleolithic and pre-Neolithic industries are deeply buried beneath the Delta. In Middle Sebilian times the level of the Nile was already about 20 feet below the modern flood plain near Beni Suef,[5] and was falling northward. It fell much below that depth before it began to rise. It remains to discover, if possible, from the deposits of the Delta itself, without further reference to evidence available south of Cairo, the maximum depth to which the river may have sunk and from which it has been raising itself by accumulation.

AGE AND STRATIGRAPHY

Field work can add little to what is known of the stratigraphy of the Delta, since knowledge must depend entirely upon past records of borings. In the near future geophysical research by seismic and other methods such as are now regularly employed especially in the search for oil and mapping of oil fields will probably add materially to knowledge gained by actual proving of the ground by bore holes. Here, then, a summary of previous work—some of it carried out for economic purposes (water supply etc.), some of it the results of special research—is required. Among the earliest workers in this field were Horner[6] and the Royal Society of London.[7] More recently Fourtau has provided a valuable study of the whole of the available material from a geological point of view,[8] and to Professor James H. Breasted is due a consideration of the archeological evidence.[9]

Some of the depths recorded below flood plain without touching solid rock are very great, for example Cairo 267 feet (81.5 m.), el-Zakazik (Royal Society's boring) 345 feet (105 m.), Abu Kir (on the coast east of Alexandria) 535 feet (163 m.). These appear to be known maxima, to which may be added a boring at Port Said made in the works of Messrs. Wills and Company in 1905 and recorded by P. L. O. Guy in 1929. It gave silt and sand to a depth of 274 feet (74.25 m.).

Samples from a large number of bores are preserved in the Geological Museum, Cairo. All

[3] See *OIP* XVIII 119 and Pl. XXXIX. [4] See p. 55, n. 3, and *OIP* X 63–66. [5] *OIP* XVIII 88–94.

[6] Royal Society of London, *Philosophical Transactions* CXLV (1855) 105–38 and CXLVIII (1858) 53–92.

[7] See John W. Judd in Royal Society of London, *Proceedings* LXI (1897) 32–40.

[8] *Mémoires présentés à l'Institut égyptien* VIII (1915) 57–94.

[9] In the *Scientific Monthly*, October, 1919—March, 1920. The subject is discussed in detail in *OIP* XVIII, chap. viii.

of them, including the deepest, show pebbles of granite and metamorphic rocks of the Red Sea Hills to the very bottom, though other constituents appear in the samples from higher levels. Such constituents are unknown in the Lower, Middle, and Upper Pliocene rocks of Wadi el-Natrun and the Nile Valley but appear only in the final Pliocene or Plio-Pleistocene sands. Since gravels with these components border Wadi el-Natrun, it cannot be assumed that the Lower Pliocene deposits of its floor were too far away from a contemporary Nile delta to receive such material, had it been available at the time. Nor do pebbles or sand of igneous or metamorphic origin occur in the recognizable Miocene rocks adjacent to the Delta, though quartz sand abounds in them. In other words, there is no reason to assume that any Tertiary deposits are represented in the lowest known sands and gravels of the Delta. At the oldest they may be final Pliocene or Plio-Pleistocene.[10]

Sandy limestones such as are associated with the pre-Paleolithic gravels west and east of the Nile are not recognizable in the borings. The evidence suggests a rapid building up of a sand-and-gravel delta in the time of the Plio-Pleistocene sands for the most part and in the ensuing period of the early terraces. Fossil evidence is slight. Fourtau records marine shells[11] at Basandilah (north of el-Mansurah, in the central part of the Delta) at 11–19.50 meters below sea-level and on the available evidence draws a southern limit of known littoral deposits beginning at the south side of Lake Maryut and extending south of Rosetta, north of el-Mansurah, and along the southern shore of Lake Manzalah to the Suez Canal a little north of Ismailia,[12] where marine shells of no great age occur, many of which now live in Lake Timsah with the aid of sea water introduced by the Suez Canal. These shells in littoral deposits across the whole belt to the remarkable dunes of Maryut (see chap. vii) explain nothing of importance but mark only the advance of the Delta in a time which cannot be estimated very closely, probably of no great antiquity. No such shells have been found at great depth or in the more central or southern parts of the Delta. A similar fauna, or dead shells, might be expected to a considerable depth at the submarine front of the Delta today, to be covered as more material is shot over them from the river or by coastal drift. Local depression also has taken place in the Delta, notably around Alexandria. Fourtau recognizes an unfossiliferous zone of marine deposits with a southern limit near Minuf, Tanta, and Zifta, joining the limits of the littoral zone at the southeast corner of Lake Manzalah.[13]

Fourtau records also the fresh-water or lacustrine shells *Limnaea* and *Planorbis* in the neighborhood of Zifta (in the center of the Delta) at a depth of −7 to −12 meters in a lakelike deposit tending to peat.[14] This is essentially a part of the deltaic series, the sea evidently having been excluded by the time the Delta had reached that position and height. To conclude, then, there is no fossil evidence whatsoever of the age of the deposits forming the deeper parts of the Delta; it is of Plio-Pleistocene and later age and may represent many phases of building-out of the great mass of detritus with phases of erosion. Nor have any flint implements been recovered from any of the samples.

One great distinction is possible and is noted by Fourtau: the greater depths of sand and gravel are separable from an upper region of Nile mud and clay mixed with coarser lenticles and bands characterized by the presence of flakes and small grains and crystals of mica and hornblende.[15] Such material occurs in the central parts of the channel of the 100-foot terrace, and it is the main constituent of the Middle Paleolithic deposits bordering the Delta, though

[10] Conclusions resulting from these facts are discussed as far as the Nile Valley is concerned in *OIP* XVIII, chap. viii.

[11] "*Cardium edule, Ostrea edulis, Corbulomya mediterranea, Modiola* sp., *Aptyxis syracusanus, Nassa alexandrina, Natica Josephinia* var *alba*" (Fourtau, *op. cit.* p. 83).

[12] *Ibid.* Pl. III. [13] *Ibid.* [14] *Ibid.* p. 78. [15] *Ibid.* pp. 93 f.

those beds are dominantly of sand and gravel farther south. Such silt was deposited in Nubia and Upper Egypt at the close of Middle Paleolithic times also[16] and passed into coarser deposits below present flood plain farther north.[17] Although silt is the dominant load of the Nile today, it has been brought northward at least since Lower Paleolithic times.

The lower parts of the silty material may thus have been shot into the growing Delta in Lower Paleolithic times and have been deeply eroded in early Middle Paleolithic and Sebilian and later times. Similar silt may have been deposited in hollows during aggradation between those periods of excavation. It has been argued[18] that the assumption that the profoundly deep channel occupied by Nilotic sands and gravels was of late Pleistocene age is incorrect. The lowest limits of the mica-hornblende silts, on the other hand, are not older than the Lower Paleolithic age; the minerals themselves may occur in older deposits, but the abundant silts which typically contain them appear first in Lower Paleolithic beds and increase in importance to the present day.

A difficulty becomes apparent when an attempt is made to use petrological distinctions. Some sands proved in bores lack both micas and hornblendes; they are quartz sands which might be associated with the Pliocene series. Some sands contain hornblende and no mica; these may be referred to the Plio-Pleistocene or Pleistocene invasion from the south. Fourtau regards the hornblende sands as Pleistocene. Above this series occur the Nilotic mica-hornblende sands already mentioned (p. 71), which are manifestly younger. Unfortunately in earlier publications Fourtau had called this group the hornblende sands, but it should now be understood that mica is characteristic of the upper (Nilotic) group, hornblende of the lower. The question arises therefore as to how far a distinction is possible. Where a Nilotic mica-hornblende sample is reported there is no doubt as to its authenticity; where a hornblende sand is specified the possibility cannot be excluded (unless there is concrete evidence) that it is a coarser deposit, poor in mica, of the Nilotic series. In these circumstances it is fortunate that defined Nilotic mica-hornblende silts are known to almost the same depth as the hornblende sands. Uncertainty as to their differentiation and the depth of their accumulation is most marked in the northern part of the Delta. Since the records of some borings are reported by those in charge of them without accompanying samples, the entries of sand, silt, and clay, without distinction of composition, provide information bereft of the greater part of its value and are useless to distinguish the Lower from the Upper Buried Channel.[19]

Fourtau has attempted, with many admirable reservations, to find the line of division between the deeper and the shallower deposits in terms of the distinction just described. Allowing for such reservations, we may tentatively recognize the division in the Delta to be 25–30 meters below flood plain.[20] But the possibility or probability that deeper channels scoured in the underlying sands and gravels may so far have escaped detection is not precluded.

Now the mid-channel deposits of Lower Paleolithic stages of the Nile are known to present flood plain, and those of the 50-foot stage may go a little deeper, but levels of 25–30 meters below flood plain are probably well below the limits of any of those stages, unless the delta-face "tip-heap" deposits shot into standing water occur here. But the discovery of Lower Paleolithic terraces along the flanks of the Delta suggests that the sea was then not south of a line from Ismailia to a point due west of it on the west side of the Delta.[21] The levels of 25–30

[16] E.g. the final Middle Paleolithic and Sebilian aggradation described in detail in *OIP* XVII 38–47.

[17] See *OIP* XVIII 83 ff.

[18] *Ibid.* pp. 98 ff.

[19] These terms are employed in *OIP* XVIII, chap. viii.

[20] So Fourtau, *op. cit.* p. 94.

[21] Deltaic sands occur at ᶜAbbasiyyah, but they belong to the Plio-Pleistocene series and are redeposited in the Lower Paleolithic strata.

meters below alluvium in the Delta are therefore within the range of degradation of the Nile in Middle Paleolithic and later times. The lakelike deposits of Zifta, with *Limnaea* and *Planorbis*, are so high above these levels that they may be of much more recent formation; they cannot be assumed to be of Paleolithic age.

It remains to be seen whether any divisions may be recognized within the upper group of deposits, that is, the Upper Buried Channel, or whether channels of that group cut deeply below the general level into the sands and gravels of the Lower Buried Channel.

The bore at Abu Ghalib on the western edge of the Delta (see p. 55) descends from the surface of the Middle Paleolithic silts to a depth of 29 meters (95 ft.) through a succession of Nilotic sands and clays characteristic of the Upper Buried Channel and continues through quartz sands and clayey sands for a further 33 meters (108 ft.). The top of the bore was about 4 meters above flood plain; that is, the Upper Buried Channel here descends about 25 meters (82 ft.) below present flood plain or about 10 meters (33 ft.) below sea-level. Since one branch of the Nile (i.e., the precursor of the Rosetta branch) seems to have been long established along this edge of the present Delta (Pl. VII), the bottom of the Middle Paleolithic deposits might be at its deepest there; nevertheless the record falls within Fourtau's estimate of 25–30 meters. This may indeed be the general level of the Middle Paleolithic delta. From what has been seen south of Hilwan it is probable that later Paleolithic degradation attained greater depths below the flood plain of the Delta than the figure quoted above.

At Minuf, a little less than 10 miles northeast of el-Khatatbah, hornblende sands were proved to 37.5 meters below the surface of alluvium and in borings made at el-Zakazik in 1905 to 39.5 meters. The latter measurement implies a depth of a little more than 100 feet below sea-level. These are in fact the greatest depths of hornblende sands proved to date in the more central parts of the Delta. They are in all probability well below the levels reached in Middle Paleolithic times and suggest the order of magnitude of the degradation in the late Paleolithic pre-Neolithic (later Sebilian) interval. At the same time it must be remembered that they are hornblende and not mica-hornblende sands and that much deeper levels may be proved, as there remains a vast amount of work yet to be done in this type of research in the Delta. Nearer the sea Nile silt may be found at great depth, but reliance cannot be placed upon it in the littoral zone. Thus in the bore made at Port Said and recorded by Guy (see p. 70) "Nile mud" is recorded to 60 meters, "fine sand with waterworn pebbles up to 5 centimeters in diameter" at 65 meters, medium sand at 72 meters, and coarse sand at 74.25 meters. The last three suggest Plio-Pleistocene deposits.

The search for the deepest parts of the Upper Buried Channel is therefore satisfactory so far as it goes; a level of at least 25–30 meters below flood plain may be Middle Paleolithic. Greater depths, found locally, may be exceeded as a result of further work, and in time a well defined lower group considerably more than 100 feet below present sea-level may emerge (see p. 99).

The numerous sections provided by borings show, as might be expected, very considerable lateral and vertical variations of thickness and nature of deposit. It does not seem practical to expect any well ordered sequence in such deltaic material. Locally within the Delta, moreover, the deposits of the Lower Buried Channel are found within a few meters of the present surface, like buried islands of old deposits among younger strata, as indeed they are. At the sides of the Delta also local down-wash of material from the neighboring country is prominent and locally overwhelms the Nilotic deposits; that is, local accumulation forced the Nile to change its course. Fourtau records a number of such instances. He points also to the contest on the western side between the Nile and a combination of down-wash and blown sand. For such local causes as these, operating in varying degrees over the whole area, no general sequence can be expected, though in certain localities given beds may be traced for short distances from one bore to another. Into all these questions Fourtau has inquired in detail, and his publication[22] should be consulted by any who wish for further information.

The occurrence of islands of earlier among later strata extends to the present surface of the Delta. Several such islands are noticeable in the broad expanses of cultivated land; as Fourtau shows, they occur only on the south side of his limit of littoral deposits.[23] Some in the eastern part of the Delta are so arranged as to suggest an arc of elevated land now broken into patches (see Fig. 10). From their shape these ancient islands are generally called "turtlebacks"; they consist essentially of sand, sandy clay, or impure silt. Their present shape is probably due to some extent to rain erosion but partly to addition of dust and to wear and tear by people and their animals passing over them on the way from their villages to cemeteries and to the fields. Probably they are not of simple origin. Some of them are no doubt exposures of beds of the Upper Buried Channel series. It is indeed tempting to regard at least some of them as relics of the Middle Paleolithic silts, analogous to the deposits of the sides of the Delta. Others have almost certainly increased in size at the expense of the fields by sand and dust accumulating around them, but it seems doubtful whether they can be regarded as of aeolian origin. It follows, needless to say, that they are slowly being submerged as the level of alluvium rises, and that some, together with the ancient buildings and cemeteries that were situated upon them, have disappeared. Here, then, arise problems of the surface of the Delta, where accumulation has been dominant since the close of Sebilian times and the development of Neolithic Egypt.[24]

The facts concerning the measurements of the rate of rise of the flood plain are well known to archeologists. They turn upon the known height of the land when certain buildings and ancient Nile gauges and works were constructed and upon the present flooding of such sites, for example Memphis, so that the old habitation or constructional levels are perpetually or annually flooded. The question is reviewed by Professor Breasted, who gives figures obtained with special reference to the apex of the Delta: "Since about 1950 B.C. the rate of accumulation at the obelisk of Sesostris I. [at Heliopolis] has been about 3.90 inches per century, while at the Memphite colossus of Ramses II., since the thirteenth century B.C., it has been about 4.08 inches."[25] Probably a working figure of 4 inches per century will serve in the Delta.

The rate of accumulation refers to *addition to the surface*, that is, to the cultivated land, the "terre végétale" of Fourtau's memoir.[26] There is no reason to assume that it would apply to any other deposit. This is important, for it means that a factor can be applied to the alluvium of the flood plain throughout the valley and perhaps to the broad sheets of silt spread out in Upper Egypt and Nubia in Sebilian times, but not to the ever changing, cross-bedded, scoured-out, and mutually replacing sands, clays, grits, sandy clays, and the like below the "terre végétale" and its lower component, the "argile nilotique." It may be applicable to the visible Middle Paleolithic silts of the margins of the Delta but not to the successions described briefly above and illustrated in detail by Fourtau. In other words, the rate of accumulation applies to flood-plain inundation and quiet deposition of silt which is added to the "terre végétale"; it must not be applied to the more turbulent stratification below this marked capping.

The thickness of the capping is limited and variable according to situation. As it has accumulated, needless to say, the lower levels, if ever cultivated (some are very old, probably older than general cultivation), have been buried. If the "terre végétale" is the surface of accumulation of civilized Egypt, these lower layers are its inseparable basal part. The two to-

[22] *Op. cit.* [23] *Ibid.* p. 92 and Pl. III.

[24] To the list of probable sites of former habitation given in *OIP* XVIII 106 f. these turtlebacks may now be added.

[25] *Scientific Monthly*, 1919, pp. 307 f. [26] *Op. cit.* p. 59.

gether at Karnak and Tahta measure 13 meters, at el-Minya 10.5, near Cairo 8, at Banha 16; but accumulation near the river or in basins may be far above the average. It is in fact extremely difficult to arrive at a figure of average thickness, excluding filling of hollows in underlying deposits and many other fortuitous circumstances of deposition and erosion. Fourtau gave a general estimate of 10 meters.[27] This final carpet has been in process of being laid down for a long time; that is, 10 meters = 393.7 inches, which at 4 inches per century would represent about 10,000 years. If, working in round figures, we assume predynastic times to have been already well established by 4500 B.C.,[28] say 6,400 years ago, the lower 12 feet of flood-plain silt should contain the earliest remains of civilization, as Professor Breasted has pointed out. The problem in recovering them is to overcome the engineering difficulties of excavation, after exploration which is probably feasible. The foregoing figures alone render it impractical to consider fragments of brick, wheelmade pottery, etc. found at such depths as 30 meters to be veritably *in situ*, since their implied age becomes stupendous. It is of paramount importance that any calculations of age based on rate of accumulation of surface silt should be most strictly limited to *flood-plain* increment.[29]

CONCLUSIONS

Nilotic deposits younger than the Middle Paleolithic silts which fringe the Delta are hidden beneath the still accumulating alluvium. Implements of industries such as that of Hilwan, as well as Neolithic material, are no doubt hidden in the silt together with rich archeological sites of prehistoric and historic times. As yet, none of this early material has been proved in stratified arrangement in the waterlogged sediments of the Delta, though it occurs in sites located on the Middle Paleolithic silts of the desert edge.

The following is the stratigraphic order of deposition, for the greater part determined by Fourtau[30] and here restated with some amendment and addition (Fig. 22; cf. Fig. 21):

1. *Lower Buried Channel.*—This is filled with sand and gravel in which pebbles of igneous and metamorphic rocks and waterworn feldspar crystals abound. The deposits, then, are not older than Plio-Pleistocene. Some quartz sands proved in bores may be local surface wash or of Pliocene origin, but there is no evidence that they are original deposits of Tertiary age. The gravels have been tapped by bores to a depth of more than 100 meters, but their bottom has not yet been found.

2. *Hornblende sands and silts.*—These are regarded by Fourtau as certainly of Pleistocene age. They are intimately associated with sands and gravels containing igneous and metamorphic rocks (Plio-Pleistocene or Pleistocene), but on the evidence yet available they cannot be separated in age from the formation of the Upper Buried Channel. They appear to rest unevenly on the gravels of the Lower Buried Channel and are known to a depth of about 30 meters below sea-level in the central part of the Delta, but deeper channels may be filled with them. On the whole they seem to have more in common with the deposits of the Upper than with those of the Lower Buried Channel.

3. *Upper Buried Channel.*—The sands and silts of the upper layers of the Delta are characteristically rich in mica flakes as well as in crystals of hornblende; that is, they represent the finer products of destruction of rock types already familiar to us. They are known to a depth of 25–30 meters below flood plain in the southern part of the Delta and in the north may be proved

[27] *Ibid.* p. 94.

[28] See Breasted, *A History of the Ancient Egyptians* ("The Historical Series for Bible Students" V [New York, 1908]) p. 419.

[29] In *OIP* XVIII 107 f. the question of sinking of pottery and other objects through waterlogged deposits is considered.

[30] *Op. cit.* pp. 91–94.

to greater depths. They may be associated with Middle and later Paleolithic periods of bed-erosion. It is probable that the later Paleolithic erosion was the deeper, but there is no evidence that the great depths of the Lower Buried Channel were then attained.

4. *The "terre végétale" of Fourtau.*—This deposit has a thickness of approximately 10 meters and is still accumulating. It is this layer alone that provides any indication of a time factor of accumulation. It is estimated to have been built up by annual increments amounting to about 4 inches per century; in other words, 10 meters mean about 10,000 years (see pp. 74 f.). The

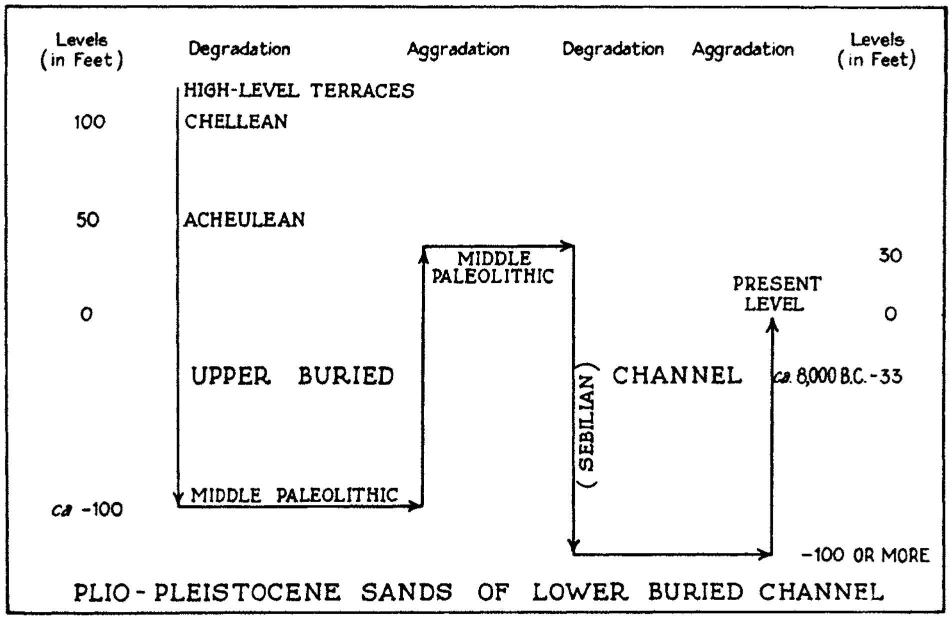

Fig. 22.—Diagrammatic Record of Paleolithic to Recent Levels in Lower Egypt (Levels above or below Modern Alluvium)

lower few meters probably contain therefore objects of prehistoric, Neolithic, and associated types, just as the upper layers have submerged monuments and sites of the historic period. Emphasis should be laid on the fact that the estimate of accumulation rate refers to the "terre végétale," including its lower component, and to no other stratum that lies below it, so far as the available information indicates.

Projecting through the cover of alluvium are turtlebacks of sand and silt, relics of former accumulation above that of the present day. They may embrace Plio-Pleistocene and Pleistocene deposits, including those of the Middle Paleolithic aggradation. They have probably served as habitation sites and refuges during later Paleolithic and subsequent times up to the present day, and the alluvium has probably closed over the tops of some, now hidden from view and to be discovered only by boring.

Along the advancing seaward border of the Delta, Nile silt is precipitated to the bottom of the sea, and records of its great depth in this region, as of marine shells, are of little real value or significance.

VII

HISTORIC CHANGES IN THE VICINITY OF LAKE MARYUT

INTRODUCTION

Unlike other lakes along the northern fringe of the Delta, for example Burullus and Manzalah, Lake Maryut is not connected with the Mediterranean. A bar of lime sand and limestone runs along the coast of Arabs Gulf, continues northeastward like a protecting arm at the northwest corner of the Delta, and sinks out of sight beneath coastal dunes and alluvium near Ramlah. Alexandria is built upon this elevated and rocky barrier.

Lake Maryut is thus a hollow between the coastal barrier and the extreme edge of the Delta, and its eastern part may be regarded as a region which has not yet been filled by the rising flood plain; indeed, such filling has been hindered or prevented since the early days of Alexandria's greatness by the cutting of canals and other works. The lake therefore received its waters by seepage from the Delta (and probably from the sea) and to some extent from rainfall. In medieval times it was navigable, but subsequently it contracted to comparatively small proportions. In 1801, during Napoleon's campaign in the Near East, British forces cut the dikes of a canal that passed between Lake Maryut and the Lake of Abu Kir and allowed the sea to flood a vast area around the latter. This land was reclaimed by a British company at the end of the century.[1] Lake Maryut also was flooded and has remained so ever since, though at reduced level. It has been utilized as a region into which the end waters of the irrigation of the alluvium between the Western Desert and the Rosetta branch of the Nile may be turned. Alexandria was cut off from the Rosetta branch during the Arab and Turkish regimes and was only connected with it again by Muhammad ᶜAli's el-Mahmudiyyah Canal early in the 19th century.[2] Lake Maryut as we see it today is therefore in part a creation of Nile drainage. On its south side is a marine plain, the Maryut upland plain (Pl. XII *A*), featureless or undulating and more or less vegetated, that rises imperceptibly to the barren gravel terraces between Wadi el-Natrun and the Nile.

The western part of Lake Maryut, which will now be described, points southwest like a finger and lies in a depression, Mallahat Maryut, which is marshy beyond the end of the lake, between two limestone ridges parallel to the coast.

THE COASTAL RIDGES

It is well to admit at the outset that these present a problem as yet unsolved. They were the subject of an official memoir by Hume and Hughes.[3] There are several alternating limestone

[1] Cf. a modern map with one of about 100 years ago, e.g. that in G. Belzoni, *Narrative of the Operations and Recent Discoveries . . . . in Egypt and Nubia* (3d ed.; London, 1822) I, where it will be seen that Maryut is coupled at sea-level with the Lake of Abu Kir, now reclaimed and no longer seen on the map (although its site is indicated on the map of the Delta in Baedeker, *Egypt and the Sudan* [8th rev. ed.; Leipzig, 1929]), and Lake Idku, now isolated from the sea and reduced to small proportions. At that time Alexandria was virtually isolated from the Delta and the rest of Egypt by an inland sea. For a general account of that region see Anthony de Cosson, *Mareotis* (London, 1935).

[2] The canal discharges into Alexandria harbor, as did the old Alexandria canal which supplied the Ptolemaic capital with Nile water.

[3] W. F. Hume and F. Hughes, *The Soils and Water Supply of the Maryut District, West of Alexandria* ("Survey of Egypt Paper" No. 37 [Cairo, 1921]). See esp. Pl. II. See also Hume, *Geology of Egypt* I 57 f. and 128 f., and the admirable summary by Hume and Little in International Geographical Union, Committee on Pliocene and Pleistocene Terraces, *First Report*, pp. 9–15.

ridges and hollows parallel to one another and to the Mediterranean shore line. The ridges rise some 36 meters (*ca.* 120 ft.) above sea-level, while the most marked hollow, Mallahat Maryut, is below sea-level. They dominate the southeast coast of Arabs Gulf and continue on the same line inland where the coast turns westward; the innermost ridge turns inland rather sharply north of Magharah, the next dies out, and the coastal ridge continues nearly to el-ᶜAlamain (almost 60 kilometers west-southwest of Burg el-ᶜArab).

Hume and Little point out that the top of the ridge nearest the sea, the Abu Sir ridge (Pls. XI and XIII *A*), exceeds the height "where a 20-meter beach, such as is present in the Red Sea area, would be recognizable. Nevertheless no evidence of the presence of such a raised beach was seen. The same is true of the next ridge to the south, Gebel Maryût, which rises to about the same height (over 34 metres)." They preface these remarks by saying: "The southern ridges, which occur some 10 kilometres from the sea, rise to a height of 40 to 60 metres above sea-level. In considering the existence of raised beaches at certain levels in relation to the Mediterranean coast-line it must not be forgotten that there have been important advances of the sea over the Delta in historic times, and that there have also been local elevations and depressions."[4]

The problem may, then, be stated more exactly: Were the ridges formed at or below sea-level, or was the oölitic material that makes the limestones wind-borne (i.e., are the ridges coastal dunes of comminuted shell fragments and shell sand)? The question of age is involved in that of altitude, but the total absence of beach material among the deposits of the ridges themselves dissociates them at once from an age as great as a 20-meter shore line of the Mediterranean would suggest. Although the ridges are obviously old, they are in all probability much younger than a 20-meter shore line.

The following notes are observations made in 1928/29, with addenda from a visit made in 1931.

1. No flint implements were found on or in the ridges or hollows. Signs of Ptolemaic and Roman cultivation are ubiquitous, and sometimes intensely thorough occupation is indicated. Characteristic of those periods are the underground rock cisterns for retaining rain water, the Ptolemaic temple of Taposiris, and not far away the famous Roman lighthouse at Burg Abu Sir, near Burg el-ᶜArab (Pl. XIII *A*). There is reason to suppose that the district was much as it is today throughout the history of ancient Egypt.[5] The absence of Paleolithic implements is strange but obviously is not conclusive evidence that the ridges are post-Paleolithic (see pp. 81 f.).

2. The present shore is composed almost entirely of comminuted shell fragments of "oölitic sand," that is, fine lime sand, quartz grains being virtually absent in the samples collected. Unbroken shells are comparatively scarce; marine annelid "tubes" are common, being found at high-tide mark and in the storm beach with seaweed often attached to them, and blown above high-tide mark by the wind. Pumice drifted from the northern side of the Mediterranean is remarkably common between tide marks.[6] Small, very light pebbles of it are rolled by the wind well above high-tide mark, together with balls of vegetable material, straw, etc. rolled by the waves.[7] So far as composition is concerned, the structure of the Abu Sir ridge is similar to that of the present shore and the loose dunes behind the high-tide mark; drifted pumice was not found in the consolidated ridge.

[4] *Op. cit.* pp. 9 f.

[5] See Oric Bates, *The Eastern Libyans* (London, 1914) chap. i.

[6] The pumice is collected, crushed, and used in cement for roofing purposes, e.g. in Major Jennings Bramley's new house near Burg el-ᶜArab.

[7] The lighthouse at Burg Abu Sir is severely sand-blasted on all sides except that toward the sea.

3. The sand dunes behind the shore line are of brilliant whiteness and consist solely of calcareous sand etc. derived from the shore. They have no dominant crest or feature but are ever-changing hummocks. Where seen in section they show acute angles of bedding and cross-bedding. At the eastern end of the Abu Sir ridge, near Mex, is a dune area, still "active," such as may be seen on a coast in any part of the world but consisting of calcareous sand etc. derived from the shore and piled up by westerly winds. Nile silt drifted into the sea farther east seems to play no recognizable part in it. The false bedding of the Abu Sir consolidated ridge also is severe, and there seems to be no real distinction between the latter and the "active" dunes, so far as intimate structure is concerned.

The relation of blowing sand to partially or wholly consolidated sandrock is interesting. In some places the latter is intensely eroded, and upon it lies fresh, loose, wind-blown sand. Elsewhere, where fresh material lies unmoved in hollows, it is being cemented and fixed and passes down without visible break into hard rock within a few feet. The action played by rain water is evidently a controlling factor. Even on the top of the high Abu Sir ridge fresh material is being deposited locally by wind and is added to the surface; such areas are planted with fig trees.

New dunes are banked on the seaward flank of the Abu Sir ridge with a marked inward slope; in the hollow so formed bushes grow.

4. In general contour the Abu Sir and Maryut ridges are remarkably smooth (Pl. XIII *A*) and have nothing in common with the disorderly hummocks of the "active" lime-sand dunes that rest upon the flanks of the former.

5. It may be suggested at this stage that cementation of lime sand by rain water passing through it might retain the lower layers of sand, while the dry upper parts could still be shifted by wind. A solid curved ridge, that is, a "cast" of the central portion of a broad belt of dunes, parallel to the coast might result. But the curve of the surface form of the Abu Sir ridge is severe (Pl. XIII *A*), and there is no proof that the upper limit of saturation of a mass of sand would be so arched. On the other hand, sand dunes near the Suez Canal, especially those at the northwest corner of Lake Timsah, contain much moisture in their main body and support an active crest and cascading front in the uppermost few feet only; these are for the greater part of quartz sand.[8]

On the whole the suggestion made above seems a little farfetched; but, if it is assumed that subsequent denudation of some of the superficial layers of the consolidated lime ridges has exaggerated the curvature of the cross-section, the suggestion appears to be not entirely outside the bounds of possibility. The ridges become more subdued inland. In the quarries near Burg Abu Sir (Pl. XI) the bedding and false bedding are on the whole seaward on the north side and landward on the south side, the landward dip being the steeper; this is transmitted to the general cross-section, the surface being steeper on the landward side.

6. In the quarries of the Abu Sir and Maryut ridges it is seen that only the top few feet or meters of oölitic sand are connected into really hard limestone; the material becomes softer from above downward. In these old quarries also exposure has imparted a hard face to the rock, which, where penetrated, reveals soft material which has been severely denuded, the crust remaining in hollowed and fantastic wreaths or broken sheets (Pl. XI).

7. In weathered surfaces of Gebel Maryut (at Major Jennings Bramley's house) small nummulites are weathered out but do not indicate by their presence a submarine origin of the ridge, since they are readily blown by the wind from shore.

8. On the floor of Mallahat Maryut a shelly limestone is exposed virtually at sea-level.

[8] Hume, *Geology of Egypt* I 51–56; Vaughan Cornish, *Ocean Waves and Kindred Geophysical Phenomena* (Cambridge, 1934) pp. 55–57.

This is an oölitic rock full of *Cardium edule*, *Mytilus*, *Conus*, etc., that is, Pleistocene to Recent Mediterranean forms. This limestone is a well known stratum over the area and is sought for special purposes. It occurred in Major Jennings Bramley's newly excavated well at 15 feet (5 m.) above sea-level.[9] As the well is situated on Gebel Maryut, there is reason to suppose that the *Cardium* band rises in a landward direction. The freshly excavated material from the well is essentially a lime sand or oölite but is full of shells and casts, and some of it is thoroughly bedded. On the other hand some lumps of the rock show scattered and for the greater part broken shells; this sort of material could be matched very closely by imagining a consolidated form of the modern storm beach. It is highly probable that the bedded rock, with living shells, could be matched below present low-tide mark.

A few miles southwest of Burg el-ᶜArab, in the valley followed by the coastal railway, south of Gebel Maryut, is a gypsum factory. Here too occurs a *Cardium* bed, at this point about 30 feet (9 m.) above sea-level, associated with bedded deposits. At the base are exposed thick seams of gypsum, covered by clays, with thin limestone bands; there is a good deal of local variation, and the clay tends to thicken rapidly. The *Cardium* bed is above the gypsum but below the uppermost bedded clays, about 6 feet from the surface. In a trial hole only limestone and clayey limestone were revealed in the quarry floor, the shells (*Cardium?*) being commi-

FIG. 23.—DIAGRAMMATIC SECTION ACROSS THE WESTERN END OF LAKE MARYUT. POSITIONS OF A *Cardium* BED ARE MARKED BY THICK BLACK LINES

nuted in an essentially marine (not wind-blown) stratum. A higher sea-level is thus indicated between Gebel Maryut and the Maryut upland plain on the south side of the valley occupied by the railway than is seen beneath Gebel Maryut or in Mallahat Maryut.

The Maryut upland plain (Pl. XII *A*) passes from the last of the ridges without visible break of surface onto marine limestone and calcareous sandstone, then onto sandy gravels, then laterally onto deltaic sands and the submarine beds north of the gravel plains that stretch from Wadi el-Natrun to the Delta (see Pl. XII *B* and chap. iii) or onto the pink rubble of denuded Miocene rocks.

9. There seems therefore to be a continuous coastal slope in which the sea has left no recognizable break from the underwater facies of the older Pleistocene terraces to about 30 feet (9 m.) above present sea-level. There is no marked beach at this point, but a *Cardium* bed appears. It is not definitely known whether there is more than one *Cardium* bed; but at any rate this shell, with others, appears in marine deposits at lower levels as one approaches the present shore (Fig. 23). The foregoing appears to be the marine sequence.

Superimposed on a sloping marine plain which is younger the nearer it approaches the sea and sea-level are the remarkable ridges. In these there seems to be no *absolute* criterion of marine deposition. The bedding could probably be achieved solely by wind action, for it can be matched in the wind-accumulated material upon and in front of the Abu Sir ridge, that nearest the sea. This does not exclude the possibility that similar material may be formed in the offshore region of turbulent water along this coast. But if these were submarine ridges, what would account for the hollows between them? Moreover, since they are of approximately similar height, why should the innermost ridge have more subdued contours and generally appear

[9] For the relation of fresh water to salt and to the sea see Hume and Hughes, *op. cit.* pp. 20–24.

to be more molded by denudation than the outermost? If, on the other hand, it is assumed that the ridges were formed above the beaches as the sea retreated and that they formed a barrier, as do coastal dunes, between sea and marshland, it follows that the outermost ridge was the last to form and that the nucleus of a new ridge is now forming on its seaward flank. Wind will account for every feature but the curved cross-section, in which saturation may have played a part. No indubitably marine character can be seen above the stratified *Cardium* beds.

The question of age is discussed on page 82.

THE VICINITY OF ALEXANDRIA

It is obvious at a glance as one enters the port that the consolidated ridges described above play a major part in forming the harbor. This becomes even clearer if one enters Alexandria from the southwest, via Mex, by road. Before Mex is reached the ridges on the seaward side of Lake Maryut sink appreciably and pass out to sea to provide the breastworks of the harbor.

The ridge that provides the only land connection between Alexandria and the mainland has been almost entirely removed by quarrying on a gigantic scale, first in Greek and Roman times, then again since the 19th century resurrection of the city from the mere village to which it had shrunk by 1800. The present century has seen a vast replacement of the city of the last hundred years. The growth has been so great that a large part of the city is built on submerged ridges, with much made ground.

It is widely known that much of Greco-Roman Alexandria lies beneath the waters of the harbor. Depression to the extent of 20–30 feet appears to have taken place since Roman times. This is a demonstrable fact, attributed to earthquake—or perhaps it would be wiser to say accompanied by earthquake—either in the 1st century or in the Middle Ages. It has been maintained also that the coast to the west, at least about Burg Abu Sir, was raised by an equivalent amount. The most quoted evidence of such elevation is Strabo's statement that there was a rocky place on the sea near Taposiris,[10] that is, the ridge upon which stand the lighthouse of Burg Abu Sir, the temple of Taposiris, and the adjacent Roman fort, whereas the sea is now separated from them by the coastal dune belt, half a mile or more in width. If Strabo's statement "on the sea" is precise, all the questions of altitude discussed above and probably the absence of flint implements are accounted for. Such an elevation might be expected also to lower the depth of water in wells, and some loss of prosperity in this famous Roman wine-growing district might be attributed to it.

Better purpose may be served, however, by studying the ends of the ridges at Alexandria, where Fourtau has done much work. Nothing can be more apposite than his statement (freely translated) of the evidence which he accumulated:

> Borings at Marar in Lake Maryut, at Kafr el-Dawwar, and at Kom Difshu show the Mex limestones and shelly lime rock that form the present shore line to be overlain by Nilotic and brackish-water deposits. . . . .
>
> The borings at Kafr el-Dawwar proved the first bed of limestone and limy clay at 7 meters below the surface, interbedded with brackish-water deposits packed with *Cardium edule* and *Pirenella conica*. From 21 to 26 meters the bore did not leave the limestone. At Kom Difshu the limestone was met at 20 meters below the surface in a 1-meter band, reappearing six times below this in beds 1–2 meters thick, the bore being carried to 122 meters. At Marar Island on the south side of Lake Maryut two beds of the same limestone, 0.70 meter and 2.20 meters thick, were met at 22 and 24.30 meters respectively below ground level.
>
> These alternating beds of calcareous tufa and more or less clayey sands with brackish or marine fauna are characteristic of the shore line, behind the protection of which the essentially brackish deposits of Lake Maryut were laid down, that is, black Nile clay full of *Cardium edule* when the Nile reached Kafr el-Dawwar, clayey sands with *Pirenella* and *Cerithium* when the estuary was a little farther off, as in the neighborhood of Kom el-Hanash at the end of the basin which forms the southern part of Lake Maryut and stretches at depth toward the west of el-Buhairah province.[11]

[10] Strabo xvii. 1. 14.

[11] *Mémoires présentés à l'Institut égyptien* VIII 84.

It is not surprising that the limestone ridges have foundered, with subsidences in the vicinity of Alexandria, when it is realized that they rest on waterlogged clay, silt, and sand. The ridges die out rapidly toward the east of Ramlah.

Although no great confidence can be put in altitude or in *Cardium edule* and its associated fauna, the species may be noted to occur from sea-level to 9 meters near Burg Abu Sir, at and about 7 meters below surface (here almost sea-level) at Kafr el-Dawwar, at 13.3–21.8 meters below surface at Basandilah (north of el-Mansurah; about 2 m. above sea-level), and to rise approximately to sea-level near Ismailia. It emerges also that limestones in the littoral zone of the Delta are intimately linked with deposits associated in this volume with the Upper Buried Channel. Perhaps, then, it is more than chance that post-Middle Paleolithic implements were found near Ismailia (p. 58).

CONCLUSIONS

The remarkable ridges of lime sand and oölitic limestone west of Alexandria, separated by parallel valleys, afford a perplexing geological problem, but on the whole there is much to support the view that they were formed by wind action along a receding shore line; a new dune area is forming between the ridge nearest the sea and the present storm beach. The ridges lie on definitely marine beds full of *Cardium edule* and other shells. Near Alexandria the limestones have been shown in borings to rest on soft clays and sands, and subsidence has taken place, notably in post-Roman times at Alexandria to a depth of 20–30 feet. The limestones thin out rapidly at their junction with the Delta, but there seems to be sufficient evidence to associate limestone beds with the Upper Buried Channel of the Nile. In part at least, then, they may be of post-Middle Paleolithic age, as may sand dunes on the east side of the Delta near Ismailia.

Beds with *Cardium edule* may be traced across the Delta at low levels, rising on either margin approximately to present sea-level or a little higher. West of Alexandria documentary evidence suggests elevation since Roman times, but this is not entirely confirmed by geological observation. Such elevation, if it took place, might have adversely affected well-water supply and thereby the prosperity of the district, famous in Roman times for its wine. It is not suggested that this might have been the only cause of deterioration before the Arab conquest.

VIII

RAIN AND SAND IN THE NORTHERN DESERTS PAST AND PRESENT CLIMATES

INTRODUCTION

In the preceding chapters numerous references to wind and rain will be found; the subject of past and present climate may now be reviewed. In earlier volumes of this series the evidence of climatic change has been of special interest in a positive sense. In the region now under review the interest is of a negative kind; in other words, there has been climatic change in quantity perhaps, but not in quality. At the present day it would be difficult to say of the region as a whole whether rain or wind was the more effective denuding and depositing medium. In certain localities one or the other is obviously dominant and in some instances seems to have been so for a very long time.

One speaks of the deserts adjacent to the Delta, but near high ground or near the sea springtime turns the land into a garden. From Wadi el-Natrun the traveler passes northward from absolute desert (Pls. V and XII *B*), a wilderness of driving sand, to a paradise of flowers, anemones, hyacinths, asphodels growing shoulder high in spring (Pl. XIII *A*), and cereal crops raised without irrigation, depending only on rainfall, harvested late in April. These same places a few weeks or months later are barren, glaring, scorching desert. But such remarks apply to the greater part of the Mediterranean lands, and it is the Mediterranean type of climate that controls the weather of the northern coasts of Egypt, from which one passes southward into absolute desert west of the Nile and to the high plateau with its vegetated valleys between the Nile and the Red Sea.

In the past no doubt the Mediterranean climatic zone stretched farther south and merged into zones less arid than they are today, but in the country adjacent to the Nile Valley north of Hilwan and Sakkarah there seems always to have been rain, just as there is today. Earlier in this book (p. 51) it was stated that a winter spent in tents in this region gave ample experience of rainfall as well as wind erosion. In closing these generalities two instances may be given: In January, 1929, we obtained all the water we needed for our camp from rain that accumulated in ʿArabi Pasha's trenches at Tell el-Kabir (Pl. VI *B*); in the same month, as we motored to Wadi el-Natrun, a sandblast burnished the paint from the wheels, lamps, and parts of the bodies of our cars. In winter the bleakness of these margins of the Delta may be extreme (Pl. XII) and the cold, wind, and dampness unpleasant; within a few weeks the heat is excessive. How, then, are past and present effects of climate upon surface and upon potential inhabitants to be analyzed?[1]

[1] The following figures taken from H. E. Hurst and P. Phillips, *The Nile Basin* I ("Physical Department Paper" No. 26 [Cairo, 1931]) Tables VIII and XIII, may be of interest. Alexandria and Gizah or Cairo, being situated near the sea and in the broad alluvium of the Nile respectively, show figures less extreme than those to be expected on the plains and plateau adjacent to the Delta.

Normal Temperatures (Degrees Centigrade)

	Mean of Day		Mean Max.		Mean Min.		Highest Recorded	Lowest Recorded
	Jan.	July	Jan.	July	Jan.	July		
Alexandria (1901–25)	13.4	25.1	18.5	30.0	10.2	22.5	43.7	3.0
Gizah (1902–25)	10.8	26.7	19.0	35.2	5.4	19.4	45.8	− 4.0

[Footnote continued on page 84]

THE COUNTRY WEST OF THE DELTA

Rain and Work Done by Running Water

A vast amount of erosion has been wrought by running water in Plio-Pleistocene and all subsequent times, observable from any high hill on the latitude of Cairo; the great area of water-controlled slopes (cf. Pl. III) that fall from nearly every side toward the depressions of Wadi el-Farigh and Wadi el-Natrun may also be noted. It seems probable that the rain from any heavy shower moves material only a short distance before it sinks into the sands, gravels, and cobble conglomerates of the region. The formation of these very obvious slopes is therefore to be considered as progressive by small stages over an extremely long period of time. The depressions themselves, being entirely inclosed by higher ground, have undoubtedly been excavated by equally prolonged wind-removal of fine particles.

Along the edge of the Nile Valley prominent cones of sand and gravel are washed down the banks, and sometimes spread over the fields, by every heavy shower. Locally the changes wrought by a single storm are striking.[2] Rain water may lie in pools above the level of alluvium if an impermeable bed is present, and it is there either evaporated or absorbed by sand, which is usually present along this side of the Delta in varying degree. Flood water from the annual inundation often remains in similar fashion. At the huge Greco-Roman site of Kom Abu Billu, north of el-Khatatbah, the upper part of the town is not excavated, and mud walls run a long way under a foot or more of gravel down-wash which has accumulated over them since they fell into ruin.

In the vicinity of Wadi el-Natrun, in less frequented districts, large herds of gazelle are to be seen. These may number 20 or more. They feed on vegetation brought up by winter rains around, north of, and in certain parts of the depression (e.g. among Miocene limestones, where the water does not immediately sink into underlying strata). Scattered small parties or single animals range westward and southward to the high country around the Faiyum and come down to the Nile if not disturbed.

Some impression of the transformation to be witnessed in spring north of Wadi el-Natrun has already been given (p. 83), and a more connected outline of the region between Wadi el-Natrun and the coast may now be provided. Scattered desert scrub is met within a mile or two or a few miles of the north side of the wadi on an entirely featureless upland of fine gravel and sand, devoid except locally of even runnels or small stream beds. A strong wind in a few minutes changes this open country into a blasted wilderness in which it is no easy matter to keep direction in the blizzard of flying sand (cf. Pl. XII *B*). About 10 miles from the wadi

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Average of Rainfall to 1927 (Millimeters)

Alexandria	191	Safagah	No record	Rainless for many years; rare torrents from hills
Suez	24	el-Kusair	No record	Rainless for many years; rare torrents from hills
Cairo	32			
Ismailia	49			

Detailed records of rain from the coast southward are given in Table XIII.
The Egyptian Government *Almanac* for 1927 gives:

Normal Rainfall (Millimeters)

	Annual Total	Highest Monthly Total	Lowest Monthly Total
Alexandria	191	Dec. 60	June–Aug. 0
Cairo (Gizah)	28	Jan. 8	June–Sept. 0

In Hurst and Phillips, *op. cit.* Pl. 23 and p. 54, it should be noted that the Nile Valley and the deserts from the Red Sea to the western frontier of Egypt between the latitudes of Hilwan and the Fourth Cataract (between Abu Hammad and Merowe) are included in a single belt, for which the normal values of rainfall and the annual total are stated as less than 25 millimeters: "practically rainless."

[2] Cf. J. de Morgan, *Recherches sur les origines de l'Égypte: L'Âge de la pierre et les métaux* (Paris, 1896) pp. 25 f. and Fig. 7.

along the main route to Alexandria begins a residue of derived Miocene limestone rubble of fine grain, which bears a somewhat greater amount of scrub, with bigger, less scattered, and greener bushes. Gradually the limestone country becomes covered with sand, in part at least weathered from underlying surfaces rather than wind-borne. It is probable that various Tertiary and Quaternary marine limestones and arenaceous beds are represented here and that they sink imperceptibly below the oldest and most subdued of the coastal lime sands. This belt of sandy country, with locally exposed limestone, is covered with prosperous-looking bush of desert species (Pl. XII *A*), and the vegetation becomes more abundant and better grown to a point at which it will support for some seasons a pasturing nomadic population living in scattered tents with small flocks of camels, sheep, and goats. Toward the coast the scattered tents are replaced by considerable encampments with large flocks.

Such concentration of people and flocks leads to a complete reversal in the appearance of the country; as they increase, the bush country becomes more barren, and finally the whole of the scrub seems to be eaten down to the roots. From among such roots, however, now rise non-desert plants in increasing variety and a number that spring up with the rains—brightly flowering anemones, vetches, and even grass, as well as asphodels. Finally there is an area in which the flocks seem to have conquered even the most thriving spring vegetation. This is quickly followed by arable plots planted with grain, and with cultivation flowering plants appear in great profusion on fallow patches in which brilliantly green, fresh grass studded with crimson poppies and anemones attracts the eye of anyone coming from the desert. In the midst of this country lie the ruins of the early Christian church at Abu Mina, one of several in the country southwest of Alexandria, all now in ruins, though four of the many Christian monasteries and hermitages that were established in and around Wadi el-Natrun have survived.

On all sides from Abu Mina to the coast are traces of a formerly flourishing and considerable agricultural population. Prominent in the countryside are *karm*'s, high artificial mounds, either isolated or more frequently more or less encircling a small patch of ground. They are now ignored by the Arab cultivators so far as their original purpose was concerned, namely to concentrate rain that ran down them into the central hollow and on their lower flanks both outward and inward. These, the huge underground cisterns, and other works remain of the intensive cultivation and prosperity of about two thousand years ago. *Karm*'s occur even beyond the edge of present occasionally ploughed land. Among them, from south of Abu Mina to the Abu Sir ridge, one is transported to that often described and illustrated beauty of springtime (Pl. XIII *A*) in Palestine. All these drastic changes occur within about 40 miles, with no advantage of topographic relief to assist them. No doubt the width of the belt varied in the past, but no evidence suggests that it stretched to Wadi el-Natrun in Neolithic or later times. The total of herds now in the country certainly reaches an astonishing figure, limited by summer drought rather than by total available pasture in winter. The Roman indubitably made better use of the country than the Arab and provided for hard times, an entirely un-Arabian trait. In fact, the zones of excessive grazing by sheep and goats are today noteworthy features which an entirely agricultural, rather than part pastoral, part agricultural, and more or less nomadic, people would do much to improve. Today the flocks ebb and flow with the season. In winter and spring camels may be found grazing singly as far as Wadi el-Natrun, and goats in charge of children and youths spread far south of the limit of the *karm*'s; most of the livestock seems to be taken south of the arable land. In late spring the animals are driven north, grazing over the stubble after the crops are cut, clearing off all edible vegetation from south to north, until they are concentrated near the coast, where large encampments spring up for the summer.

It will be realized that with severe grazing by the most destructive ungulate in the world, the goat, and the far-flung operations of the camel the belt of bush country has little chance to widen. Add to this the lack of provision or thought for tomorrow by the people, when left to themselves, and the universal destruction or neglect of so much that would be useful, and one gains an impression that, in spite of present wealth, the country is probably now supporting fewer people, herds, and crops than at any time known to history before the Arab conquest. In other words, historical accounts of great herds in the Mediterranean littoral southwest of Alexandria indicate probably more sane or more drastically controlled use of natural assets and do not suggest and should not allow the assumption that there was more rain before the Arab conquest. It would be difficult to point confidently to any change in available water supply either on the surface or underground that cannot be fully explained by neglect and destruction since that time.

Wind Erosion and Deposition of Sand

It has been suggested (p. 50) that the scouring of Wadi el-Natrun may have started early in Pleistocene times, but the aridity so implied probably applied to the nature of the ground rather than to the relative humidity of the air. In cobble gravels with sand it is manifestly impossible for water to remain on the surface unless the water table is at that level, a state that could hardly be expected in such a terrain except in northern temperate regions. Moreover, there is nothing in such a rocky formation to form any soil in any climate, since it consists almost entirely of silica. Even if some soil and vegetation formed today, the Mediterranean summer would desiccate it and lead to its removal, as in the limestone and gravel country of Provence, Aragon, or Istria. The country west of the Nile on the latitude of Wadi el-Natrun seems to have been a self-made desert. As aridity increased in Nubia and the Libyan Desert westward to the continental watershed, the water table sank lower and lower, with marked effects in the north which Ball has analyzed.[3]

Perhaps it is not a matter of surprise that, according to Ball, the long sand dunes of the Libyan Desert began their southward march from this latitude at an early date. These dunes may have started from self-made deserts, irrespective of some rainfall (as at the present day, or rather more), aided by falling water table due to true aridity in the south. Further proof of the blowing of sand into the western side of the Delta is seen in deep borings where great thicknesses of sand, partly blown and partly washed off the surface, have been proved.[4]

Further, coastal ridges may be due to wind action, and coastal dunes are now forming which bear no more relation to aridity on the Mediterranean than do those in western Ireland or Cornwall. It is a question of superabundant and unfailing supply of sand from the sea which no amount of rain can remove. These dunes may have been accumulating since post-Middle Paleolithic times.

So far as past and present are concerned, therefore, there is the paradox that in these northern lands wind erosion and sand accumulation indicate the nature of the rock and of the summer but do not prove perennial aridity. Perhaps these obvious factors have not been as widely recognized as they deserve, nor has Ball's demonstration that the real trouble was transmitted underground from far south to extreme north (by falling static level of underground water) been fully appreciated by those who have argued the question of northern climate from an archeological point of view.

[3] *Geographical Journal* LXX 21–38, 105–28, 209–24 and LXXXII 289–34. See also K. S. Sandford in *Geographical Journal* LXXXV (1935) 412–31.

[4] Fourtau in *Mémoires présentés à l'Institut égyptien* VIII 57–94.

Of recent accumulation of sand within this part of the region little need be said. Great dune systems do not appear, and the considerable hollows that might have been filled with sand are swept by westerly winds and suffer further erosion rather than deposition. Great quantities of sand swept along the surface out of these hollows come to rest on the edge of the western Delta.

THE COUNTRY EAST OF THE DELTA

Rain and Work Done by Running Water

The rugged topography and great altitude of much of the country east of the Delta has already been noted and explained (pp. 4 f.). Signs of the work of rain are naturally ubiquitous, and, owing to the predominance of hard rocks and the minor part played by cobble gravels, except as thin skins on Miocene and Eocene strata, much of the surface water runs off instead of being absorbed where it falls (Pls. II and IX).

Broad, well vegetated wadies are typical of the country between Cairo and Suez. In them for the most part desert scrub and rough grasses thrive, with occasional big thorny acacias (Pl. XIII *B*). The sporadic and heavy showers of winter are followed quickly by intense heat, which is reflected by the light-colored rocks, and amelioration by coastal humidity is lacking. A carpet of brilliant spring flowers is not seen east of the Delta or along the Suez Canal, but in the wadies of the high country on the latitude of the Cairo–Suez road thickets of fragrant broom mark the advent of spring. Few of the remarks on the country between Wadi el-Natrun and the coast apply east of the Delta. Everywhere are signs of erosion by surface run-off, past and present. The gravel terraces are sufficient indication of past run-off. The banks and lakelike expansions of mud above constrictions of valley walls, as in Wadi el-Gafraʾ, and the scoured beds of wadi floors (Pl. XIII *B*) show that the same processes are still active, though somewhat reduced. The destruction wrought upon the embankments of the old Cairo–Suez railway since it was abandoned is most instructive, no less so than the signs of struggles with floods during its short-lived maintenance.

Huge fans of detrital material sweep from the steep cliffs of Gebel ʿAtakah, eclipsing the cones of débris along the Mukattam Hills from Gebel el-Ahmar to the Citadel and the sandy waste that spreads at intervals over the low desert from Cairo through el-Maʿadi to Hilwan.[5] It should be emphasized therefore that the present bears a close relation to the past, though in former times the material moved was on the whole of larger size and was carried farther and probably more frequently. An interesting change may be noted in this connection in some of the fans, for example the huge cone of detrital material at the northeast corner of Gebel ʿAtakah (Pl. IX *B*). This may be approached either from the Cairo–Suez road or from the extreme northwest corner of the Gulf of Suez. An old fan with very low angle of deposition and surface slope is first traversed for as much as 2½ miles; some of this material may have been deposited under water when the sea-level was higher with relation to the land (see chap. v). At the present day this fan and others like it will be found to be deeply cut by localized streams that issue after rains from the high plateau, dashing down well defined and steep rocky-sided wadies. At the mouth of the wadi supplying the fan in question has been cut a splendid cliff, with a 50-foot vertical face of well bedded rubble and gravel, the bedding being very clear up to the solid rock face. A dark line of rubble forms a distinct band about 12 feet wide against the cliff, as if it were the original small scree. The change of condition from construction of a huge fan to the cutting of a narrow channel through it is very significant. At close range the erosion of the ʿAtakah scarp is seen to be enormous; in the solid rock is cut fantastic scenery of towering cliffs,

[5] Examples of destructive floods in Cairo and elsewhere are quoted by Hume, *Geology of Egypt* I 93–96.

pinnacles, and pyramids. Recent rains have cut chimney-like stream courses in steep-sided screes. On every hand are signs of recent and severe water erosion, but limited to definite and small channels in contrast to the older, broader and deeper features of erosion and deposition.

The vast scale of prolonged down-washing of local over Nilotic gravel in the high plains between the Miocene outcrops, in the Delta, and in Wadi el-Tumilat (Pl. VI) must also be recalled. A visit to Wadi el-Gafra' in both the Miocene and the gravel country of the north (p. 6) leaves no doubt as to the amount of material still transported and spread out over broad areas.

Fourtau has also called attention to the amount of sand and gravel, proved in deep and shallow borings, washed into the eastern Delta by local streams. To conclude, therefore, there can be no doubt of the continuation of surface-water erosion from Pleistocene times to the present day. In no instance can it be shown that there is more rainfall now than then; always the modern deposits and erosion are within the older and on a smaller scale.

Wind Erosion and Deposition of Sand

Sandblasting is not the key word of denudation east of the Delta. Sand and dust storms are at times severe, and locally much damage is done to exposed surfaces. The variety and severity of the topography in the country south of the Miocene outcrop tend to trap wind-borne sand: hence the magnificent dunes in a deep valley near the Cairo sewage works, also many lesser accumulations. Dunes accumulate round the shores of the Bitter Lakes also, as might be expected.

Similarly dust, dried mud, and sand are blown from the extreme eastern part of the Delta and from Lake Manzalah and are piled along the northern side of the Tell el-Kabir "island." Another area of accumulation occurs on the south side of Wadi el-Tumilat. In fact, although wind erosion is so marked in the area from Cairo and Wadi el-Natrun to the coast, deposition of sand in well formed and dominating dune areas is far more striking east of the Delta and west of Suez. There dunes are active at the present day and give no impression of great antiquity except in the Ismailia–Tell el-Kabir "island"–Lake Manzalah area, where their lower parts, formless and widespread, may be old littoral dunes upon which modern, active dunes have been superimposed. It should be borne in mind that Manzalah is now a muddy, marshy region, not a littoral sand area. It was among these dunes, on the surface of underlying gravel and in slight sandy banks, that in 1928/29 we found fresh and wind-worn post-Middle Paleolithic implements. Implements were found scattered in the sand also, but it was difficult to determine to what extent it might have been disturbed. We formed the impression in the field that the implements were closely associated with the lowest part of the dune area.

IX

HUMAN INDUSTRIES

(PLS. XVII–XXX)

In the earlier volumes of this series two principles have been followed in illustrating flint implements: first, the specimens must have been found *in situ*, and preferably in groups, in geological strata or in some special location; second, repetition of types has been avoided as far as possible. In the present volume few gaps remain to be filled. A few Lower Paleolithic implements are illustrated, along with two groups of Middle Paleolithic types—examples from Zawiyat Abu Musallam near Sakkarah and from the Red Sea littoral (see pp. 54 and 65). In addition, implements of note, that is, some of those from Wadi el-Natrun and Wadi el-Tumilat, are included.

Though Breuil has proposed that the term "Chellean" should be replaced by "Abbévillien," the former is retained here since such a change in the course of a series of volumes would be likely to cause confusion. In the last few years, moreover, Breuil has devoted much attention to the classification of flakes and cores. The terms "Clactonian," "Levalloisian," and "Mousterian" are now in general use; the last has become much restricted in its application, at least in Europe, Africa, and the Mediterranean coast. The Levalloisian has been subdivided into some seven units, at least some of which were formerly termed by the same author "Old Mousterian." The word "Clactonian" has already been used in these volumes, with some reservation. Flakes comparable with the work of each of these three industries are found in Egypt; and in post-Lower Paleolithic deposits both Levalloisian and "Mousterian" as well as African industries such as the Aterian are known at least on the surface.[1]

In the present state of flux in the terminology employed by prehistorians it seems unwise to adopt in its entirety any one classification for the Nile Valley. On the other hand, use of the word "Mousterian" in its old general sense is also unwise. To overcome the difficulty "Egyptian Mousterian" and "Middle Paleolithic" (see p. 54) have been adopted in these volumes, and the latter is used here. In the future specialists can at least realize what is intended and can refer in their own way to the plates of the volumes of this series. "Early Middle Paleolithic" implies somewhat heavy flakes akin to those of the 30-foot terrace and especially to the oldest of the flakes in the 10- to 15-foot terrace gravels of Upper Egypt. These have Levalloisian affinities, but the striking-platform may or may not be faceted. Some prehistorians would include the unfaceted type in the Clactonian. Flakes of Lower Paleolithic horizons are unfaceted and may reasonably be called Clactonian. In the older Middle Paleolithic levels both types occur side by side, equally fresh and unabraded. The later type of Middle Paleolithic flake is the forerunner of the industry that passes into the oldest Sebilian of Middle and Upper Egypt and Nubia.

The implements of the oldest group of gravels of ᶜAbbasiyyah, resting on the Plio-Pleistocene sands, include coarse core-implements (e.g. No. 1) made by the removal of large flakes from pebbles and rather crude triangular coups-de-poing (e.g. No. 2) made from chert or flint pebbles derived from the Oligocene beds, with others of rather better workmanship made from

[1] The question of nomenclature is discussed in *OIP* XVIII 110 f., footnotes. The Acheulean has now been subdivided into some seven groups; see Harper Kelley, "Acheulian flake tools" (Prehistoric Society, *Proceedings*, new series, Vol. III, Part I [for Jan.–June, 1937] pp. 15–28). For use of the term "Middle Paleolithic" see our p. 54.

siliceous sandstone or quartzite. It must be admitted that, since such large pebbles are difficult to convert into implements, the coarse flaking and zigzag edge may give a false impression of primitive antiquity. Moreover, the gravels of the 100-foot terrace from Wadi Halfa northward have given a varied collection of implements, from similar coarse triangular types of rather old Chellean aspect to well developed two-sided implements of Chelleo-Acheulean or Acheulean form.[2] At ᶜAbbasiyyah the latter occur in gravels that lie just above those which rest on the Plio-Pleistocene sands. In some the workmanship is of a high order (e.g. No. 3): edges are straight and finely retouched; flat pebbles were used, and the smooth surface was retained at the butt. Similar though less developed types (e.g. No. 4) occur in the 100-foot gravels north of Hilwan. Coarse flakes occur in these gravels. The sequence at ᶜAbbasiyyah is concluded by silt containing small and retouched points, flakes, cores, and disks (e.g. No. 5), some at least of Middle Paleolithic type; cores of good workmanship, also made from flat pebbles, likewise occur above the Lower Paleolithic gravels north of Hilwan (e.g. No. 6).

Reference has already been made to the work of Bovier-Lapierre in the Cairo district (p. 49).[3]

Lower and Middle Paleolithic implements occur abundantly on the surface of the deserts on both sides of the Nile, but north of the latitude of Cairo they are less plentiful, owing to continued denudation, and many are much abraded. Junker and Menghin have made extensive collections of such material along the western edge of the Delta and in its neighborhood. Paleolithic implements seem to be rare on the floor of Wadi el-Natrun, but coup-de-poing No. 7 was found on the floor near Biʾr Hooker; it is made of Pliocene chert from the locality and has been flaked from the edges, including most of the butt. The edge figured has a reversed S-twist, which does not seem to be common in Egyptian coups-de-poing. A few Middle Paleolithic cores also were found. Northward to the Mediterranean coast implements are scarce or concealed by down-wash sand or vegetation.

The silts at Zawiyat Abu Musallam contain cores of Middle Paleolithic type from which flakes seem to have been detached from opposed striking-platforms (Nos. 8–9). With them occur small disks (e.g. No. 10) and sharp-pointed triangular cores and flakes (Nos. 11–13) similar to some of those figured in *OIP* Volumes XVII and XVIII from the 10- to 15-foot gravels of Upper Egypt and from the gravels of Tunah el-Gebel (i.e., the 25-foot gravels rising to 30 feet and passing into silts in the Delta). The angle made by the faceted striking-platforms and the bulbar surfaces is about 95–105°. Rather similar, but on the whole smaller, flakes (e.g. Nos. 15–16) and double-ended cores (e.g. No. 14) occur near el-Khatatbah; their striking-platforms are faceted and make angles of about 100° with the bulbar surfaces.

The last implements figured here from Lower Egypt are small double-ended cores (Nos. 17–18) and flakes (e.g. No. 19) from the silts of Wadi el-Tumilat and from sand dunes near by on the north side of the wadi near Abu Suwair (No. 20) and Ismailia which recall the later developments of Middle Paleolithic technique of Egypt.[4] On the whole one is conscious of great gaps in the series owing to the submergence of the later Paleolithic strata beneath the modern alluvium of the Delta and the disturbance of desert surfaces by wind and rain. With regard to the latter no stronger contrast could be found than that between the rainless south, for example the Thebaid, with a multitude of flakes and other material possibly lying where they fell, and the rain- and wind-swept north with its scattered, re-incorporated, abraded, and wind-polished implements, flakes, and cores. Among this surface and subsurface litter are types that yet remain to be found *in situ*.

Implements are rather scarce in the country east of the Delta, and none was found *in situ* in

[2] See plates in *OIP* XVII and XVIII. [3] See also *OIP* XVIII 55. [4] Cf. *OIP* X, Fig. 22, and XVII, Pl. XL 45.

the vicinity of Suez. But near the Red Sea Lower and Middle Paleolithic implements and flakes are abundant on the isolated hills and ridges of Cretaceous and Lower Eocene rocks between Safagah and el-Kusair, though comparatively rare on the coast and on surrounding Archean and pre-Cambrian rocks. It is from such localities of available flint that implements have been washed down wadies toward the sea, and of those found in gravels the specimens from the terrace gravels at the foot of Gebel Duwi are of the same general type.

The series from the Red Sea littoral chosen for illustration includes a Lower Paleolithic coup-de-poing (No. 21) found on the hill surface above Wadi Saki, headwaters of Wadi Kuwaiᶜ, by Mr. G. W. Murray. Although this form, so common in Egypt west of the Red Sea Hills, has not yet been found *in situ* in the wadi gravels or littoral deposits of the coast, a form closely allied to it (waterworn and unpatinated) was found in 1931 on the surface of the 25-foot terrace gravels of Wadi Safagah (No. 22). From the same terrace surface comes a large waterworn flake (No. 23) found in 1931. Its striking-platform is plain and makes an angle of about 125° with the bulbar surface. In the same year implements were found on the coastal plain south of Waḍi Safagah, for example a disk (No. 24) and a flake (No. 25). One side of the disk is a bulbar surface struck from a small unfaceted platform, the angle between them being 110°; it is made of quartzite and was found on the surface between Wadi Safagah and Wadi Guwaisis; it is slightly waterworn. The flake, also struck from a plain platform (angle 115°), is made of unpatinated chert; it is retouched with high-angle flakes along one side; it was found on the surface of the 50-foot terrace of Wadi Hamrawain. Similar material was found on the surface of the 70-foot terrace behind el-Kusair el-Kadim.

Lastly, a small collection of flakes found in Wadi Duwi in 1927 is illustrated (Nos. 26–29). They are made of chert or flint unpatinated and waterworn. The platforms of Nos. 26 and 27 are well faceted with small flake scars (angle of a small series 90–105°). This type recalls flakes that occur in the Nile Valley in wadi gravels of the same height (10- to 15-foot stage) above the present dry courses[5] and is the most marked among the material collected from the terrace gravel in Wadi Duwi. No. 28, a large thick flake from Wadi Duwi, recalling the type of the 30-foot terrace gravels of Upper Egypt (probably of older Middle Paleolithic age), was struck from a coarsely prepared platform. No. 29, a strongly ribbed and thick flake, has a plain platform and likewise resembles the material of the Upper Egyptian 30-foot terrace[6] rather than that of the lower gravels of the 10- to 15-foot stage. In these two thick flakes the angles between bulbar and striking surfaces are about 110°. They appear to be more worn and battered than the other two. Although only a limited amount of material is so far available, there is reason to suppose that two Middle Paleolithic industries are represented in the Wadi Duwi terrace gravel, analogous respectively to the material in the 30-foot gravels of the Nile in Upper Egypt, with rather a high angle (*ca.* 110°) between striking-platform and bulbar surface, and to the flakes and cores of the 10- to 15-foot terrace, finer, with well faceted platforms (angle *ca.* 90–105°).

[5] Cf. *OIP* XVII, Pl. XXXIII 28, and *OIP* XVIII, Pl. XXXIII 32.

[6] Cf. *OIP* XVIII, Pl. XXXI 26–27.

X
SUMMARY

This volume describes two distinct regions (see Fig. 1): (1) Lower Egypt, that is, the Nile Valley, the Delta, and the adjoining deserts northward from Sakkarah to Wadi el-Natrun and the Mediterranean coast on the west bank and from Hilwan to Ismailia and the Suez Canal on the east bank; (2) two areas of the Erythrean region, the vicinity of Suez and the Red Sea littoral of Egypt between Safagah and el-Kusair. The field work is treated regionally, and parallels are drawn in an attempt to deduce a coherent history of the whole. The treatment of the field work, spread over several seasons, and of the classical sections of ʿAbbasiyyah is explained in the Editorial Foreword and in the Introduction

GEOLOGY

Physiography

Lower Egypt.—South of Cairo the Nile is flanked on the west by low plains of Upper Eocene and Oligocene strata covered by extensive cobble gravels, with high ridges of similar composition a few miles farther to the west; on the east are precipitous cliffs of hard Eocene rocks capped by Oligocene sands and gravel. The strata are disturbed and folded on the east bank, and in the immediate vicinity of Cairo the Oligocene sands are brought down to the level of the river. On the opposite bank at this point is the prominent faulted dome of Gebel Abu Roash, in which concentric rings of Eocene and Cretaceous sediments and Nubian sandstone are revealed, with unconformities that show a remarkable thinning of strata from south to north. In particular the great thickness of Upper Eocene beds seen in the Faiyum is reduced to a few feet (Pl. I *A*).

Northwest of Gebel Abu Roash monotonous gravel plains, Oligocene, Pliocene, and Pleistocene, stretch to the Mediterranean coast (Pl. XII), broken only by hills near the Nile (Pl. III) and by the depression of Wadi el-Natrun, which owes its origin to lateral change in the lithology of Upper Tertiary beds, soft clays having been scoured out by wind from among more resistant beds (see Fig. 2 and Pl. V *B*). The floor of the depression is now a little below sea-level. At the west end of Wadi el-Natrun Middle Miocene limestones appear and stretch far to the west. To the east they disappear and are next seen on the east side of the Delta, where they form bold hills, intensely faulted, which extend to the head of the Gulf of Suez. Domal structures, monoclines, and several sets of faults, in which Miocene and Oligocene strata are involved, are characteristic of the high country between Cairo and the Gulf of Suez, where some of the drainage lines are probably directly developed from Upper Miocene streams. North of this line of hills a low featureless gravel plain descends to the coast, broken by a former arm of the Delta which debouched in the vicinity of Ismailia (Fig. 14). This is now Wadi el-Tumilat, reputed to be the district from which the Israelites emigrated into Sinai at the Exodus.

Erythrean region.—The west coast of the Gulf of Suez reveals severe faulting, which has been analyzed by Sadek. He concludes that a group of northwest-southeast faults may be attributed to pre-Miocene times and that the depression of the gulf was formed at that time, to be occupied by the Miocene Mediterranean (see pp. 23 f.). A second period of faulting, mainly east-west, is clearly post-Miocene, possibly early Pliocene. Some north-south faults are associated with those of east-west trend, and both seem to have been caused by the rising of the blocks which they surround. Domal structures also occur. There thus seems to be a broad region of vertical movement between the Gulf of Suez and the Nile, presumably affecting also the Archean complex. Sadek associates basaltic intrusions with pre-Miocene faults.

The clysmic area is therefore one of bold cliffs, scarps, and more or less truncated domes (Pls. II and IX *B*) in which Archean rocks are brought to the surface, notably on the coasts of Sinai. Farther south, on the west side, are the broad undulations of the Wadi ᶜArabah dome. The absence of recognizable Mediterranean Pliocene rocks from the region of the isthmus south of Gebel Shubra Wit, a few miles west of the Bitter Lakes, is significant.

Southward along the west side of the Red Sea the Archean and pre-Cambrian complex is magnificently exposed in the rugged and mountainous region of the Red Sea Hills. On their west side are successive belts of Nubian sandstone, Cretaceous and Lower Eocene sediments such as are seen on the east side of and among the hills also in infaulted and infolded outliers. The exposed margins of the complex have a north-northwest-south-southeast trend reminiscent of the northwest-southeast faults of the north, and the ancient rocks seem to have been brought to the surface by arching on a grand scale, with faulting, the sedimentary cover having since been almost entirely destroyed. It must be remembered that the rocks of this cover are nevertheless present probably over a large part of the Red Sea littoral, buried beneath Miocene and later sediments. No Middle or Upper Eocene or Oligocene strata can be identified, and it is assumed that the Red Sea Hills were being elevated during those periods while, independently, the Mediterranean (Tethys) contracted northward across Egypt. Lower Miocene rocks, if present, are hidden beneath Middle Miocene beds of the Red Sea. By Middle Miocene times the northern and central parts of the Gulf of Suez and Red Sea had evidently been depressed and had attained very much their present form and supported a Mediterranean fauna. The denudation of the Red Sea Hills arch was already advanced. Connection between the Red Sea and the Indian Ocean does not seem to have been made until after Miocene times, and Macfadyen believes that the barrier between the two was probably in the vicinity of Perim Island at the southern end of the Red Sea (see p. 9). Depression continued through most of Miocene times, but in the north the strait of Suez seems to have been elevated and to have remained an isthmus ever since, the Red Sea and Gulf of Suez thereafter being parts of the Indian Ocean. As in the north, so in the Red Sea Hills many of the great drainage lines are of Miocene age, and enormous thicknesses of gravel have been proved among the profoundly deep lagoon deposits of the Miocene reefs (cf. Fig. 3 and Pl. XVI).

Pliocene

Lower Egypt.—Lower Pliocene estuarine clays are exposed in the floor of Wadi el-Natrun, where they contain an important assemblage of marine and land vertebrates which have been the subject of many reports. Laterally and vertically the clays pass into flinty limestones which lie unconformably upon Oligocene and Middle Miocene beds. Lower Pliocene beds were probably exposed in the digging of the Suez Canal also; elsewhere they are hidden. Their upper limit on both sides of the Delta therefore approximates present sea-level.

The Middle and Upper Pliocene Mediterranean flooded the Nile Valley, which had been cut to great depth in Mio-Pliocene (Pontic) times. Near the mouth of the gulf thus formed, marine and brackish-water fossils are found, with *Pecten* and *Cardium* beds, attributed to the Middle Pliocene. With these the well known fauna of the *Clypeaster* bed of Kom el-Shellul (see p. 13), south of the pyramids of Gizah, is now associated (see Fig. 4). It has in the past been referred to the Miocene.

Fossiliferous and barren strata lying stratigraphically above these beds are correlated with the Middle Pliocene beds of the Nile Valley in Middle and Upper Egypt. A break between Middle and Upper Pliocene beds is occupied, especially in the south, by thick false-bedded quartz sands. The Upper Pliocene sediments are of estuarine or fresh-water facies (cf. Fig. 5), with *Melanopsis* fauna in the north and thick travertines and conglomerates in the south. On the flanks of the Delta travertines give place to white porcelaneous limestones with *Pirenella.*

The Upper Pliocene beds attain an altitude of about 180–200 meters above sea-level throughout Upper, Middle, and Lower Egypt. Systems of tributary valleys as well as streams flowing directly into the sea may be traced, and their gravels are prominent in the high ground between Cairo and Suez and on Gebel el-Khashab west of the Nile. Certain modifications of the existing geological maps of the country between Cairo and Suez and observations on the Upper Miocene and Pliocene stream courses (cf. Fig. 6) are suggested. Pliocene porcelaneous limestones have been traced at intervals from Heliopolis to the neighborhood of the Gulf of Suez.

Erythrean region.—It has been stated that the final Miocene deposits of the clysmic area are of fresh-water facies, evidently filling a depression. On the coastal plain to the north of the Gulf of Suez Pliocene gravels are recognizable at Gebel Shubra Wit up to 161 meters (p. 28); but south of this in the isthmus no definitely Pliocene rocks are identified. Post-Miocene deformation caused, presumably by Upper Pliocene times, a barrier more than 200 meters high to arise between the Mediterranean and the Gulf of Suez, which, with the Red Sea, became a branch of the Indian Ocean. Differential movements and formation of domes (some at least are salt domes, others are presumed to be of structural origin) continued probably into Quaternary times. The Miocene facies of coral reefs, thick gravels carried off the land, and lagoon deposits was unchanged, but the fauna was that of the Indian Ocean and has so continued to the present day. There is no admixture of Mediterranean and Indian Ocean fauna. It is probable that the barrier which separated the Mediterranean from the Gulf of Suez and the Red Sea was only about 10 miles wide and that it was situated over part of the present site of Great Bitter Lake and Gebel Gunaifah. The normal altitude attained by the *Laganum-Clypeaster* series, even when tilted in the domes, falls far short of the 200 meters familiar along the Nile and in the Delta, and seaward dip carries them below present sea-level. There are thus radical differences in altitudes between beds presumed contemporary in the two regions. Post-Pliocene differential movements have certainly taken place in the Red Sea but not in the Nile Valley and the Delta. Stratigraphical series of great variety may be observed along the coast of the Red Sea and are illustrated from the country between Safagah and el-Kusair (see Figs. 7–8).

Plio-Pleistocene

Lower Egypt.—After the peak of Pliocene submergence had been passed, some erosion seems to have taken place and thick sands were laid down indifferently over Middle and Upper Pliocene beds. Such sands are clearly differentiated from those of the Pliocene sequence by the presence of abundant crystals of pink feldspar and pebbles of igneous and metamorphic rocks derived from the Red Sea Hills in Upper Egypt. It appears that drainage from the hills westward to the Nile had not previously penetrated the sedimentary capping, or, if it had, the new type of detritus had not reached the Nile. The feldspar sands are of considerable thickness and are prominent near the pyramids of Gizah and in the plain of ᶜAbbasiyyah and Heliopolis (Pl. IV). So far as can be determined, they are older than the succeeding terrace gravels.

With the filling of the Nile Valley gulf and withdrawal of the sea a fluviatile phase was instituted and vast quantities of gravel were transported northward. Much of this was brought in by tributaries or collected by the river itself and consists essentially of flint and quartz, but pebbles derived from the complex of the Red Sea Hills are ubiquitous and abundant. As the river incised itself into the Pliocene filling of its old valley, successive terraces were formed and abandoned; but similar gravels were found on the west bank at even greater altitude than had been attained by Pliocene submergence, notably on Gebel el-Khashab (Pl. III) at 820 feet above sea-level and, farther north, on Gebel el-Haddadin at 765 feet. These altitudes exceed that of any terrace known south of Cairo within the Nile Valley (see Fig. 9). Since there is no evidence that such terraces were formed farther south, there is probably a local explanation for them.

Terraces at lower altitudes are prominent and may be traced virtually without break from Sakkarah (and farther south) to the latitude of Wadi el-Natrun (Pl. VII). They show no indication of differential movement or warping. They spread widely both west and east beyond the confines of the present Delta and may be observed to assume deltaic form and to reveal subaqueous sedimentation (see Figs. 10–11). The approximate positions of the delta mouths may thus be estimated from stage to stage. Feldspar sands were carried at least as far as the west end of Wadi el-Natrun, where they are fossiliferous and form the north side of the depression, which was therefore excavated for the greater part in Pleistocene times (Pl. V). On the east side of the Delta subsequent down-wash from the hills between Cairo and Suez has almost entirely hidden the high-level Nilotic gravels (Pl. VI *A*).

So far as their ages are concerned, the oldest feldspar-bearing sands may with some reason be included in the final Pliocene period of submergence, and some of the lower terraces may be correlated with the highest (or Sicilian) stage of Depéret's Pleistocene series. The remainder must be retained as a post-Pliocene, pre-Pleistocene group (see chap. iii).

Erythrean region.—No distinct group of deposits marks the close of Pliocene and the beginning of Pleistocene times. There has been a history of continuous erosion and deposition. No distinct features or high terraces are to be marked that are in any way comparable with the terraces of the Nile Valley. The application of Depéret's classification to the Red Sea is discussed on pages 46 f.

Pleistocene: Lower Paleolithic

Lower Egypt.—The highest terrace in which Paleolithic implements have been found is at 100 feet above the Nile. Higher terraces may be included in the Pleistocene if altitude alone is taken as the criterion.

THE 100-FOOT TERRACE

Immediately south of Sakkarah the river at this stage swung across the valley to the east bank near Hilwan (Pl. X *B*), whence its gravels may be followed toward Cairo. They are best exposed in the embayment of the Mukattam cliffs between the Citadel and Heliopolis, in the pits of ᶜAbbasiyyah (Pl. VIII) made famous by Père Bovier-Lapierre, where they lie unconformably upon Plio-Pleistocene sands (see Figs. 12–13). At ᶜAbbasiyyah the river seems to have started to meander westward and to have abandoned successive strips of its east bank as it swung away and deepened its channel. A stratified succession of gravels resulted, with interbedded fluviatile sands; the lowest and youngest gravels are not much more than 50 feet above the river. At the same time it must be remembered that in the earlier stages the more central, and lower, parts of the river's cross-section were situated where the marginal banks were formed in later times. Père Bovier-Lapierre is of the opinion that three successive implementiferous layers may be identified, the lowest primitive Chellean, the middle Chellean, and the upper Acheulean. Implements are abundant and may be found *in situ*, it being unnecessary therefore to postulate such a succession on grounds of typology alone. There is thus support for Père Bovier-Lapierre's main contentions so far as the stratigraphic succession is concerned. After the river had withdrawn westward a cone of local detritus—rederived gravels and silt—was spread over the older gravels. It contains Middle Paleolithic implements, many of which are not abraded. Still later types have dropped down cracks in the mud, where they are found in vertical position.

The Nile gravels of the 100-foot terrace are found on the west bank opposite Heliopolis and north of Gebel Abu Roash and may be followed for many miles along the edge of the Western Desert (Pl. VII). On the east bank local washes from the hills have concealed similar gravels; but Wadi el-Tumilat was a branch of the delta of this stage, and fresh-water deposits in the Suez Canal near by may be of the same age. The Tyrrhenian stage of Depéret's classification seems to be fully substantiated in the Nile Valley (see p. 53).

THE 50-FOOT TERRACE

Although this stage was probably represented, few traces of it remain today north of Cairo. Since the river was then approximately in the position it occupies today between the lower levels of ᶜAbbasiyyah and the edge of the Western Desert immediately north of Cairo, any gravels would have been destroyed. There seem to be traces of such a terrace near the west end of Wadi el-Tumilat, and it occurs north of el-Khatatbah.

Erythrean region.—Implements of Lower Paleolithic age have not yet been found *in situ* in bedded deposits on the west shore of the Gulf of Suez and Red Sea. Terraces of wadies draining into the sea, marine beaches, and old coral platforms are prominent and have been studied in some detail. There is remarkable similarity in their altitudes at the head of the Gulf of Suez and between Safagah and el-Kusair (Pls. XIV–XVI). In Pleistocene times the coast in these two districts at least seems to have had a uniform history. Some authors have suggested that the Milazzian shore line may be identified, but for this more evidence is required. A table of the stages represented will be found on page 67.

PLEISTOCENE: MIDDLE PALEOLITHIC

Lower Egypt.—The deposits of this stage consist predominantly of Nile silt and fine gravel. Their base is hidden below present level of alluvium, and locally their upper part fills pre-existing hollows such as Wadi el-Tumilat. In every respect therefore they are typical products of aggradation. At the southern end of the area their summit is about 25 feet above alluvium, but northward they mount to about 30 feet (Pl. X *A*). They form locally a striking feature along the Western Desert edge, where they are burdened with wind-blown sand. North of el-Khatatbah also they are especially noticeable and overlap deltaic sands and limy beds correlated with older terrace gravels. They occur sporadically on the east bank and in Wadi el-Tumilat, which during the previous degradation had drained westward into the Delta. Their importance lies above all in the indication that they so clearly give of Middle Paleolithic degradation and conformity to a base level below present sea-level and of ensuing aggradation above that datum. The implements that they contain are likewise significant, being of a type younger than those found in the 30- and 10- to 15-foot terrace gravels of Upper Egypt but comparable with those of gravels rising above 15 feet in Middle Egypt and those of deposits in the Hawarah Channel and in the Faiyum. The silts contain implements similar to those of the surface washes that spread over the gravels of ᶜAbbasiyyah. The history of Wadi el-Tumilat during this phase (see Figs. 14 and 21) is analogous to that postulated for the Faiyum in *OIP* Volume X.

Erythrean region.—The series of benches, beaches, and coral platforms (see Pls. XIV–XVI) is described on pages 60–62. Special importance attaches to the fact that Middle Paleolithic implements have been found in the wadi gravels of the 10- to 15-foot terrace in the Safagah–el-Kusair district, for thereby a first step has been taken in the definite linking of Pleistocene formations west and east of the Red Sea Hills. The absence of corals at certain stages marked by marine and terrestrial deposits may indicate a short-lived submergence (see p. 65 and Figs. 15–20).

The Delta

After the Middle Paleolithic aggradation the Nile took a further plunge, the visible evidence of which is to be found south of Hilwan and Sakkarah and in borings within the Delta. Moreover, surface washes on the silts described above (p. 96) contain implements of younger Paleolithic industries which elsewhere within the region are not seen *in situ*. The knowledge derived from boring is still incomplete, but is sufficient to show that there is a Lower Buried Channel, of which the bottom has not yet been reached, consisting of typical Plio-Pleistocene sands and gravels. Hornblende sands and silts lie above; then come silts rich in mica and hornblende forming the Upper Buried Channel, of which the higher reaches have been traced in Middle Egypt and found to be of Sebilian (post-Middle Paleolithic) age (see p. 75 and cf. Figs. 21–22). With the silts of the Upper Buried Channel must be included the basal parts of the Middle Paleolithic sands, gravels, and especially silts which occur to a depth of some 100 feet below present alluvium near the Delta Barrage. A definite impression cannot yet be formed of the depth to which deposits of the Upper Buried Channel may descend; but, if the hornblende sands are deemed to be part of it (since they seem to be associated with it rather than with the Lower Buried Channel), a depth of at least 100 feet below sea-level at el-Zakazik can be assumed.

Surmounting the varied deposits of the Delta is the "terre végétale" of Fourtau (see p. 76), of which the rate of accumulation by annual inundation is known. It represents a period of about 10,000 years (see p. 74 f.). Since this heavy silt wraps round the desert edge and islands (turtlebacks) of older deposits (see p. 76) within the Delta, there is reason to suppose that its lower layers contain some of the oldest relics of civilization. Unfortunately its waterlogged condition makes exploration excessively difficult.

Lake Maryut

Some notes and observations upon the coastal ridges and dunes west of Alexandria are given. It appears probable that they were accumulated by wind rather than under the sea. They lie on marine *Cardium* beds which seem to sink seaward (see Fig. 23). When traced toward Alexandria the ridges are found to lie on waterlogged Nilotic alluvium, their instability in this district thus being patent. Submergence within historic times of the ridges and of the town situated upon them thus seems to be readily explained and to be a natural corollary of such stratification. Whether the ridges farther west have been elevated is an unsolved problem. Certain analogies may be made between the western and eastern corners of the Delta, and in both districts some indications of age may be obtained from a study of relation to alluvium or to flint implements. The ridges are illustrated in Plates XI and XIII *A*.

CLIMATE

Lower Egypt

At the present day the margins of the Delta and the Delta itself receive a substantial rainfall in winter. Locally either wind or rain erosion may be dominant, or the two may be inextricably mixed. The plains of the Western Desert bear many signs of intense rain erosion, but the nature of the pebbly surfaces renders them arid. Wind erosion is therefore very severe. At the present day cereal and other crops are raised without irrigation and large herds maintained along the coast southwest of Alexandria. Greco-Roman cisterns and other devices for conserving rainwater have been in ruins for more than a thousand years, and vegetation seems to suffer severe depredations at the hand of man (cf. Pls. XII and XIII *A*). Between Cairo and Suez there are many indications of former rainfall heavier than the present (Pls. IX and

XIII *B*). On the whole, although there has evidently been a slow increase in aridity, the climate is still far from being arid during the winter months; but the summer is more severe here than on the north side of the Mediterranean.

Erythrean Region

In the past, as at present, the whole of this region has been subject to sudden and severe floods from the hills. Later Tertiary and Pleistocene deposits show that on the whole more and larger material was carried farther than is now the general rule. Whatever the general climate, such a mountainous region will in any event lead to severe floods, and the record of their passing will be preserved while finer deposits of more normal times will be swept away. Of the intense activity of running water in the past there is overwhelming evidence on every side (cf. Pls. XIV and XVI).

HUMAN INDUSTRIES

A short chapter is devoted to a discussion of the Paleolithic implements found in the regions under observation. Their stratigraphic relations are given on pages 95 f. The industries, terraces, and deposits may be tabulated as follows:

Lower Egypt[1]

PLIOCENE

Summit of Pliocene marine submergence at about 660 feet (200 m.)

PLIO-PLEISTOCENE (SEE ALSO FIG. 9)

820	(250)	S	
765	(233)	S	
360	(110)	S	

PLEISTOCENE

320–265	(98–80)	Al.	Sicilian
230–200	(70–61)	Al.	Milazzian
ca. 150	(*ca.* 46)	Al.	Milazzian?
100	(30)	Al.	Tyrrhenian (primitive Chellean to Acheulean)
50	(15)	Al.	Monastirian (Acheulean [by analogy])
−100?–+30	(−30?–+9)	Al.	Monastirian (Middle Paleolithic [with late types])
−100 or more	(−30 or more)	S	Monastirian (Sebilian and later [by analogy])
− 33–0	(−10–0)	Al.	Approximately the last 10,000 years

Erythrean Region[2]

					WADI TERRACES							
Near Suez			72	(22)	55	(17)	28	(9)	16–10–6	(5–3–2)	
Safagah-el-Kusair	100–90	(30–27)	70	(21)	50	(15)	30–25	(9–8)	15–10	(5–3)	(early Middle Paleolithic)
					MARINE BEACHES							
Near Suez					51	(16)	26	(8)	8	(2)	(storm beach)
Safagah-el-Kusair	90	(27)	70	(21)	50	(15)	25	(8)	10?	(3?)	
					CORAL SURFACES							
Near Suez							26	(8)	6	(2)	
Safagah-el-Kusair			70?	(21?)			25	(8)	?		

The implements of the 10- to 15-foot gravels are comparable with the older types of the 10- to 15-foot stage of the Nile Valley in Upper Egypt.

[1] Levels are given in feet (meters [fractions omitted] in parentheses) above or below sea-level (S) or alluvium (Al.).

[2] Levels above sea.

POSTSCRIPT

While this volume has been in preparation results have been made known by other authors which may now be briefly considered in so far as they bear on problems here discussed.

Of outstanding importance is the work of the Geological Survey of Egypt in the Faiyum; the full results are not yet available, but a general account has appeared in which are given the records of bores put down in the Hawarah Channel, between the Nile and the Faiyum.[1] The maximum depth of alluvial material so proved is 17.4 meters (57 ft.) below sea-level, the surface of the alluvium at the site being 24.63 meters (80 ft.) above sea-level[2] and the channel thus 137 feet deep. There is reason to suppose that it may have been open to this depth from late Paleolithic to perhaps historic times.[3] This concrete evidence reflects in a satisfactory manner the views expressed on the subject in *OIP* Volumes X and XVIII and adds strength to the thesis put forward in the present volume that the youngest deposits of the buried channel of the Delta may exceed 100 feet in depth and penetrate below those of the Middle Paleolithic degradation. On the whole the conclusions of the official survey do not seem to call for drastic alteration of earlier views on the Faiyum and Nile-Faiyum divide given in these volumes.

A. C. Blanc has shown by recent work[4] that the Mediterranean sank to low levels in late glacial times. He concludes from studies especially in Italy that the sea-level was lowered by at least 95 meters (312 ft.). Such depths are so far proved in the Nile Delta only near the seaward margin, but the bottom of the deltaic material has nowhere been plumbed. The conservative estimate of 100 feet or more for the younger of the two buried channels here given, based on available figures, may eventually prove to be an underestimate.

[1] Little, "Recent geological work in the Faiyûm and in the adjoining portion of the Nile Valley" (Institut d'Égypte, *Bulletin* XVIII [Le Caire, 1936] 201–40).

[2] *Ibid.* p. 221.

[3] *Ibid.* p. 227.

[4] See "Le dune fossili di Castiglioncello e la regressione marina post-tirreniana" (*Rivista geografica italiana* XLII [Firenze, 1935] 1–14); "La stratigraphie de la plaine côtière de la Basse-Versilia (Italie) et la transgression flandrienne en Méditerranée" (*Revue de géographie physique et de géologie dynamique* IX [Paris, 1936] 129–62); "Low levels of the Mediterranean Sea during the Pleistocene glaciation" (Geological Society of London, *Quarterly Journal* XCIII [London,1937] 621–48). In the last-mentioned paper (pp. 622 f.) Blanc refers to Maurice Gignoux's evidence (*Géologie stratigraphique* [2. éd.; Paris, 1936]) for removing the Monastirian stage and perhaps substituting Tyrrhenian II.

INDEX

[Egyptian place-names include some, such as Cairo, Alexandria, Ismailia, and Luxor, which are thoroughly at home in the English language. In compound names more or less phonetic spellings of certain elements have likewise become relatively fixed in popular English usage. To facilitate pronunciation by the reader such spellings are here retained for the following terms:

Spelling Adopted	Written in Arabic as	Meaning
beni	*banī*	sons
deir	*dair*	monastery
gebel	*gabal*[1]	mountain
gezirah (construct, *-ret*)	*gazīrah* (construct, *-rat*)	island
kom	*kūm*	heap
medinah (construct, *-net*)	*madīnah* (construct, *-nat*)	city
tell	*tall*	mound

On the same basis the Arabic article is here transliterated not as *al-* but as *el-*. An *e* is used for Arabic *a* in a few other cases analogous to the foregoing, e.g. in the names Mex (al-Maks) and Semnah. An *e* takes the place of Arabic *ai* in Beni Suef and of Arabic *i* in Kena. An *i* takes the place of Arabic *u* in Hilwan. An *o* is used not only for Arabic *u* in Kom and in elements harmonized therewith (e.g. Kom Ombo) but also for Arabic *au* in el-Rodah and Hof and for Arabic *aww* in Abu Roash.

For the greater part, however, the geographic names or elements found in this volume are relatively unfamiliar to English or American readers. The written Arabic forms of such terms have when available been exactly transliterated in our Index. In the text proper the same spellings are used, but diacritical markings are omitted. Cross-references to spellings used in the Prehistoric Survey's previous reports and to other common spellings are also included in the Index. The original Arabic forms have been obtained primarily from the map of Egypt 1:50,000 by the Survey of Egypt, supplemented by its English and Arabic volumes of indexes to place-names appearing on its 1:100,000 map series and by Baedeker's *Egypt and the Sudan*, 8th ed. (Leipzig, 1929).[2]

The system followed for exact transliteration is that worked out for the archives of the Oriental Institute by Dr. A. A. Brux and published under the title "Arabic-English transliteration for library purposes" in the *American Journal of Semitic Languages and Literatures*, October, 1930, Part 2. Previous systems are discussed, and the reasons behind the Oriental Institute's system given, in Dr. Brux's paper. The problem of geographic names in particular is treated at its end.—EDITOR.]

[1] Since in Egypt *j* is sounded as *g*, we use the latter symbol throughout our Egyptian place-names.

[2] Edited by Georg Steindorff. Arabic transliterations apparently by Dr. Curt Prüfer; see its p. xxviii.

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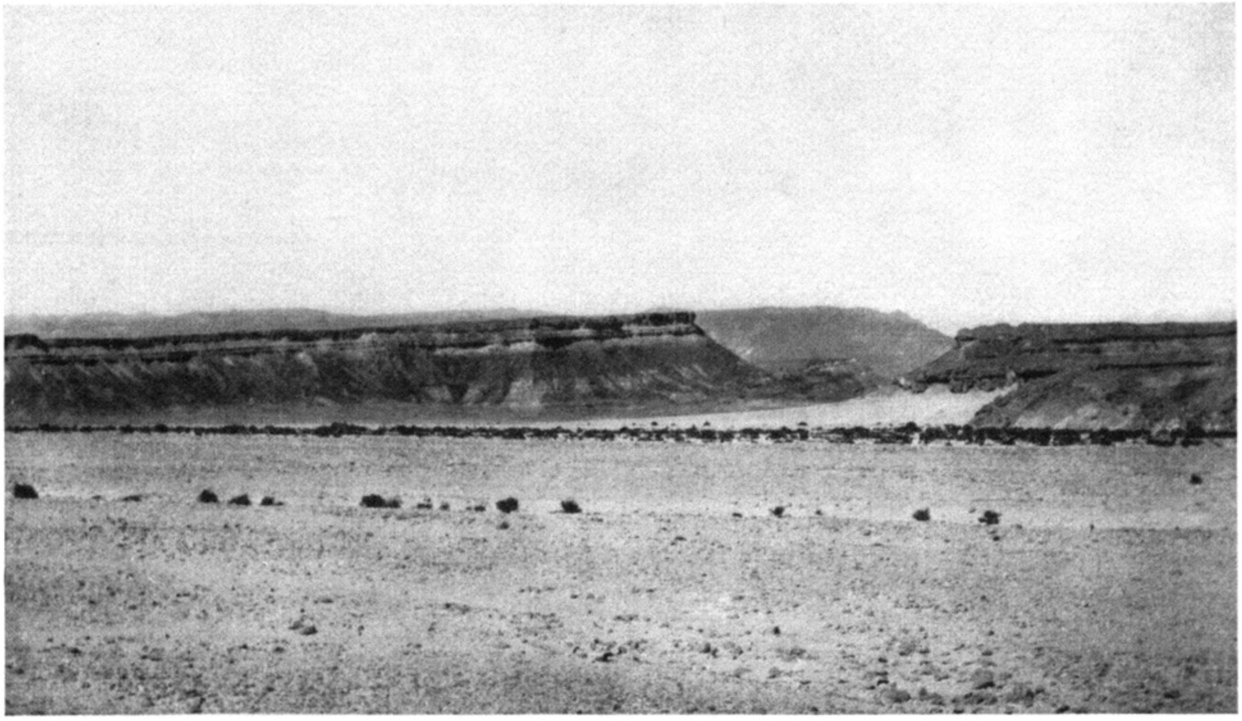
PLATES

A

B

A.—Giran el-Ful, with conglomerate of basal Oligocene or Upper Eocene age on Cretaceous rocks at the right. *B*.—Gebel Shubra Wit, west of Great Bitter Lake, showing folded Cretaceous and Eocene strata with Pliocene conglomerate in the foreground and on the left.

PLATE II



A

B

A.—Miocene rocks, slightly folded and breached by a wadi, near Gebel el-Barabir, south of Gebel ᶜAtakah, which appears in the background. *B*.—North flank of Gebel ᶜAtakah, showing inclined Miocene beds truncated by 70-foot wadi terrace; Gebel ᶜUwaibid in the background.

PLATE III

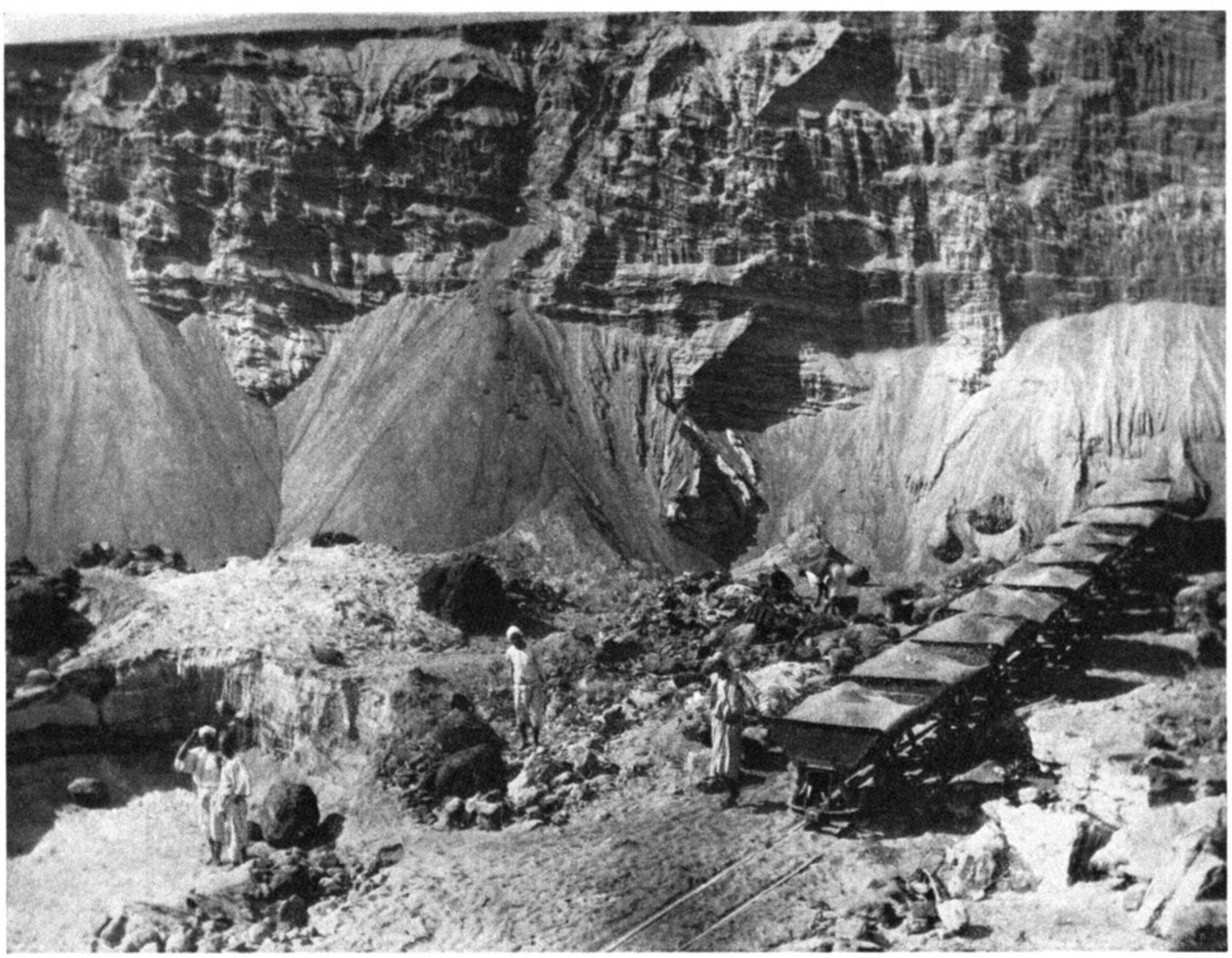
A

B

A.—Summit of Gebel el-Khashab west-southwest of the Gizah pyramids, showing Pliocene wadi gravels cutting across Oligocene deposits. *B.*—The Pliocene and Plio-Pleistocene gravels of Gebel el-Khashab.

PLATE IV

A



B

A.—Plio-Pleistocene sands, Heliopolis. *B*.—False-bedded Plio-Pleistocene sands near Mena House, Gizah pyramids

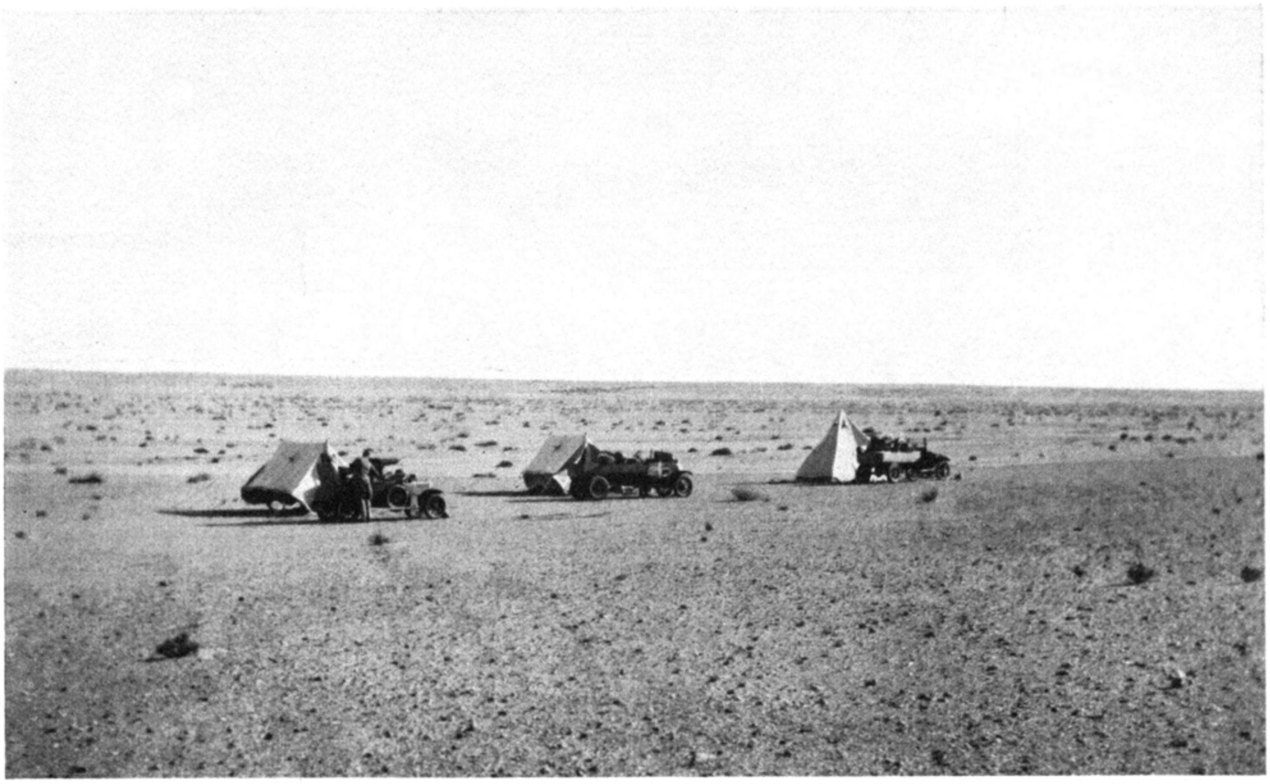
PLATE V

A

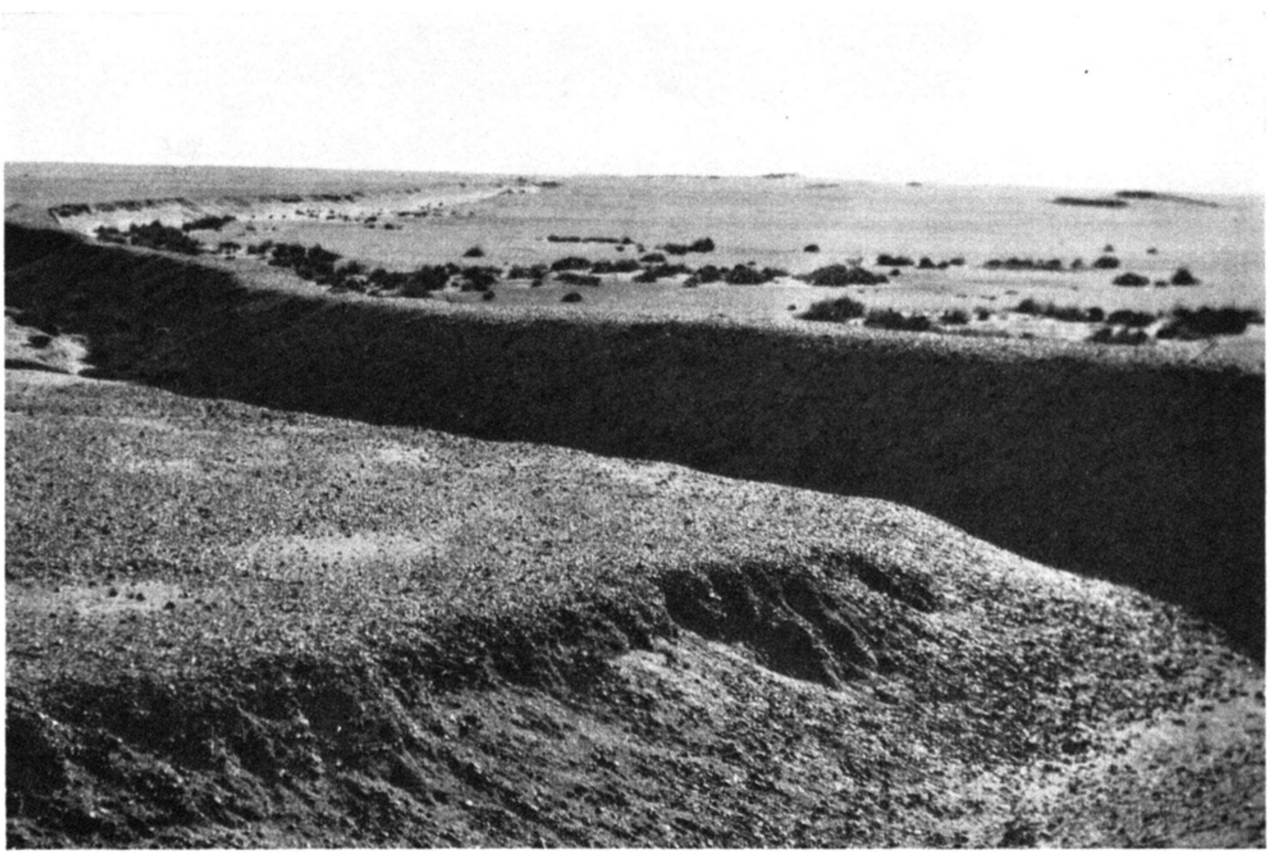
B

A.—Plateau of Plio-Pleistocene sands and fine gravels forming the north side of Wadi el-Natrun near its western end. *B*.—Wadi el-Natrun from scarp of Plio-Pleistocene gravels; view across depression of Lower Pliocene clays to southern scarp; Bir Hooker and salt lakes in the middle distance.

PLATE VI



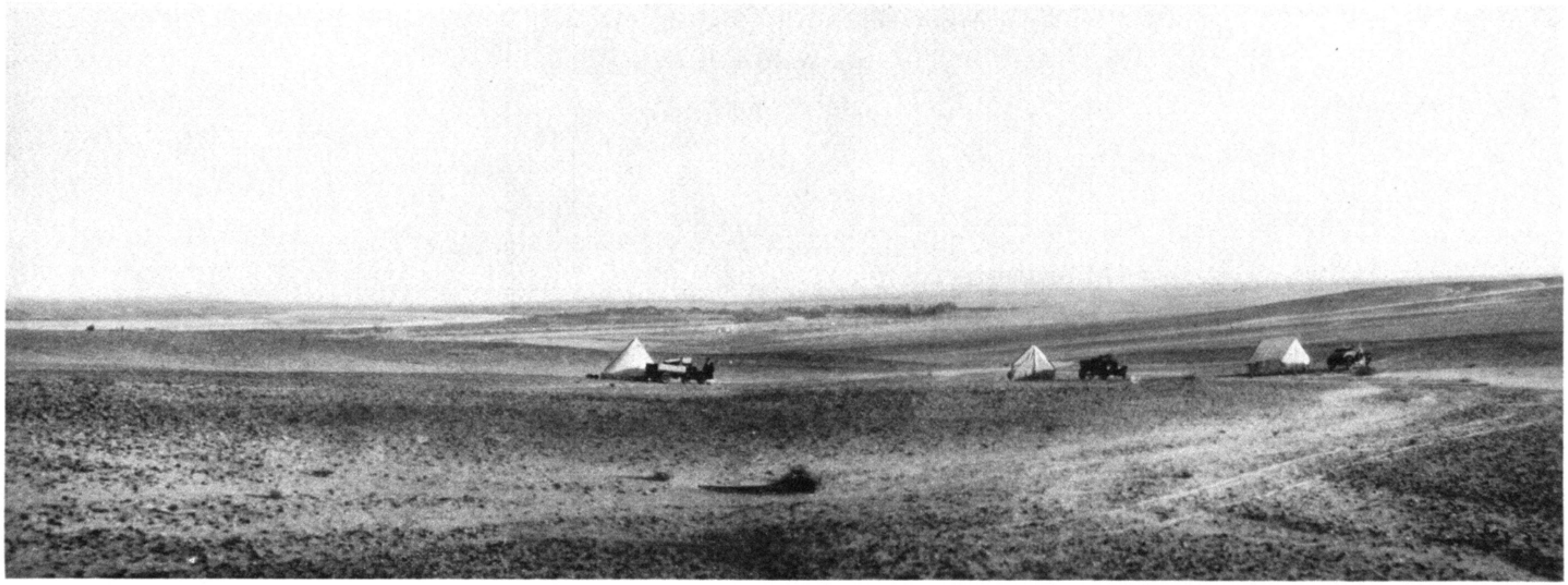
A



B

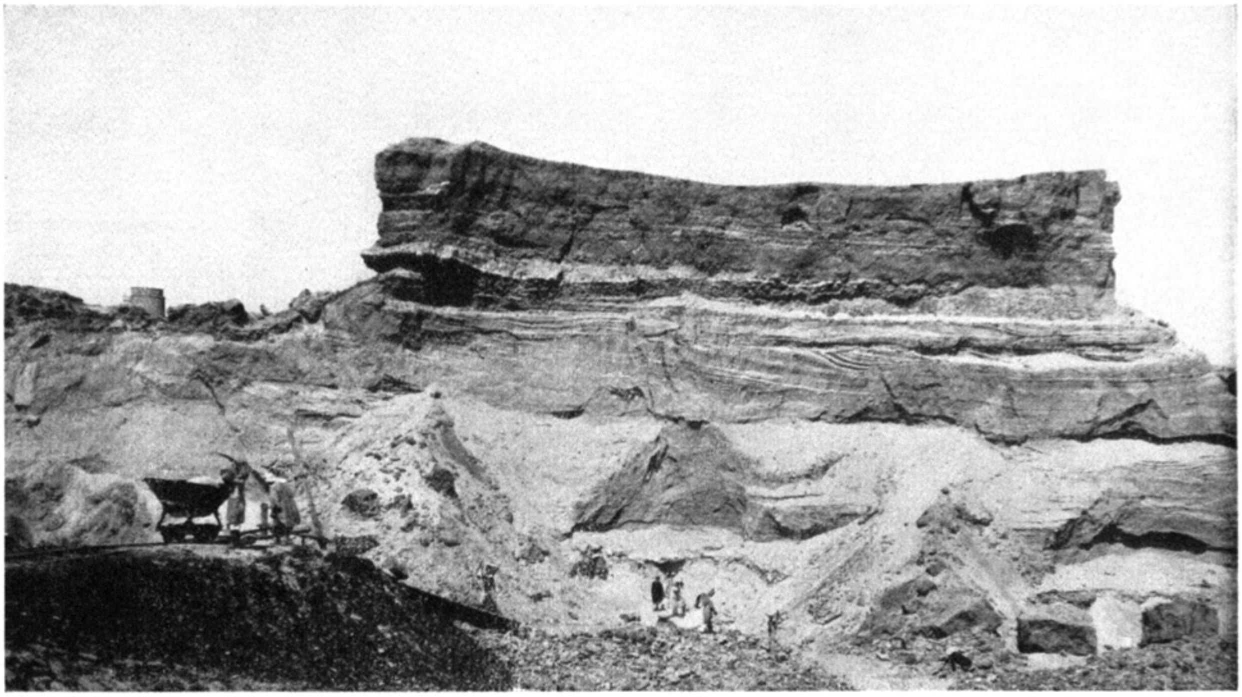
A.—Gravel plains east of Bilbais. *B*.—Gravels of the Tell el-Kabir "island," showing sections exposed by ʿArabi Pasha's trenches of 1882.

PLATE VII

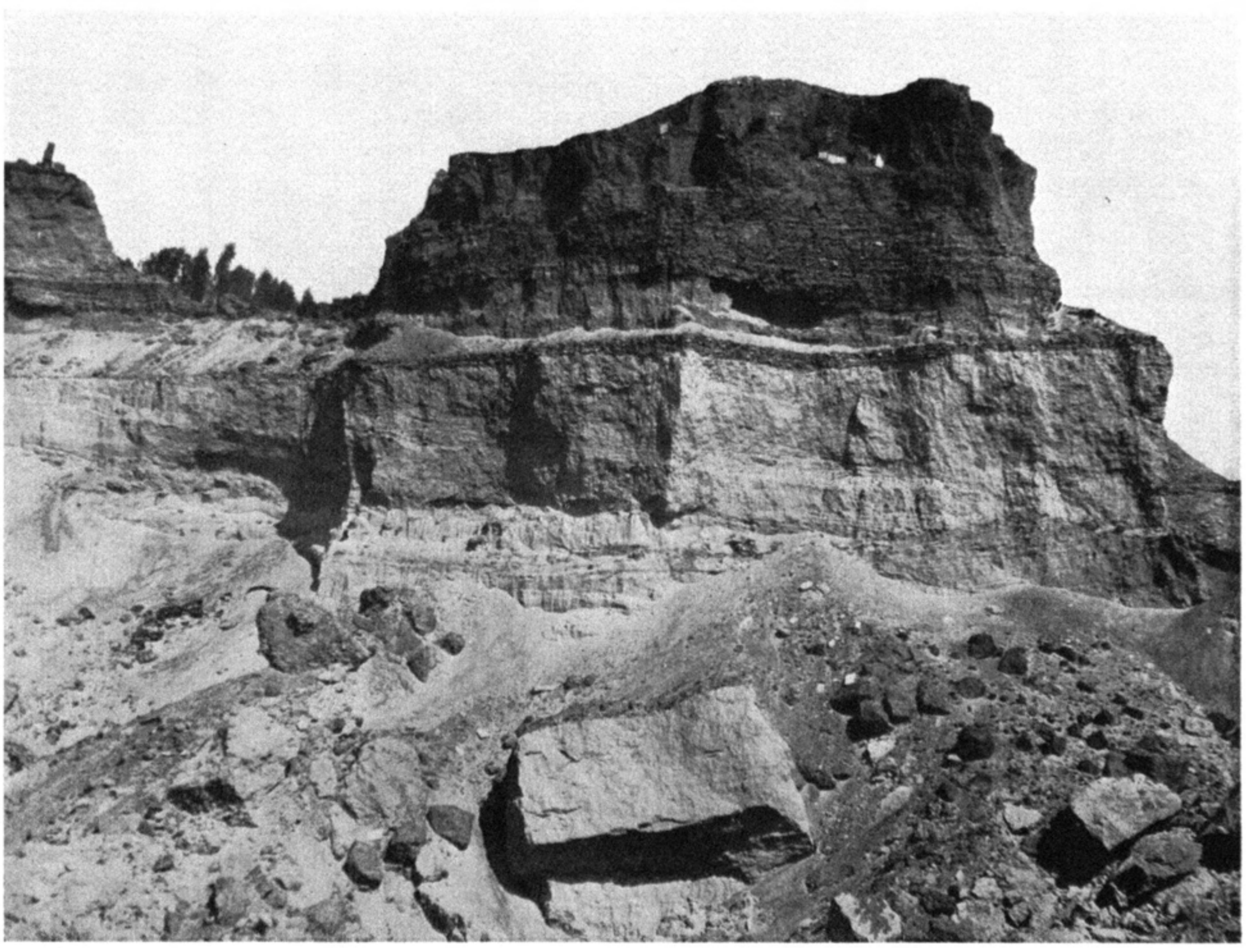


El-Khatatbah, Showing High Terrace (320–265 ft.) on the Right, 150-Foot Terrace in the Foreground, Abandoned Meander of 100-Foot Terrace in Right Center, Nile and Alluvium of Delta in the Center and on the Left

PLATE VIII



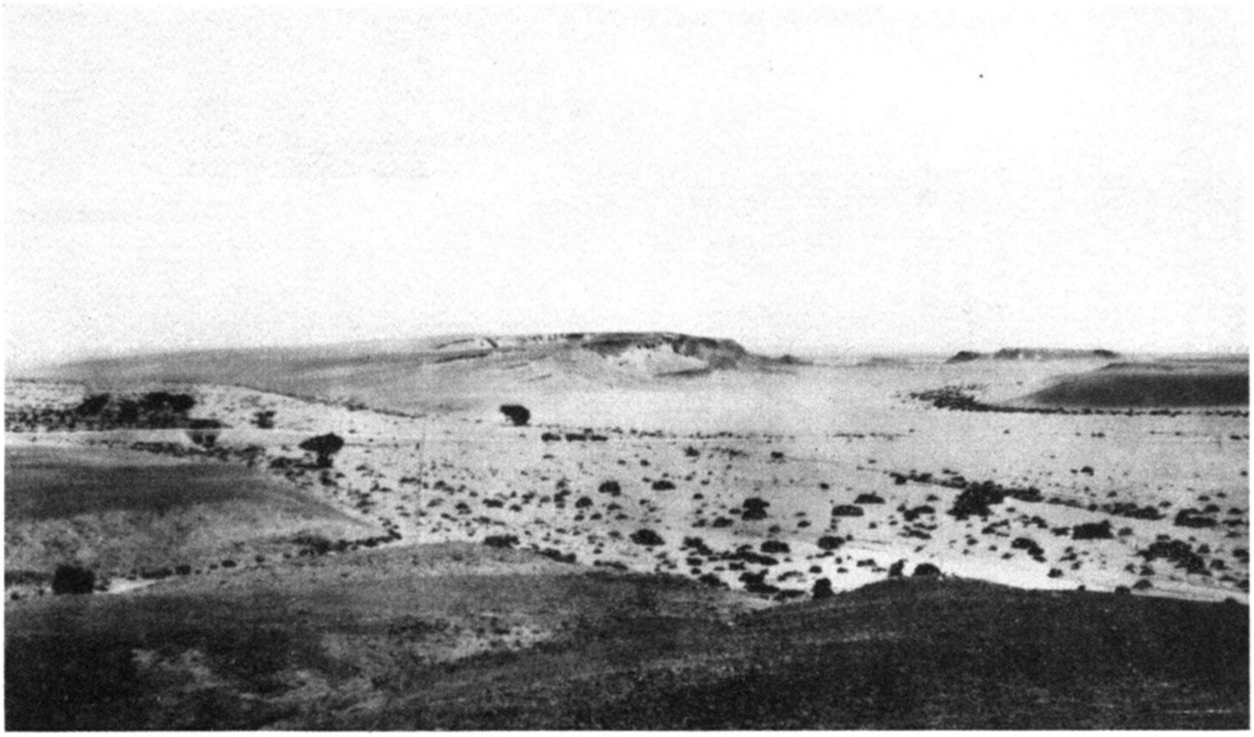
A



B

A.—Lower Paleolithic gravels of ʿAbbasiyyah resting on white Plio-Pleistocene sands. *B*.—Lower Paleolithic gravels of ʿAbbasiyyah, showing succession and silt at summit.

PLATE IX



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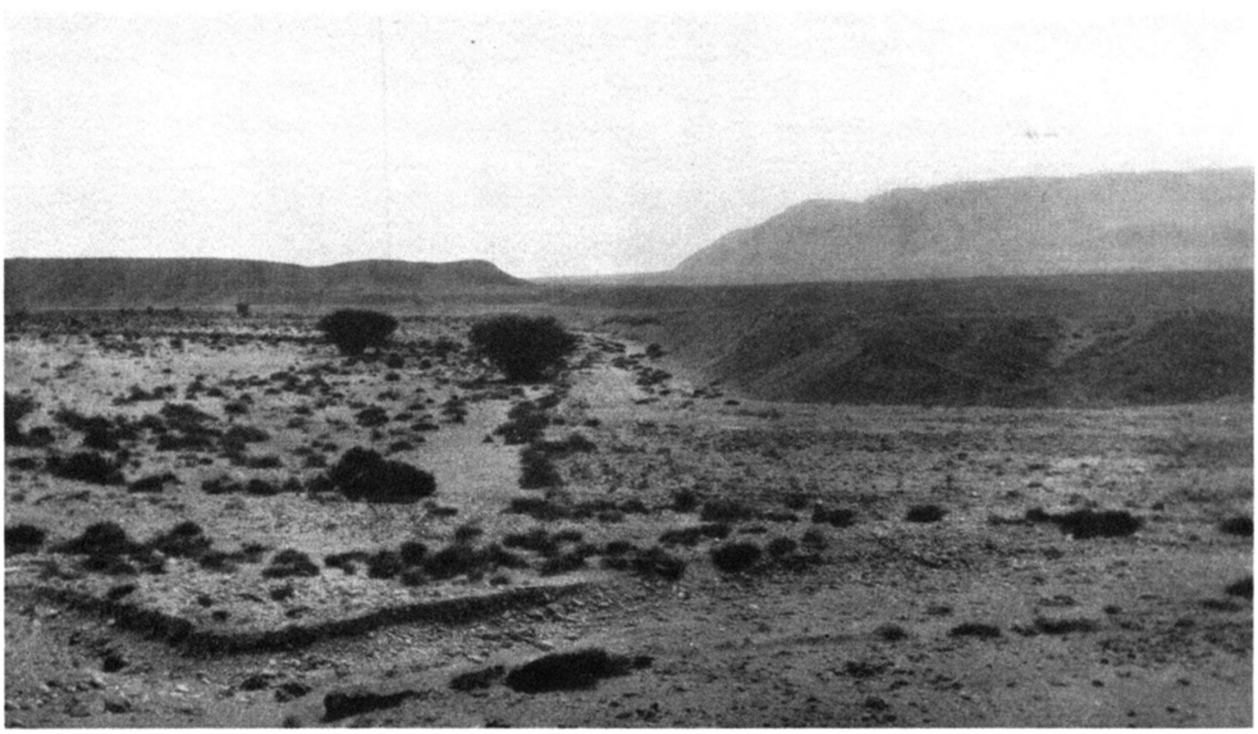
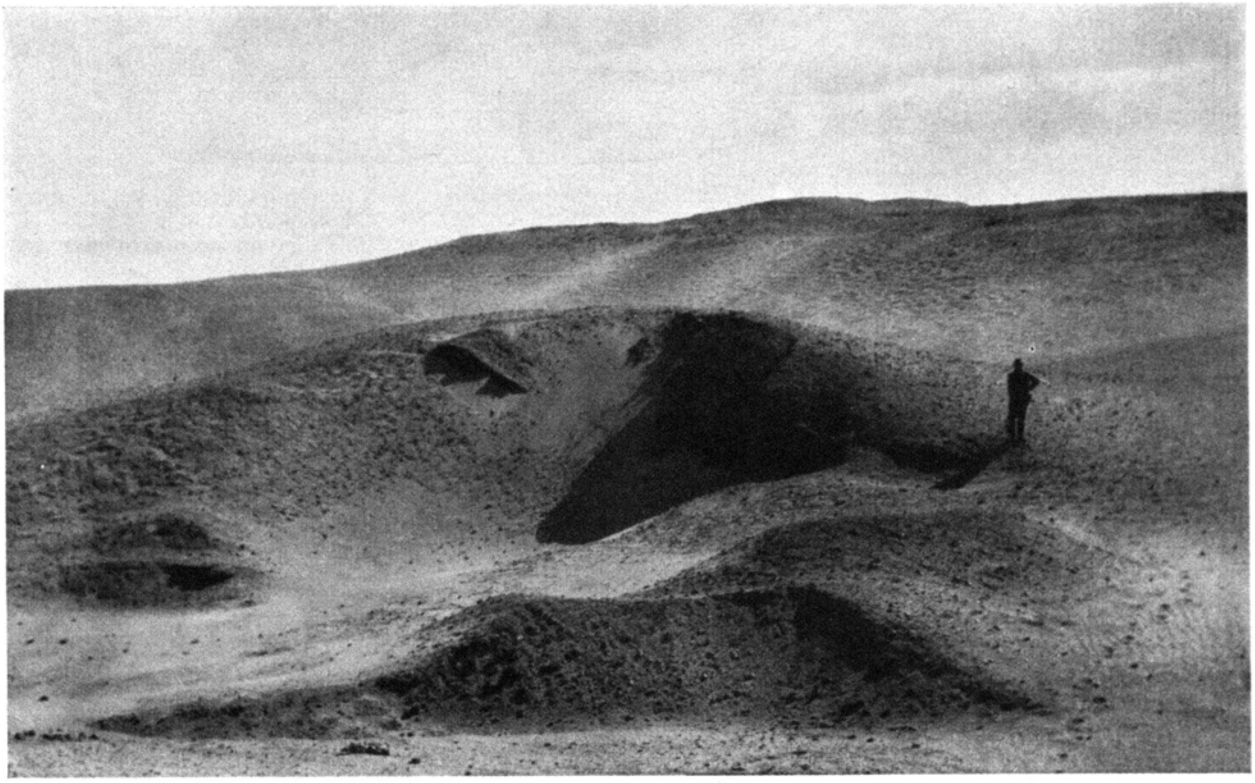


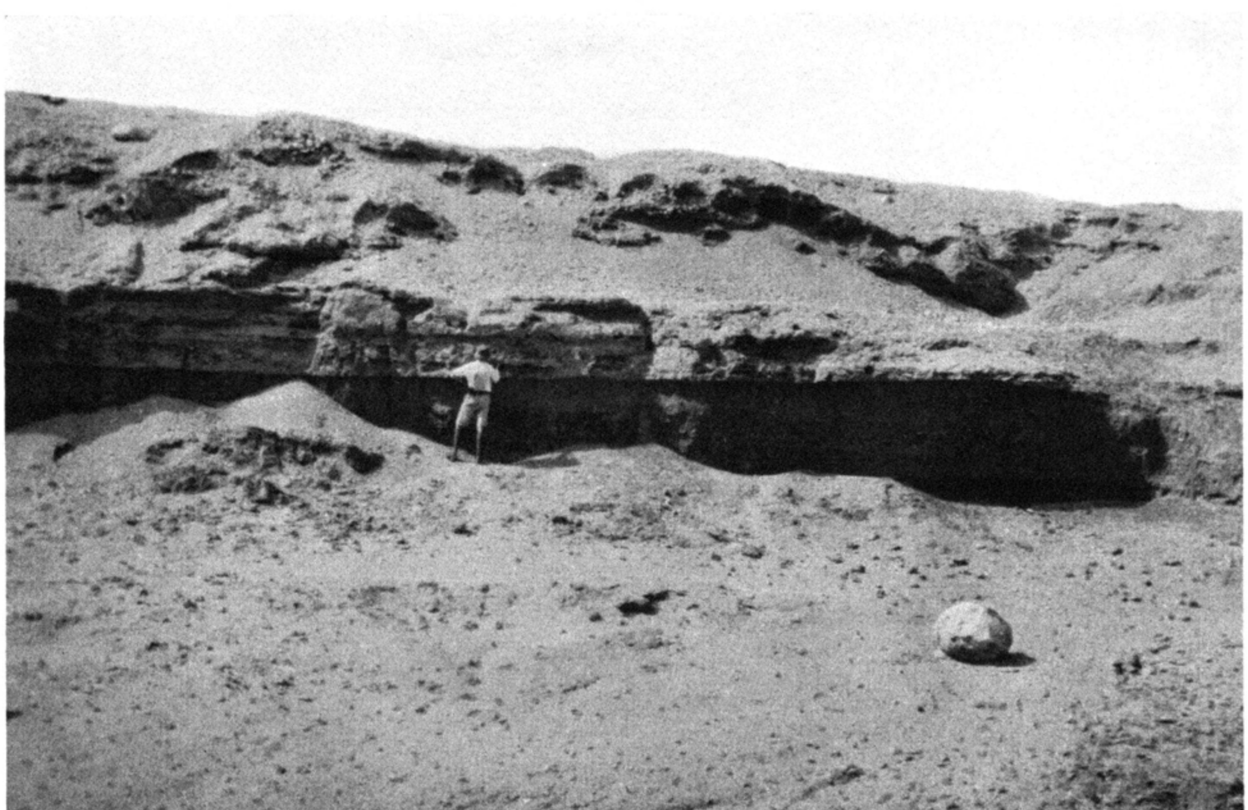
B

A.—Wadi terraces (on left and right) near the northern flank of Gebel ʿAtakah, near kilometer post 98 on the Cairo–Suez road. *B*.—Wadi terraces along the northern flank of Gebel ʿAtakah (on right sky line): 15-foot terrace on the right, 70-foot terrace on the left.

PLATE X



A



B

A.—Middle Paleolithic silts (exposed to left of figure) of Zawiyat Abu Musallam, between the pyramids of Abu Sir and Gizah. *B.*—Old Nile silts covered by local terrace gravels north of Hilwan.

A

B

Oölitic Sands of the Ridge North of Burg el-ʿArab at Taposiris, near the Roman Lighthouse

A

B

A.—Southern part of the Maryut upland plain, semidesert about midway between Wadi el-Natrun and the Mediterranean coast. View looking southward to bare desert. *B.*—Gravel desert south of Biᵓr Victoria, between el-Khatatbah and the east end of Wadi el-Natrun.

A

B

A.—Spring flowers at the west end of Lake Maryut; oölitic sand ridge north of Burg el-ʿArab in the background.
B.—Vegetation in Wadi el-Gafraʾ, near the palace of ʿAbbas I between Cairo and Suez, with bare desert adjacent to wadi.

A

B

A.—Wadi Kuwai', midway between Safagah and el-Kusair, showing variegated sands and gravels capped by deposits of 50-foot terrace. *B*.—Section in small wadi on the north side of Wadi Hamrawain, showing inclined Pliocene beds beveled by 50-foot terrace. View looking northeastward.

PLATE XV

A

B

THE 70- AND 50-FOOT BENCHES AT HEADLAND IMMEDIATELY SOUTH OF WADI HAMRAWAIN

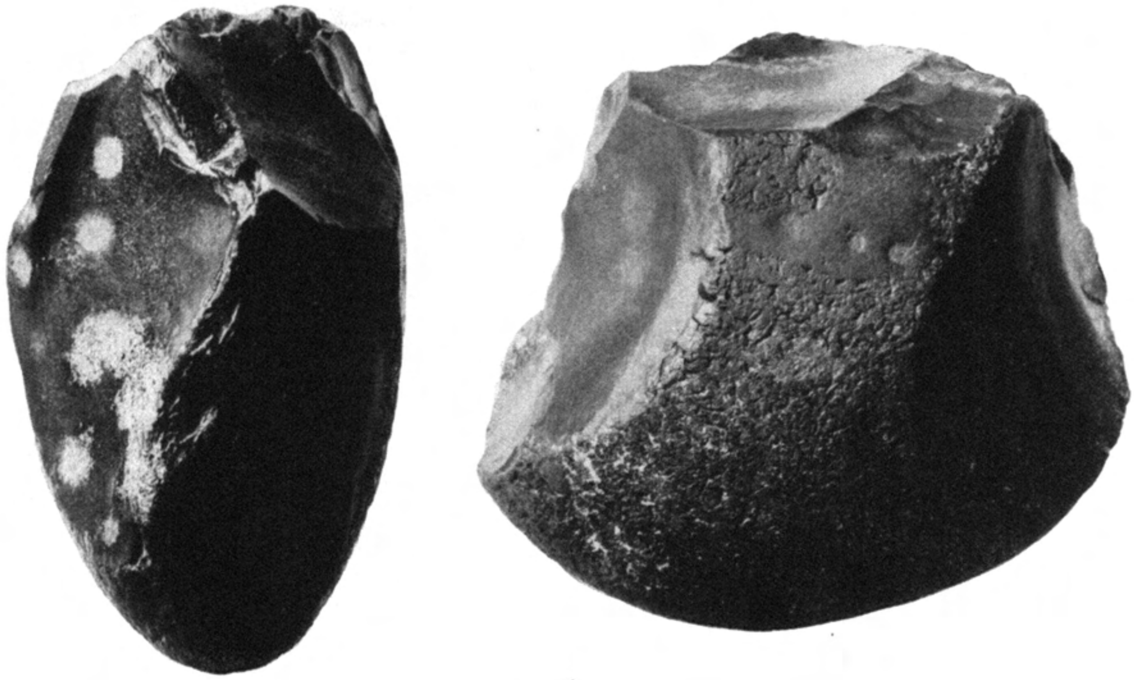
PLATE XVI

A

B

A.—Wadi ʿAnbagi, east of el-Kusair, showing 70- and 30-foot terraces on the right and in the background. *B*.—Wadi ʿAnbagi, showing succession of terraces; Miocene hills in the background.

PLATE XVII



1

2

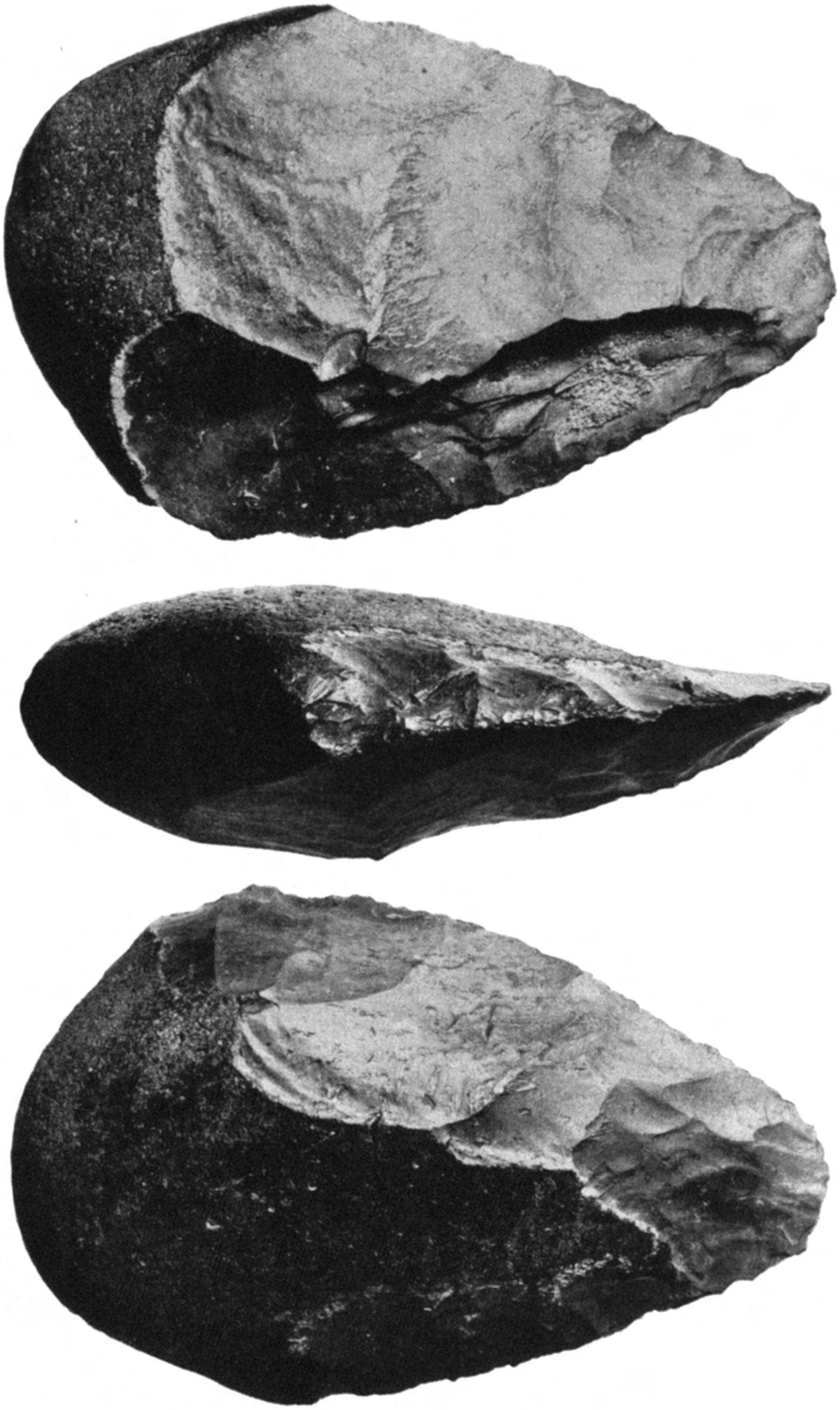
1.—Implement from the Lower Paleolithic gravels of ᶜAbbasiyyah. *2.*—Triangular coup-de-poing from the Lower Paleolithic gravels of ᶜAbbasiyyah (see Pl. XVIII for another view).

PLATE XVIII

2

2.—Triangular coup-de-poing from the Lower Paleolithic gravels of ʿAbbasiyyah

PLATE XIX



3

3.—Acheulean coup-de-poing from the gravels of ʿAbbasiyyah

4

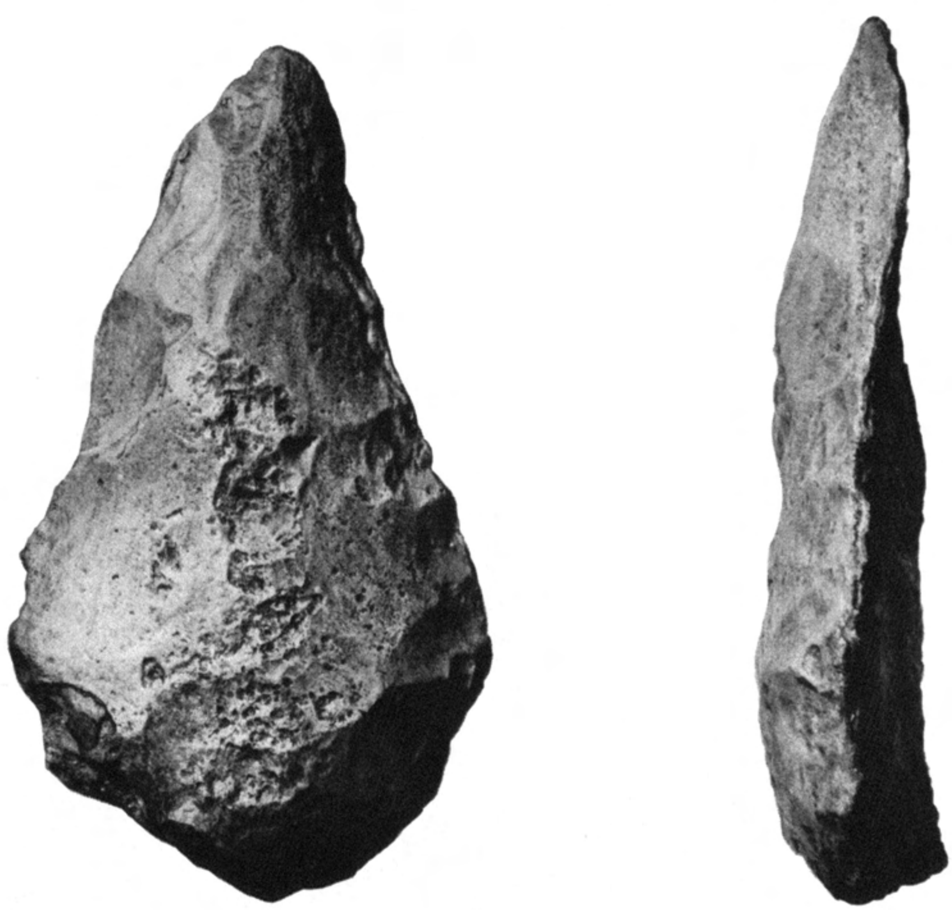
4.—Acheulean implement from the gravels of the 100-foot terrace near the mouth of Wadi Hof, north of Hilwan

5

5.—Disk from the silt capping the Acheulean gravels of ʿAbbasiyyah

PLATE XXII

6



7

6.—Middle Paleolithic core from gravels at the mouth of Wadi Hof, north of Hilwan. *7.*—Acheulean implement from the floor of Wadi el-Natrun near Biʾr Hooker.

PLATE XXIII

8

10

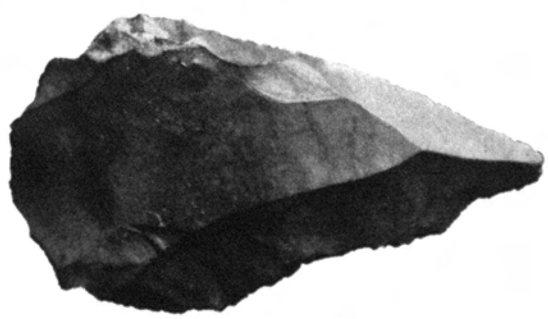
9

8–9.—Cores from the silts of Zawiyat Abu Musallam. *10.*—Disk from the silts of Zawiyat Abu Musallam

PLATE XXIV

11

12



13

11–12.—Cores from the silts of Zawiyat Abu Musallam, No. 12 from a depth of 12 feet. *13.*—Flake from the silts of Zawiyat Abu Musallam.

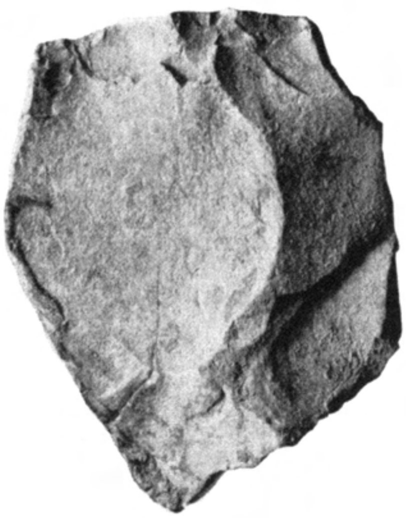
PLATE XXV

19

18

17

20



14

16

15

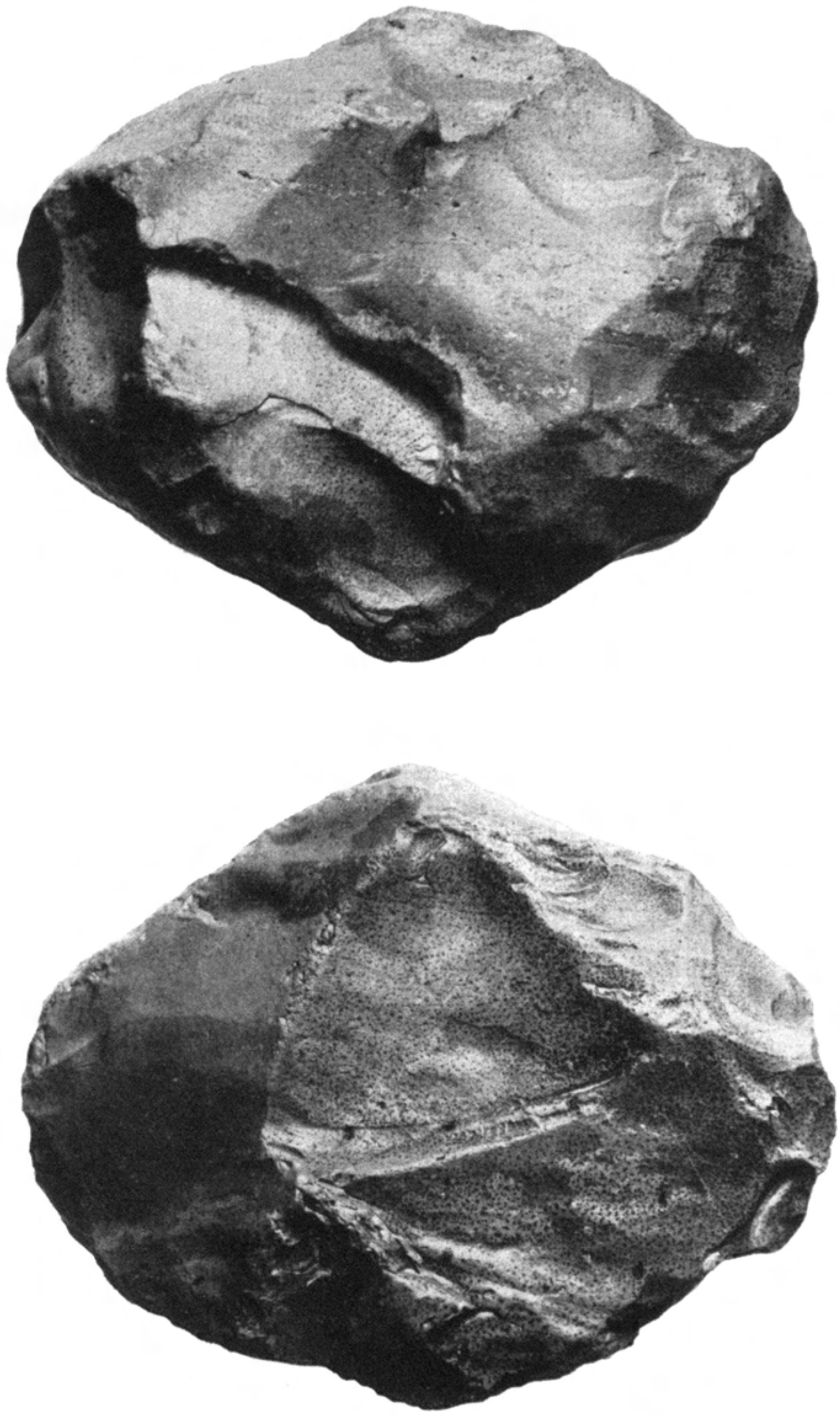
14.—Core from surface wash near el-Khatatbah. *15–16.*—Flakes from surface wash near el-Khatatbah. *17–18.*—Cores from the silts of Wadi el-Tumilat near Abu Suwair. *19.*—Flake from the silts of Wadi el-Tumilat near Abu Suwair. *20.*—Core from the sand dunes near Abu Suwair.

PLATE XXVI

21

21.—Lower Paleolithic implement from the surface near Wadi Saki, headwaters of Wadi Kuwai‘

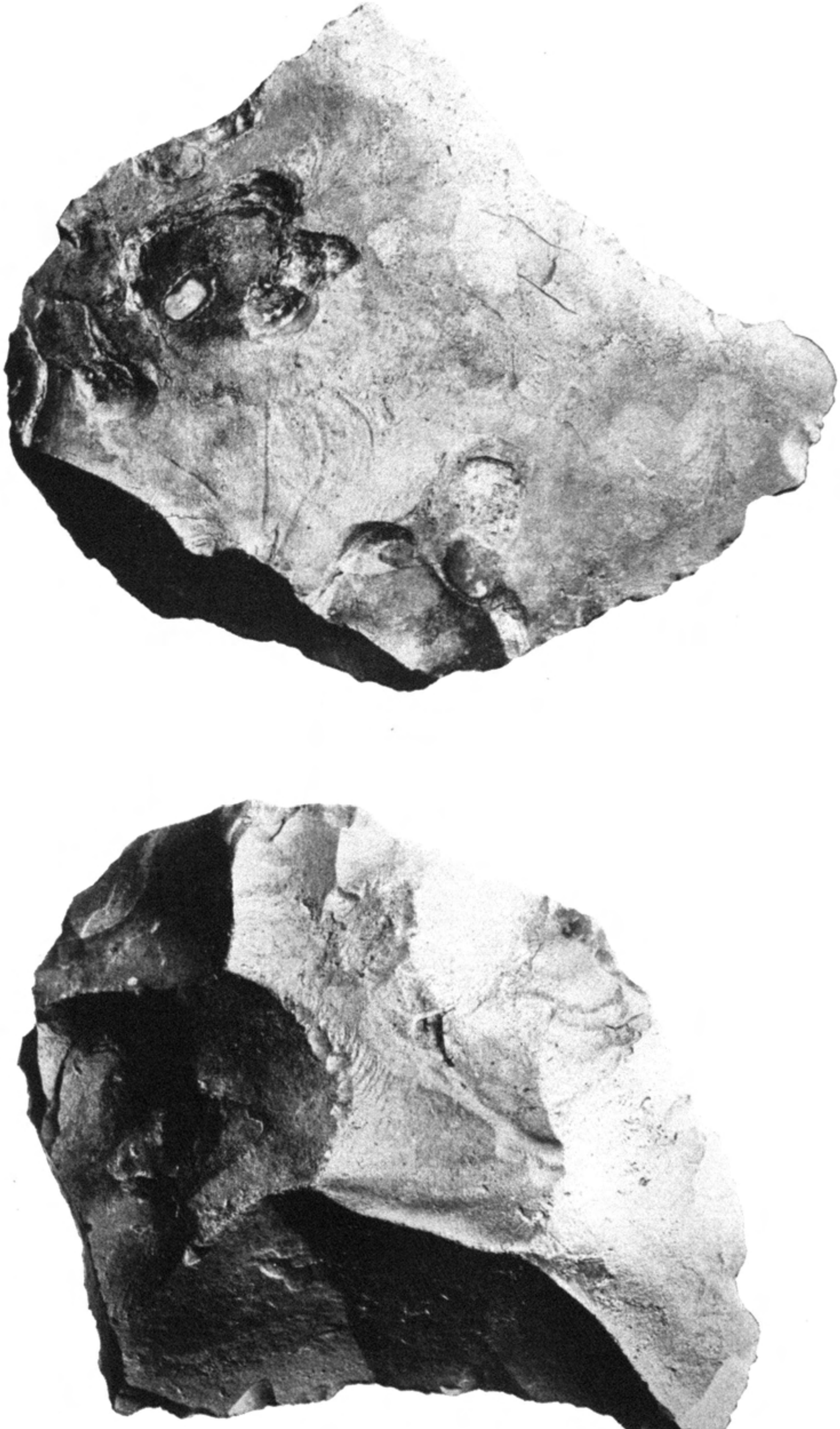
PLATE XXVII



22

22.—Lower Paleolithic implement from the surface of the 25-foot terrace gravels of Wadi Safagah

PLATE XXVIII

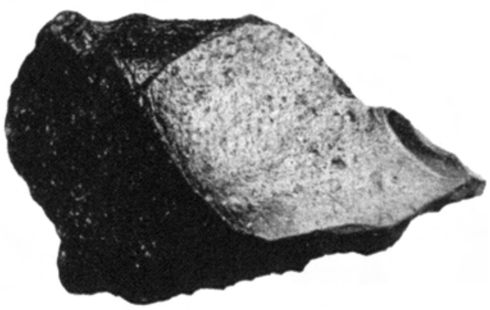


23

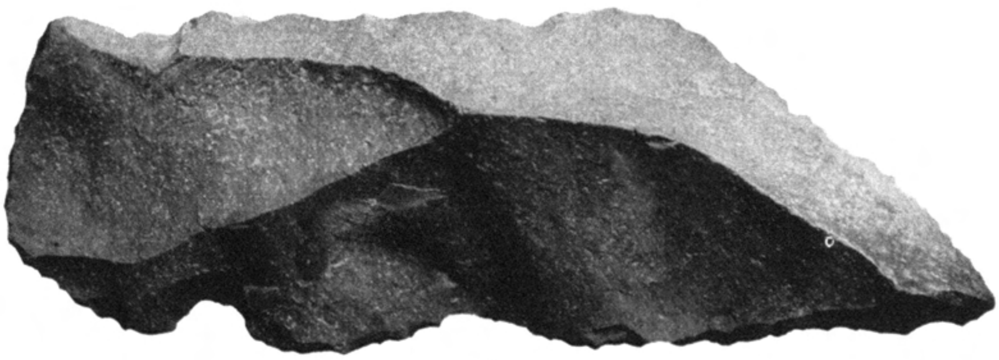
23.—Large flake from the surface of the 25-foot terrace gravels of Wadi Safagah

PLATE XXIX

24

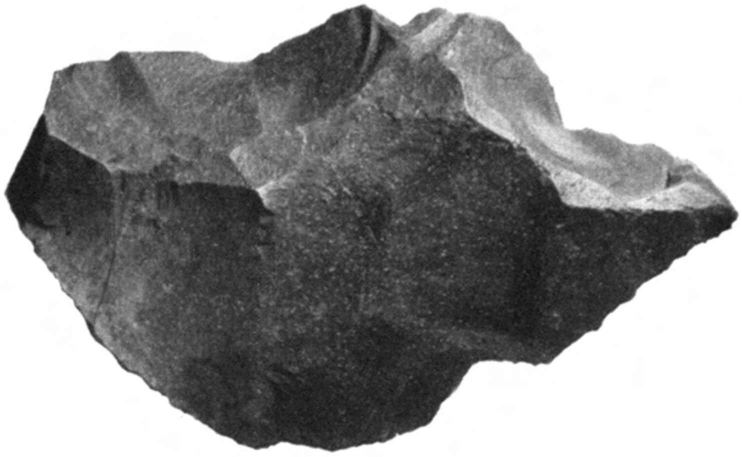


25



26

24.—Disk-shaped implement with bulbar surface from the coastal plain between Wadi Safagah and Wadi Guwaisis. *25.*—Flake with retouched edge from the surface of the 50-foot terrace gravels of Wadi Hamrawain. *26.*—Large flake from the Middle Paleolithic gravels of Wadi Duwi.

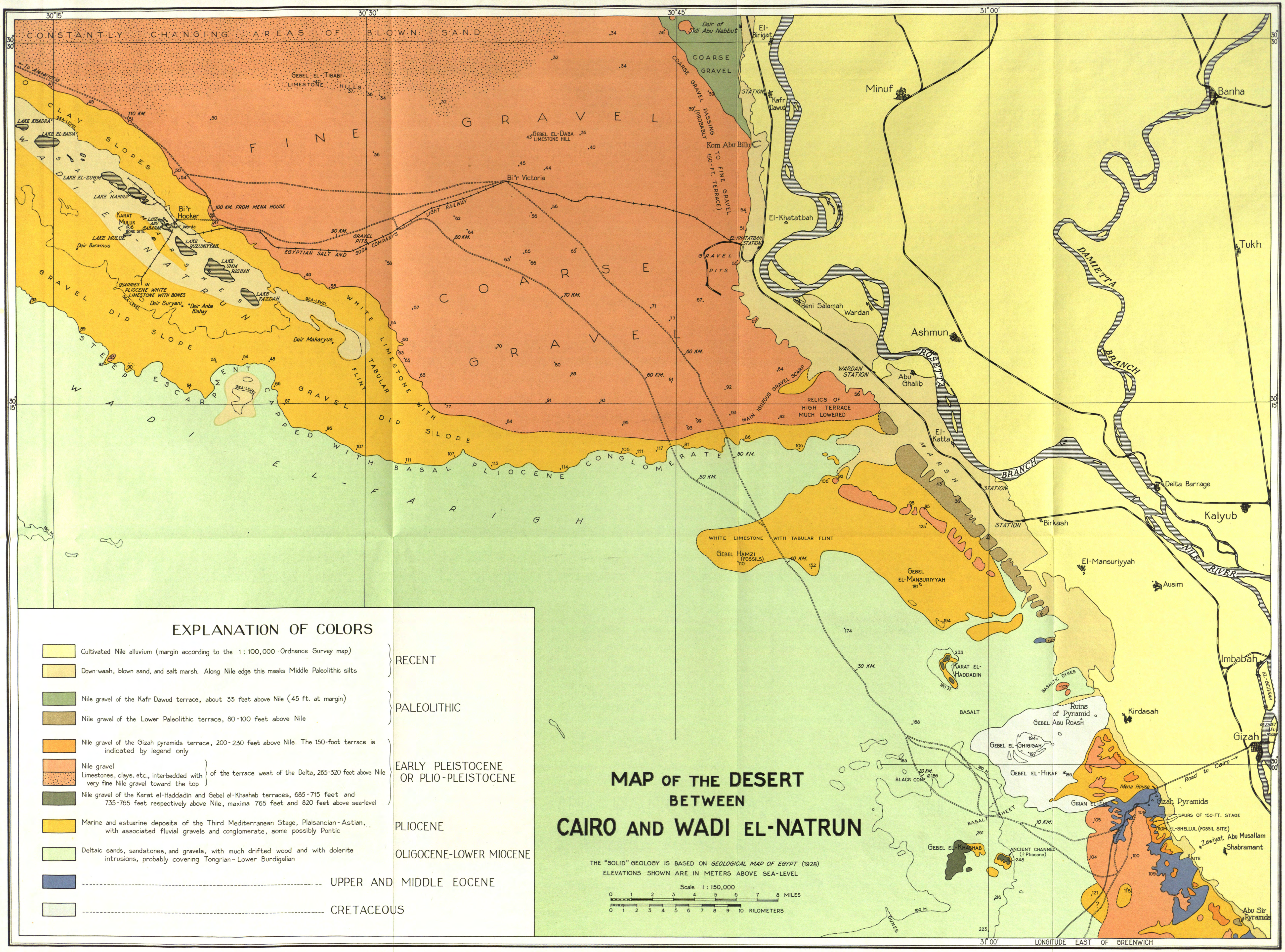


27

28

29

27.—Flake from the Middle Paleolithic gravels of Wadi Duwi. *28–29.*—Thick flakes from the Middle Paleolithic gravels of Wadi Duwi.



MAP OF THE DESERT
BETWEEN
CAIRO AND WADI EL-NATRUN
THE "SOLID" GEOLOGY IS BASED ON GEOLOGICAL MAP OF EGYPT (1928)
ELEVATIONS SHOWN ARE IN METERS ABOVE SEA-LEVEL
Scale 1 : 150,000
0 1 2 3 4 5 6 7 8 MILES
0 1 2 3 4 5 6 7 8 9 10 KILOMETERS
EXPLANATION OF COLORS
Cultivated Nile alluvium (margin according to the 1 : 100,000 Ordnance Survey map)
Down-wash, blown sand, and salt marsh. Along Nile edge this masks Middle Paleolithic silts
RECENT
Nile gravel of the Kafr Dawud terrace, about 33 feet above Nile (45 ft. at margin)
Nile gravel of the Lower Paleolithic terrace, 80-100 feet above Nile
PALEOLITHIC
Nile gravel of the Gizah pyramids terrace, 200-230 feet above Nile. The 150-foot terrace is indicated by legend only
Nile gravel
Limestones, clays, etc., interbedded with very fine Nile gravel toward the top
of the terrace west of the Delta, 265-320 feet above Nile
Nile gravel of the Karat el-Haddadin and Gebel el-Khashab terraces, 685-715 feet and 735-765 feet respectively above Nile, maxima 765 feet and 820 feet above sea-level
EARLY PLEISTOCENE OR PLIO-PLEISTOCENE
Marine and estuarine deposits of the Third Mediterranean Stage, Plaisancian-Astian, with associated fluvial gravels and conglomerate, some possibly Pontic
PLIOCENE
Deltaic sands, sandstones, and gravels, with much drifted wood and with dolerite intrusions, probably covering Tongrian-Lower Burdigalian
OLIGOCENE-LOWER MIOCENE
UPPER AND MIDDLE EOCENE
CRETACEOUS
CONSTANTLY CHANGING AREAS OF BLOWN SAND
FINE GRAVEL
COARSE GRAVEL
COARSE GRAVEL PASSING (PROBABLY 150-FT. TERRACE) TO FINE GRAVEL
GEBEL EL-TIBABI LIMESTONE HILLS
GEBEL EL-DABA LIMESTONE HILL
Bi'r Victoria
Bi'r Hooker
100 KM. FROM MENA HOUSE
EGYPTIAN SALT AND SODA COMPANY'S LIGHT RAILWAY
WADI EL-NATRUN
CLAY SLOPES
LAKE KHADRA
LAKE EL-BAIDA
LAKE EL-ZUGM
LAKE HAMRA
LAKE MULUK
LAKE BUZUNIYYAH
LAKE UMM RISHAH
LAKE FAZDAH
Deir Baramus
Deir Suryani
Deir Anba Bishoy
Deir Makaryus
QUARRIES IN PLIOCENE WHITE LIMESTONE WITH BONES
WHITE LIMESTONE WITH TABULAR FLINT
GRAVEL DIP SLOPE
STEEP ESCARPMENT CAPPED WITH BASAL PLIOCENE CONGLOMERATE
WADI EL-FARIGH
GRAVEL PITS
MAIN IGNEOUS GRAVEL SCARP
RELICS OF HIGH TERRACE MUCH LOWERED
MARSH
WARDAN STATION
GEBEL HAMZI (FOSSILS)
GEBEL EL-MANSURIYYAH
KARAT EL-HADDADIN
BASALT
BASALTIC DYKES
Ruins of Pyramid
GEBEL ABU ROASH
GEBEL EL-GHIGIGAH
GEBEL EL-HIKAF
BLACK CONE
GEBEL EL-KHASHAB
ANCIENT CHANNEL (? Pliocene)
Mena House
Gizah Pyramids
SPURS OF 150-FT. STAGE
KOM EL-SHELLUL (FOSSIL SITE)
Zawiyat Abu Musallam
Shabramant
Abu Sir Pyramids
Road to Cairo
Deir of Sidi Abu Nabbut
El-Birigat
Kafr Dawud
Kom Abu Billu
El-Khatatbah
Beni Salamah
Wardan
Minuf
Ashmun
Abu Ghalib
El-Katta
ROSETTA BRANCH
DAMIETTA BRANCH
NILE RIVER
Banha
Tukh
Delta Barrage
Kalyub
Birkash
El-Mansuriyyah
Ausim
Imbabah
Kirdasah
Gizah
LONGITUDE EAST OF GREENWICH