18. CONTRIBUTIONS to the GEOLOGY of CYRENAICA. By Prof. J. W. GREGORY and others. (Read March 8th, 1911.)

[PLATES XLII–XLIX.]

(A) *The GEOLOGY of CYRENAICA.* By JOHN WALTER GREGORY, D.Sc., F.R.S., F.G.S., Professor of Geology in the University of Glasgow.

[PLATE XLII—MAP AND SECTIONS.]

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I. INTRODUCTION.

CYRENAICA, a province of Eastern Tripoli, is the projection on the northern coast of Africa between the Gulf of Sidra (the Greater Syrtis) on the west and the Bay of Bomba on the east. The name is sometimes used to include Marmarica and the Libyan coast, as far as the still undetermined western frontier of Egypt; but the restriction of Cyrenaica to the wide foreland occupied by the famous Greek colony whose capital was Cyrene renders it a more natural geographical division. It is thus equivalent to the Gebel el Akdar—the Green Hills—of Arab nomenclature; while the Gebel el Akabah—the Abrupt Hills,—its eastward continuation between the Bay of Bomba and the Bay of Salum,¹ is the plateau of Marmarica.

Cyrenaica, as thus restricted, is a land of great classical interest: it includes the ancient Pentapolis; the city of Cyrene stood on the northern edge of its plateau; and the Garden of the Hesperides and the River Lethe lay in hollows in the limestone on its coastal plain.

¹ The spelling of most of the Egyptian place-names is adopted from the recent map of Egypt published by the Geological Survey of that country.

Cyrenaica is, however, geologically the least-known area on the shores of the Mediterranean. The geology of the parts of Egypt near the eastern frontier of Cyrenaica is known from the work of Zittel¹ and Fuchs² at Siwa, and from collections made on the coast of Marmarica at Mersa Tobruk by Schweinfurth,³ and on the Libyan coast by Ball⁴ and by Pachundaki⁵ at Mersa Matruh, about half-way between Alexandria and the Bay of Salum. The correlation of the rocks on the eastern frontiers of Cyrenaica has been carefully discussed by Dr. Blanckenhorn.⁶ An admirable summary of the geological data regarding Cyrenaica was published in 1904 by Dr. Hildebrand, who shows that the existing information was then both scanty and uncertain.⁷

From the evidence available in 1908, three different explanations of the geological structure of Cyrenaica were possible. It might be a fragment of a mountain-loop that had once connected the Atlas with the mountain-ranges of Crete and Asia Minor; or it might be a plateau of Eocene rocks—an outlier of the Mokattam Series of Egypt; or again, it might be a horst of Miocene and Pliocene limestones, once continuous with those of Malta.

The first theory—the connexion between Cyrenaica and the Atlas—was suggested by several considerations, including the probability that the mountains of Cyrenaica had an axial core of ancient rocks.

The first information as to the geological structure of Cyrenaica was collected by Della Cella, an Italian doctor who accompanied a military expedition led by the Bey of Tripoli into Cyrenaica in 1817. Della Cella clearly recognized that the mountains of Cyrenaica were not a simple continuation of the Atlas, though he regarded both areas as composed of similar rocks. He remarks:—

‘In some of my letters, I have attempted to shew, that the mountains of the Cyrenaica form no part of the eastern prolongation of that chain which

¹ K. A. von Zittel, ‘Beiträge zur Geologie & Paläontologie der Libyschen Wüste & der angrenzenden Gebiete von Ägypten’ *Paläontographica*, vol. xxx, pt. I (1883) pp. cxxiv–cxxxvi.

² Th. Fuchs, ‘Beiträge zur Kenntniss der Miocän-Fauna Ägyptens & der Libyschen Wüste’ *Ibid.* pp. 18–66 & pls. vi–xxii.

³ G. Schweinfurth, ‘Ein Besuch in Tobruk an der Küste von Marmarica’ *Marineverordnungsblatt*, No. 47 (1883) pp. 14–29. For reference to the discovery of these fossils, see G. Hildebrand, ‘Cyrenaika als Gebiet künftiger Besiedelung’ Bonn, 1904, pp. 78–79, and M. Blanckenhorn, ‘Neues zur Geologie & Paläontologie Ägyptens, III. Das Miocän’ *Zeitschr. Deutsch. Geol. Gesellsch.* vol. liii (1901) pp. 104–105.

⁴ Maps of the Districts of Mersa Matruh & Ras Allem Rum ‘showing . . . and the Main Outlines of the Surface-Geology’—scale 1 : 25,000. Cairo, 1903.

⁵ D. E. Pachundaki, ‘Sur la Constitution Géologique des Environs de Mersa Matrouh (Marmarique)’ *C. R. Acad. Sci. Paris*, vol. cxxxvii (1903) pp. 350–51; also ‘Contribution à l’Étude Géologique des Environs de Mersa Matrouh (Marmarique)’ *Revue Internationale d’Égypte*, vol. iv (1907) 36 pp., pt. ii.

⁶ M. Blanckenhorn, ‘Neues zur Geologie & Paläontologie Ägyptens, II. Das Paläogen’ *Zeitschr. Deutsch. Geol. Gesellsch.* vol. lii (1900) table facing p. 406; and ‘III. Das Miocän’ *ibid.* vol. liii (1901) table facing p. 52.

⁷ G. Hildebrand, ‘Cyrenaika als Gebiet künftiger Besiedelung’ Bonn, 1904, pp. 77–95.

risers upon the northern border of the African coast, and extends from the western shores of the gulph of the Great Syrtis as far as the kingdom of Morocco; and my observations upon the termination of the gulph demonstrate that there exists no such connexion. But this does not prevent the calcareous constitution of Mount Atlas from forming also the character of the Cyrenean mountains. I am unacquainted with the Atlantic chain of mountains to the west of Tripoli, but I have seen several specimens of the rocks between Tripoli and Tunis, and they display the same character and formation.'¹

He recorded the presence in Cyrenaica of many fossils different from the existing Mediterranean fauna, and he described some of the fossils from the mountains as 'presenting in their fractures the character of Ammonites.'² It therefore appeared possible, from Della Cella's statements, that Cyrenaica might have a foundation of Mesozoic rocks containing Ammonites.

The existence in Cyrenaica of Palæozoic or pre-Palæozoic crystalline marbles seemed also possible. For, according to Della Cella,

'the heart of these mountains consists of a compact chalk which has the usual hardness of all kinds of marble; and, though of secondary formation, and bearing frequent traces of shells, its grain is fine and often glitters like saline marble.' (*Op. cit.* p. 116.)

The Italian traveller Camperio remarked³ in 1882, that the marble used for the statues at Cyrene might either have come from the Greek islands or from the neighbouring mountains. The statues, of which the British Museum has a valuable collection, are of saccharoidal marble, and so also is the one specimen that I have examined in the Louvre. Hence Capt. Camperio's suggestion of the local origin of this material was consistent with the occurrence of a Palæozoic, or perhaps even older, formation in the mountains of Cyrenaica.

Hamilton, in 1856, described the coast-hills from the Wadi Nahr, where the track to Cyrene leads on to the plateau, past Derna towards Ras el Tin, as composed of 'barren sandstone,'⁴ and Dr. Hildebrand⁵ quotes Meier-Jobst as asserting the occurrence of sandstone at Cyrene on the summit of the plateau. These reports suggested that sandstones might play an important part in the structure of Cyrenaica.

The geological evidence connecting the Cyrenaican mountains with the Atlas was indefinite; but it was supported by the con-

¹ Paolo Della Cella, 'Physician Attendant on the Bey': 'Narrative of an Expedition from Tripoli in Barbary to the Western Frontier of Egypt, in 1817, by the Bey of Tripoli; in letters to Dr. Viviani of Genoa, by...; with an Appendix, containing instructions for navigating the great Syrtis.' Translated from the Italian by Anthony Aufrere, Esq. London, 1822, pp. 165-66.

² *Ibid.* p. 165. The original of this passage is as follows:—'Talvolta trovai guarnita di piccoli testacei lentiformi, che nella loro spaccatura presentano i caratteri delle Ammoniti' (Lettera xiii, p. 162).

³ Camperio, 'Una Gita in Cirenaica' *Esploratore*, vol. vi, 1882, p. 16.

⁴ James Hamilton, 'Wanderings in North Africa' 1856, p. 113.

⁵ G. Hildebrand, 'Cyrenaika als Gebiet künftiger Besiedelung' Bonn, 1904, p. 86.

clusions of Sir R. Lambert Playfair, who, in his Presidential Address to the Geographical Section of the British Association in 1890, accepted Cyrenaica (from geographical considerations) as a detached fragment of the Atlas Mountains.

‘The Atlas range’..., he states, ‘runs...through Algeria and Tunisia; it becomes interrupted in Tripoli, and it ends in the beautiful green hills of the Cyrenaica, which must not be confounded with the oases of the Sahara, but is an island detached from the eastern spurs of the Atlas, in the ocean of the desert.’ (‘The Mediterranean, Physical & Historical’ p. 875.)

This view, however, has not received any recent support,¹ and Cyrenaica has been generally regarded as a plateau of Kainozoic rocks. Thus Taramelli & Bellio, on their geological map of Africa,² represent Cyrenaica as composed wholly of Eocene and Oligocene formations; they refer to the country as having been separated from the older rocks of the Sahara by a Pleistocene sea, some of the evidence for which they regard, however, as doubtful.

The occurrence of Eocene rocks in Cyrenaica appeared probable from the identification of nummulites in them. Thus, the Archduke Salvator³ described the walls of the Cave of Lethe as composed of ‘Nummulitenkalk.’ Dr. Hildebrand⁴ quotes a statement by Haimann (‘Cyrenaica’ 1886) that the mountains of Cyrenaica are formed of an Eocene limestone full of nummulites. Hildebrand nevertheless rejected the reported nummulites and Eocene beds as based on unreliable evidence⁵; and, in regard to the rock at the ‘River’ Lethe, his scepticism was justified, for it contains *Orbitoides* and not nummulites. He expressed himself in doubt whether the sandstones reported along the coast of Cyrenaica are the outcrop of an Eocene base of the country, or whether, as he thought more probable, they are a Pliocene or ‘Quaternary’ series deposited upon the flanks of the Miocene limestone (*op. cit.* p. 86). Hildebrand was quite correct in his view as to the recent age of the low-level sandstones; but, despite his remarkably thorough acquaintance

¹ It is, however, consistent with some recent topographical maps, as, for example, C. Diercke, ‘Europa. Bodenverhältnisse’ Schulwandkarten, 1:3,000,000, Brunswick.

² T. Taramelli & V. Bellio, ‘Geografia & Geologia dell’ Africa’ Milan, 1890, pl. ii.

³ [Ludwig-Salvator] ‘Yacht-Reise in den Syrten, 1873’ Prag, 1874, p. 52. Reprinted as ‘Eine Yachtreise an den Küsten von Tripolitaniën & Tunisien.’ Woerl’s Reisebibliothek, Würzburg, 1890, p. 49.

⁴ G. Hildebrand, ‘Cyrenaika als Gebiet künftiger Besiedelung’ Bonn, 1904, p. 83.

⁵ ‘These two records’—those of Haimann and the Archduke—‘are therefore for us especially important,’ says Hildebrand (‘Cyrenaika’ 1904, pp. 83–84), ‘because they are in direct opposition to all others that we know. For there is scarcely any mention of nummulites, which would certainly point to an old Tertiary formation, and still less of formations of the Eocene time. These statements as to age stand quite alone. Besides, they inspire no special confidence. Haimann was neither geographer nor geologist, as may be recognized “Schrift und Tritt.” And the Archduke Salvator also makes no claim to geological knowledge.’

with the literature of Cyrenaica, he overlooked Admiral Spratt's account of the geology of Derna and the identification of a nummulite from Mersa Susa by the late Prof. T. Rupert Jones.

The most precise geological information regarding Cyrenaica was given by Admiral Spratt¹; but, as it was an Appendix to a book on Crete, it has been overlooked. He contrasted the jagged mountains of Crete with the plateaux of Libya extending from Tripoli to the Nile; and he recognized the numerous sudden flexures of the coast, as in the Syrtis, the Gulf of Salum, and at Ras el Tin, as due to faults. His most important contribution to the geology of Cyrenaica was an account of the section at Derna, which he described as composed of a lower series of white or cream-coloured limestones 'full of nummulitic shells resembling those of Crete' (*op. cit.* p. 377); and this lower series, 250 feet thick, he described as passing conformably upwards into yellowish marly sands or sandstone, resembling the yellow sandstones of Malta and containing many of the Maltese fossils. That Spratt's foraminifera were really nummulites cannot be doubted, as one specimen, now in the (Natural History) British Museum, was identified as the Lower Eocene *Nummulites perforata*.²

The identification of nummulites from Cyrenaica having been overlooked or discredited, Cyrenaica has been generally described in recent years as composed of a sheet of Miocene and perhaps also Pliocene limestones. This view was expressed by Dr. Gürich,³ who described the country as mainly Middle Miocene; and he appears to exclude the possible occurrence of Oligocene deposits by reference to the existence of an important gap in this region between the Eocene and the Miocene. Zittel⁴ and Suess⁵ both also accepted Cyrenaica as Miocene. Suess referred to it, though doubtfully, as belonging to the second Mediterranean stage—that is, Upper or Middle Miocene. This view was based on the collections made by Schweinfurth at Mersa Tobruk, on the coast of Marmarica; and in Suess's sketch-map (*loc. cit.* fig. 41) the whole country is represented as belonging to the Upper Mediterranean stage and younger formations, while the later French edition by M. de Margerie⁶ includes a map after G. Rolland, in which the country is all marked as Middle Miocene. According to the last statement on the subject, issued in 1907 by M. D. E. Pachundaki,⁷ the

¹ T. A. B. Spratt, 'Travels & Researches in Crete' vol. ii (1865) app. iv, pp. 375-80.

² T. R. Jones, 'Catalogue of the Fossil Foraminifera in the British Museum (Nat. Hist.)' 1882, p. 45.

³ G. Gürich, 'Ueberblick über den geologischen Bau des afrikanischen Kontinents' Petermann's Mitteilungen, vol. xxxiii (1887) p. 261 & pl. xiii.

⁴ K. A. von Zittel, 'Beiträge zur Geologie & Paläontologie der Libyschen Wüste' Paläontographica, vol. xxx (1883) pp. xxvi-xxvii & cxxxi.

⁵ E. Suess, 'Das Antlitz der Erde' vol. i (1885) p. 465.

⁶ 'La Face de la Terre' vol. i (1897) pp. 459 (fig. 68) & 464.

⁷ D. E. Pachundaki, 'Contribution à l'Étude Géologique des Environs de Marsa Matrouh (Marmarique)' Revue Internationale d'Égypte, vol. iv (1907) p. 8.

conclusion of Zittel as to the age of the 'Plateau Marmarico-Cyrenaïque' had been confirmed.

With such an array of authority in favour of the Miocene age of the rocks, it is not surprising that the 'Carte Géologique Internationale de l'Europe' (Sheet D vii), issued in 1905, colours the whole of Cyrenaica as Miocene, except for a band of recent formations along the coast and in some of the wadis, and a strip of 'Quaternary' running inland from Benghazi to the Wadi el Bal, as also an area of the same age beside the Gulf of Bomba.

The scantiness of available information as to the geology of Cyrenaica is due to the country having been closed to travellers, especially during recent years, by the Turkish authorities. Most of those who have visited Cyrenaica have been archæologists, whose attention has been engaged by its numerous antiquities, or Italian explorers interested in its commercial resources and its suitability for Italian colonization.

In 1908 I had the opportunity of visiting Cyrenaica as leader of an expedition sent to investigate whether the country would be suitable as a colony for Jewish refugees.¹ In spite of the support and the firman of the late Redjeb Pasha, then the enlightened Governor of Tripoli, the conditions were not always favourable to geological survey. Moreover, as we landed at Derna on July 24th, 1908, and arrived at Benghazi on August 14th, after a march, including excursions off our main route, of about 300 miles, the geological study of the country was only in the nature of a rapid reconnaissance. I should have liked to go eastwards in the direction of the Egyptian frontier, to trace the connexion between the rocks of Cyrenaica and the Miocene limestones of Western Egypt and Marmarica; but I had pledged my word to Redjeb Pasha that we would not go farther east than could be managed in one day's journey from Derna.

After engaging a camel-caravan at Derna, and having been supplied with an escort by the officer in command of the Turkish garrison, we marched overland across the plateau of Cyrenaica to Benghazi on the Great Syrtis; we supplemented this traverse by excursions northwards to the coast and southwards to the open plains, as far as was allowed by time, water-supply, and the Turkish permission.

I have to express my great indebtedness for the opportunity of the journey across Cyrenaica to Mr. Israel Zangwill, who arranged the expedition and secured the consent of the Turkish authorities; also to my companions Mr. M. B. Duff, Dr. M. D. Eder, Dr. J. Trotter, and Prof. M. N. Slousch, for the pleasure of their company

¹ J. W. Gregory, 'Report on the Work of the Commission sent out by the Jewish Territorial Organization under the Auspices of the Governor-General of Tripoli to Examine the Territory proposed for the Purpose of a Jewish Settlement in Cyrenaica.' The report includes an Introduction by Israel Zangwill; an Agricultural Report by J. Trotter; a Report on the Water-Supply and Engineering by R. E. Middleton, W. Hunter, & M. B. Duff; a Medical Report by M. D. Eder; and an Appendix by Prof. N. Slousch, 52 pp., 3 maps, 14 pls. London, 1909.

and the benefit of their indefatigable co-operation. They collected many of the fossils, and to Mr. Duff is due the map of our route,¹ on which the geological map (Pl. XLII, fig. 1) is based. I have also to express my thanks to Mr. Justin C. W. Alvarez, our Consul-General at Tripoli, and to Messrs. R. A. Fontana and G. Farrugia, the British Consuls at Benghazi and Derna, and to M. Jacoub Krieger, the confidential secretary to the late Redjeb Pasha, for his unflinching courtesy and help.

I am greatly indebted to Mr. R. B. Newton for the care with which he has studied the fossil mollusca collected by the expedition, and the accompanying memoir on them. I am also indebted to Mr. F. Chapman for his report on the foraminifera, and to Mr. D. P. Macdonald for his careful microscopic examination of the limestones. Dr. C. W. Andrews has kindly helped me with reference to the literature on the fossil mammalia of the adjacent areas.

The magnetic variation in Cyrenaica was taken as 6° W.

For the literature on Cyrenaica, reference may be made to two chief bibliographies—R. L. Playfair, 'The Bibliography of the Barbary States: Part I, Tripoli & the Cyrenaica' Roy. Geogr. Soc., Supplementary Papers, vol. ii, pt. 4 (1889) pp. 559–614; and G. Hildebrand, 'Cyrenaika als Gebiet künftiger Besiedelung' Bonn, 1904, pp. 329–78.

II. FIELD-OBSERVATIONS.

(a) The Neighbourhood of Derna.

Derna is situated on a delta-fan of limestone-gravel at the mouth of the Wadi Derna. The gardens in the town are irrigated by water from springs at Seghia and Bonmansur, respectively about 4 and 5½ miles up the wadi. The river-bed is covered by coarse limestone-shingle, and is usually waterless. It forms, in fact, the main thoroughfare through the town. Above Derna the river emerges from a deep gorge, and near its mouth is a bank of tufa, which rises to the height of 100 feet up the eastern side of the wadi: it consists of successive layers of calcareous sand, of tufa largely composed of cylindrical fragments, and of rolled limestone boulders. This deposit obviously represented a delta-fan which had been formed at the mouth of the wadi, before the gorge had been corroded to its base-level. The material was due to the alternate deposition of coarse shingle during floods, and of tufa during intervals when the only water came from adjacent springs.

The sections along the Wadi Derna expose two main rocks: the lower part of the cliffs consists of a soft white to cream-coloured limestone, crowded with large flat nummulites, and similar to the typical Nummulitic Limestones of the Mokattam Series of Egypt.

According to Mr. Chapman, the foraminifera, which are unusually well preserved, are of Middle Eocene age. The most characteristic

¹ [A MS. copy of the map will be placed in the Society's Library.]

Fig. 1.—Section drawn southwards from a point about 6 miles south-east of Derna; approximate length = $6\frac{3}{4}$ miles.

species is *Nummulites* (*Paronia*) *curvispira* Menegh.¹ Old rock-dwellings have been excavated in this rock, which extends up the wadi as far as we could see. It includes layers of broken shell-fragments and echinoid spines, and some layers, as at Seghia, of pinkish limestone full of *N. curvispira* and *N. ehrenbergi*, 2 inches in diameter. This cream-coloured limestone and its associated beds, which may be grouped together as the Derna Limestone, are some 250 feet thick. This series is covered by harder limestones, which weather brown and are more conspicuously stratified. They are over 200 feet thick at Derna, and from their great development at Slonta are subsequently referred to as the Slonta Limestones.

About 6 miles from Derna the wadi divides at the springs of Bonmansur; a platform composed of 20 feet of calcareous sands and gravels, interbedded with layers of travertine from 1 to 3 feet thick, separates the two branches of the valley. The face of this platform is covered by a sheet of calcareous tufa with many fantastic projections. The sands contain shells, which have been identified by Mr. R. B. Newton as *Hygromia sordulenta* (Morelet), showing the age to be

¹ In the following pages any foraminifera the species of which are mentioned have been determined by Mr. Chapman, and similarly the mollusca by Mr. R. B. Newton.

Pleistocene. The surface of the platform is strewn with so many palæolithic chert-implements, that it was probably the site of an ancient camp.

The stratigraphical relations of the Derna Limestone are shown by a section across the face of the plateau, about 5 miles south-east of the town, from an ancient megalithic ruin known as Gasr el Harib to the wells at Bint. The ruin stands at the height of 750 feet near the northern edge of the plateau, which extends far southwards, to the foot of the hills of Gebel Feteha. The northern face of the plateau shows a good section, illustrated by fig. 1 (p. 579). The lower part of the main scarp, up to the height of about 200 feet above sea-level, consists of the cream-coloured Derna Limestone: this is overlain, at the height of 340 feet above sea-level, by a sandy foraminiferal limestone, from which Mr. Chapman has identified fourteen species of foraminifera, including *Nummulites curvispira* and *Operculina libyca*.

Above this foraminiferal bed follow 60 feet of the brown-weathering, well-bedded limestones; they end above in a hard rock containing reef-building corals. This coral limestone forms a shoulder on the scarp, surmounted by a megalithic ruin. Above this point there is a more gradual ascent on to the plateau, up a valley cut through a series of massive rough-weathering limestones, and having on its floor some ancient wells from 30 to 40 feet deep, still used by the Arabs. Upon the plateau are some hills of a soft, marly, friable limestone of a pale buff colour, resembling some layers of the *Globigerina* Limestone of Malta; it yielded a *Schizaster* which, although too crushed for certain specific determination, resembles *Schizaster ederi*, sp. nov.

The main sequence in this section is, therefore, from a limestone which is probably Aquitanian, through the Slonta Limestones, down to the Derna Limestones. At the foot of the main scarp is a belt of limestones, one of which, at 200 feet above sea-level, yielded a fossil determined by Mr. Newton as the Priabonian *Pecten arcuatus* Brocchi, and consequently belonging to a horizon much higher than the rocks level with it in the cliffs on the south. The steep scarp south-east of Derna is, therefore, probably a fault-scarp, and the foot-hills at the coast are composed of the downthrown Slonta Limestones. I had, however, no opportunity of collecting further specimens from this area, or of completing the section to the sea.

(b) Derna to Cyrene.

We marched from Derna for about 6 miles westwards along the coast, crossing a belt of shore-deposits and delta-fans, which sloped up from the sea to the foot of the plateau-scarp. Along the lower part of the cliff could be seen the cream-coloured Derna Limestones, capped by the bedded, brown-weathering limestones. In a wadi about 3 miles west of Derna, the limestones on the coastal plain dip 5° northwards. Outcrops of a chalky limestone containing flint nodules occur to the west of a wadi, about 4 miles from Derna, and

form a small hill between the path and the shore. This chert-bearing rock is also well exposed in the banks of the Wadi Nagra, where it is represented by a soft chalk-like limestone with lines of flat chert-nodules, dipping 5° northwards. This chert-bearing limestone extends along the foot of the cliffs, to the west of our camp.

West of the wadi, Dr. Trotter collected a fossil which Mr. Newton has determined as *Lucina* cf. *nokbahensis* Oppenh., in a limestone free from *Nummulites*. If this specimen were *in situ*, then, as at Bint, east of Derna, Upper Eocene rocks are faulted down at the foot of the plateau-scarp.

Fig. 2.—Section in the plateau-face at Wadi Nagra,
west of Derna.

The sequence of the rocks in this district may be observed in the ascent of the Okbah or Aukubah, the Arab name for the cliff which forms the northern face of the plateau. The rocks are well exposed there, except that some bands are covered by an efflorescent limestone-crust. The chalky chert-bearing limestone passes gradually up into a harder limestone with chert-nodules, which is succeeded by the cream-coloured *N. curvispira* Limestone: this, being very soft, has been carved into caves, and is in places overhung by the rock above. At about 500 feet above sea-level the slope becomes steeper, up a cliff of the brown-weathering limestones (the Slonta Limestones), which begin with a layer of limestone full of small foraminifera, succeeded by a white limestone with *Orthophragmina pratti* and *Operculina*, which continues up to the height of about 630 feet. It is succeeded by a pinkish limestone, 30 feet thick, containing nullipores and some foraminifera, among which Mr. Chapman has identified *Nummulites curvispira* and *Truncatulina*; so he refers the brown limestones to the Middle Eocene. At 660 feet is a band of white marl, followed by the typical brown-weathering limestone, which continues to the edge of the plateau at about 750 feet. (See fig. 2, above.)

From the edge of the plateau above the Wadi Nagr the country rises gradually westwards and southwards, although the surface is broken by deep wadis. The Slonta Limestones, containing occasional shelly horizons, form the surface of the plateau. The dip is slight and to the north. A limestone with casts of reef-building corals occurs at the height of a little over 1100 feet, about 7 miles west of our first camp. A short distance farther west we saw exposures of a soft yellowish limestone, which we had the best opportunities of examining in the wells near an Arab burial-ground known as Birlibah. Here I found an echinoid, *Hypsoclypeus hemisphericus* (Greg.), the first Miocene¹ fossil found.

From Birlibah to Gubah, a distance of about 12 miles, the country is thinly wooded moorland. It rises gradually from 1100 to 1800 feet; the rocks are yellowish granular limestones, with some nodular, marly seams, which, especially near Wadi Umzigga, form a number of small springs. The characteristic fossil is a large pecten, which Mr. R. B. Newton has identified as *Oopecten rotundatus* (Lam.). The fossil mollusca collected at the Wadi Umzigga and seen at other adjacent exposures, indicate that these limestones are not lower than Aquitanian; and, according to Mr. Chapman, the limestone at Wadi Umzigga is full of *Lepidocyclina elephantina* Mun.-Ch., and is Aquitanian or Stampian. The age of the Wadi-Umzigga beds may, therefore, be regarded as Aquitanian.

At Gubah, beside the ruins of a Greek bath, we found some fossils, among which Mr. Newton identified *Strombus coronatus* Defr., *Alectryonia plicatula* (Gmel.), and the cirriped *Balanus concavus* Bronn. He therefore assigns the rock to the Upper or Middle Miocene. After leaving Gubah, we ascended another platform about 100 feet high, formed of a rough-weathering limestone; but, as we were passing close beside a Senussi settlement, Zawiah Charrah, we had no opportunity of collecting fossils until 6 miles from Gubah, when we reached the ruins of the Roman town of Lamludeh (the ancient Lebdis). There we found some casts of lamellibranchs and a large gastropod, weathered out of beds of earthy limestone and marl: these fossils, according to Mr. Newton, indicate an Aquitanian age. West of Lamludeh the ground is rocky, and much of it is covered with scrub growing in the depressions between hummocks of a hard, white limestone, containing many large Ostreids, including *Ostrea crassicostata* Sow. Immediately west of Zawiah Turt is an exposure of a limestone containing many echinoid plates and foraminifera, and an associated limestone yielded an *Amphiope*.

At Labruk, 10 miles west of Lamludeh, the earthy limestones, like those at Lamludeh, crop out north of the track; close beside the water-hole is a band of hard limestone containing casts of reef-building corals. About half a mile west of Labruk is a bed containing many specimens of *Echinolampas*.

A waste of rocky scrub and rough hills of coral-limestone, with the *Echinolampas* Bed cropping out in the depressions, extends for 6 miles from Labruk to the marabut of shrine of Sidi Dia-

¹ For the accepted limit of the Miocene, see p. 593.

siasia (or Sidi Jaja). From our camp there we visited Safsaf, some bare limestone-hills used by the Romans as a collecting-ground for water, which was carried by an aqueduct to the city of Cyrene, 6 or 7 miles distant in a direct line. The same hard Slonta Limestones, which weather irregularly, occur north-west of Sidi Rof Diasiasia; they pass in that direction under a series of soft, earthy, white and grey limestones and marls. These rocks form the hills over which are scattered the widespread ruins of the city of Cyrene. The rocks agree lithologically with those of Lamludeh and the fossils collected show that the Cyrene Limestones are of Aquitanian age.

(c) Mersa Susa (Apollonia) to Slonta.

It was necessary for our work to determine the conditions which control the water-supply of the district near Cyrene and the chances of finding situations suitable for storage-reservoirs. Hence we made a north-and-south traverse across the country from the sea at Mersa Susa (Apollonia) through Cyrene, to the southern downs at Slonta. This section (fig. 3, p. 584) illustrates the general geological structure of that part of Cyrenaica.

The city of Cyrene stands at the height of about 1950 feet above sea-level, on the northern edge of a plateau which rises gradually southwards to 2700 feet near Slonta. Immediately north of Cyrene is a steep cliff, which falls to the level of about 1300 feet, whence a platform, generally referred to as the 'lower plateau,' extends for about 3 miles northwards, and from its edge, at the height of about 1000 feet, the steep lower cliff falls abruptly to the shore. The lower cliff, being the extension of the cliff near Mersa Susa, may be a fault-scarp; it was, therefore, necessary to consider whether the upper cliff at Cyrene was of the same origin. This view appeared the more possible, as a little below the Fountain of Apollo is a white soft limestone, containing nummulites indistinguishable in the field from those in the similar rock of the Derna Limestone, which is exposed in the upper part of the lower cliff. I could, however, find no repetition of the Echinoid Limestone, which overlies the Derna Limestone, above the upper nummulitic limestone, and was accordingly forced to reject the possibility of the two similar nummulitic limestones being the same bed repeated by faults. This conclusion is supported by Mr. Chapman's identification of the characteristic foraminifer of the upper limestone as *Nummulites gizehensis* var. *lyelli*; while that found in the Derna Limestone is the typical form of the species. The upper cliff, moreover, has the characters of an escarpment, and not of a fault-scarp: it has been cut back into numerous gullies, and projects between them in irregular spurs. The uneven escarpment-like weathering of the cliff is well shown in the plan of Cyrene by Smith & Porcher.¹

¹ R. M. Smith & E. A. Porcher, 'History of the Recent Discoveries at Cyrene' 1864, pl. xl.

Fig. 3.—Section from Slonta through Cyrene to the sea: distance = about $27\frac{1}{2}$ miles.

The series is, therefore, a steadily ascending one from Mersa Susa to Cyrene.

The old port of Mersa Susa is built on a series of dune-limestones, behind which is an alluvial delta deposited by the Wadi Susa. The route to Cyrene goes westwards across the alluvial deposits for about a mile; and then, in the banks of a large wadi, limestone is exposed dipping 5° northwards and containing *Gisortia gigantea* Munst., *Trachycardium* cf. *grancornense* Oppenh., and *Pecten arcuatus* Brocchi. Mr. Newton, therefore, refers this limestone to the Priabonian.¹ At the foot of the plateau the cherty limestones—the Apollonia Limestones—are exposed, and they continue up the track from 150 to 530 feet above sea-level. This limestone, as a rule, is massive, and contains many foraminifera and some shell-fragments. Some indeterminate molluscs were collected at the height of 450 feet in a band of cherty limestone. The chert-bearing series ends at the height of 530 feet with a chert-breccia. Above this follows the compact, creamy-white Derna Limestone, full of *Nummulites curvispira* and identical in character with that so well exposed at Derna. At 600 feet is a white, foraminiferal limestone with echinoid fragments. At 620 feet is an oolitic band, also observed at a corresponding position in the section above Ptolemeta.

¹ The specimen determined as *Nummulites perforata* by the late Prof. T. Rupert Jones from Mersa Susa doubtless came from the same limestone, with which it agrees lithologically. Mr. Newton has kindly examined it, and is disposed to regard it as *N. intermedia*, an Upper Eocene species.

The limestone at the level of about 900 feet is soft, and has been excavated for cave-dwellings. It passes, apparently gradually, into the hard, brown-weathering limestones; they form the surface of a wide plateau, which rises slowly inland to the foot of the upper or Cyrene Escarpment. At the level of 1100 feet, in the lower part of these limestones, is a layer crowded with scattered echinoid-plates.

This lower plateau has a rough, irregular surface with many limestone-hummocks, and small patches of thin soil in the hollows between them. This limestone continues past Ain Hafra, where it yielded the Priabonian *Euspira possaguensis* Oppenh., and forms the surface of the 'lower plateau' directly to the north of Cyrene. The section there begins on the north with the Echinoid Limestone at the height of about 1100 feet; it underlies a white hard limestone, which weathers very irregularly and forms the foundation of the plain covered by sandy alluvium north of Cyrene. At the base of the cliff which leads to the upper plateau is a limestone containing the Middle Eocene echinoid *Fibularia luciani* and *Nummulites curvispira*; it crops out at the height of 1215 feet. This rock is succeeded by a shelly limestone containing many nummulites, including *N. gizehensis* var. *lyelli*. The upper part of this '*lyelli*' limestone yields a few specimens of *Echinolampas*, one of which was collected from the height of 1320 feet; and the tombs of the northern necropolis of Cyrenaica have been mostly excavated in the beds of this soft foraminiferal limestone, which are interstratified with the harder bands.

The limestones used for the tombs are succeeded by a marly limestone, which is full of irregular nodules and many flattened stem-like fragments, and contains grains of glauconite. This bed has an irregular horizontal lamination, which helps to render it relatively impermeable to water sinking downwards through the overlying porous jointed limestone. This layer accordingly throws out a series of springs along the face of the escarpment. The most famous is the 'Fountain of Apollo' (or Ain Sciahat), at the height of about 1760 feet above sea-level. The limestone above the Fountain of Apollo is massive and contains some reef-corals, and it passes into a soft earthy limestone containing layers of marl and many pectens, identified by Mr. Newton as *Aequipecten zitteli* Fuchs, *A. camartensis* (Font.), *A. scabrellus* (Lam.), *Pecten vezzanensis* Oppenh., etc.: the horizon is, therefore, Aquitanian. This *Pecten* Bed and the limestone above it also yielded some echinoids, including one which, though imperfect by reason of weathering, I had no hesitation in identifying from its characteristic form as *Hemiaster scillæ*. According to this identification, the echinoids agree with the mollusca in demonstrating the Aquitanian age of the Cyrene Limestones.

The general dip of the rocks in this area is slightly northwards, but occasionally it is reversed, and in the hill-face east of Ain-Sciahat is a clear dip of 3° southwards.

The hills south of Ain Sciahat, between it and the upper part of the wadi of Bil Ghadir, the next wadi to the west, consist of the Cyrene Limestones, with the spring-forming marl at their

base. The upper part of that wadi is a deep ravine, cut by the recession of a waterfall which exists only in the rainy season. Above the fall the valley continues as a wide dale, on the floor of which are exposures of the limestone that overlies the nodular seam of the Fountain of Apollo. The Cyrene Limestones extend for about 2 miles to the south, and then, after crossing a flat-floored valley covered with a sheet of alluvium about a mile in length, the ground rises to scrub-covered hills of the hard Slonta Limestones. The *Echinolampas* Bed occurs at a well known as Bir-Hu, at the height of 2020 feet. The country is intersected by a series of deep ravines, and water must be more easily obtained here than in most parts of Cyrenaica. About a mile south of Bir-Hu is a ridge capped by the Cyrene Limestones, and on the lower ground to the south the rough-weathering hummocky limestone containing casts of shells and *Echinolampas* crops out at Gaafs-a-mudi. At the height of 2200 feet in the Wadi Firyah, above the horizon of the *Echinolampas* Bed, is a limestone full of reef-building corals. A little farther south, at the height of 2470 feet, we crossed the divide between those streams the beds of which descend northwards through the Wadi Firyah and those that begin their course southwards in the direction of Slonta. At the height of 2350 feet is a well, in which the water is upheld by a laminated sandy limestone containing flattened stems like that at Ain Sciahat. It yields many shell-fragments. The limestone above it yields the same pectens as at Ain Sciahat, and also *Ostrea crassicostata* G. B. Sow.; it is evident, therefore, that the beds are of Aquitanian age.

This outlier of the Cyrene Limestones is about 3 miles wide, and it is succeeded on the south by the nummulitic Slonta Limestones, which are much harder and weather brown. They contain, as below Ain Sciahat, *N. gizehensis* var. *lyelli*, and many specimens of *N. curvispira*, the latter of which, however, occurs also in the Derna Limestones. I did not see the coral-limestones which usually mark the upper bed of the Slonta Series, probably owing to the enforced quickness of our march. The Slonta Limestones here form open treeless downs extending as far southwards as we could see. The *Echinolampas* Bed occurs on the summit of some of the hills near a conspicuous landmark, the shrine of Sidi Mahomet Mahridi, as also at the old Roman cisterns near Slonta.

A few Arabs were living at Slonta, and I endeavoured from them to learn the nature of the country farther south. North of the shrine of Sidi Mahomet Mahridi we had crossed a slight ridge at the height of 2600 feet above sea-level; the well at Slonta is at 2400 feet, and the country apparently has a long gradual slope southwards. According to the sketch-maps of this district, the Cyrenaican plateau descends to the Siwa-Aujela depression in two abrupt steps. But, according to the Arabs, the plateau sinks gradually into the plains to the south.

(d) Slonta to Messa.

From Slonta we marched northwards up a picturesque dale cut through well-stratified limestones, which are either horizontal or have a dip of about 1° to the north. The rocks included a bed yielding *Echinolampas*, bands with small nummulites, and some containing a large nummulite 2 inches in diameter. We camped beside a Roman fort at Shermatu, and thence descended into the deep ravine of the Wadi Khumas near its head. This wadi descends to the north: its cliffs at first consist of the brown-weathering stratified Slonta Limestones; but farther north the cream-coloured Derna Limestones, presenting the same characters as at Derna and south of Mersa Susa, appear from beneath the upper series. The Derna Limestone cropped out from the level of 1860 feet in the upper Wadi Khumas down to 1240 feet. As the top of this formation near Mersa Susa, 18 miles away to the north-east, is at 1000 feet above sea-level, the dip of the rocks in this part of Cyrenaica must be 1° downwards to the north-east.

We descended the Wadi Khumas for 4 miles and left it where, at the level of 1240 feet, it turned westwards; we rode up a tributary gully on to the Messa plateau. The top of the cream-coloured Derna Limestone in this gully is at a little over 1300 feet, and the brown stratified Slonta Limestones, containing mollusca identified by Mr. Newton as *Lucina* cf. *pharaonis* Bellardi, *Mastra* cf. *fourtaii* Cossm., and *Cardita* cf. *acuticostata* (Lam.), extended from that level to the summit at 1640 feet. Our path joined the main track from Cyrene to Messa near a well, at the height of 1520 feet, in a stratified limestone which contains some clay and flattened stems, and thus resembles the impermeable layer of the Fountain of Apollo. The adjacent limestones yielded *Echinolampas chericherensis*, a species characteristic of the upper part of the Slonta Series. Thence we crossed a rough limestone-ridge and descended to Messa, where there are several springs produced by the laminar limestone with stem-like fragments. Owing to lack of time, I was unfortunately unable to continue the section from Slonta through Messa to the coast.

(e) Messa to Merj.

At Messa we joined the track from Cyrene to Benghazi. The wells at Messa are among the most important in Cyrenaica. They lie on the floor of a deep valley, and are maintained by drainage from the limestone around. The supply seems to be unfailing, and is sufficient for the irrigation of some gardens. The adjacent ruins show that the wells were important in ancient times. On leaving Messa we climbed on to the plateau, and crossed for 3 miles scrub-covered limestone moors to the shrine of Abdul Wahil. Thence we descended a steep path into a tributary of the Wadi Jeraib (or Wadi Ishgerib, or Jerib), and we followed the tributary until it joined the main valley. The cliffs of the Wadi Jeraib are in

places almost vertical, and they consist in part of the cream-coloured Derna Limestone. Farther down the wadi the cliffs increase to the height of about 400 feet, and the Derna Limestone is doubtless capped by the Echinoid Limestone, as fallen blocks of this rock lay at the foot of the cliff. We descended the Wadi Jeraib to the level of about 820 feet, when it bent round to the north-east.¹ There was no sign, even in the lowest part of the wadi, of the chert-bearing limestones. Leaving the main valley, we ascended a tributary to the south-west; we crossed the Echinoid Limestone above the Derna Limestone, and reached the surface of the plateau in front of the Roman castle, Gasr el Migdum. A limestone composed of reef-building corals crops out beside it, and on the west of it is a limestone containing small quartz-pebbles. The rocks in this area and for some distance westwards include more mechanically derived sediment than those farther east, and the ground is often covered by a white residual clay. From Gasr el Migdum we marched for 30 miles over an undulating limestone-plateau; the original surface varied in level from 1400 to 1500 feet, but it has now been dissected, by the excavation of numerous valleys, the floors of which are at the level of 1200 or sometimes of 1100 feet. The country is a wilderness of scrub, which became denser as we approached the Wadi Gharib.² The few fossils found included a large gastropod from below the shrine of Sidi Abdullah, identified by Mr. R. B. Newton as *Hippochrenes ampla* (Sol.), which we also found on the plateau south-east of Messa. This fossil and an occasional *Echinolampas* show that the rocks are of Upper Eocene (Priabonian) age. The last *Echinolampas* was found 6 miles east of the Wadi Gharib; but, as in that district we were marching in single file through dense scrub, we could not make any effective search for fossils. The valley of the Wadi Gharib shows fine sections of stratified foraminiferal limestones, resembling those of the Slonta Series. The rock-exposures, however, were covered with a crust of efflorescent limestone, and when this layer was broken through the fossils seen were indeterminable casts; but it was dark before there was an opportunity of searching the rocks, and we had to resume our march at dawn next morning.

We continued across the plateau of scrub-covered limestone, until we reached an alluvial plain at Bigratah or Bugrat; the hillsides around the plain consist of the cream-coloured Derna Limestone

¹ The Admiralty Chart represents this wadi as part of a basin of internal drainage, and separated from the sea by a continuous ridge from Messa to Gasr el Migdum. Judging from the levels, the Wadi Khumas probably joins the Wadi Jeraib above the confluence with the wadi from the shrine of Abdul Wahil, and both should discharge northwards; otherwise, it seems improbable that the route should descend into the Wadi Jeraib, instead of keeping on the plateau to the north of it.

² We were assured that there was no water between Messa and Merj, except for some small wells in the Wadi Gharib. The Commandant of the Turkish garrison at Messa kindly sent a camel laden with water with us to Gasr el Migdum, to save us from drawing on our own loads. The few Arabs remaining in this district were said to live on scanty supplies of stored water.

yielding the large *Nummulites curvispira*. The track from Bigratah to the plain of Merj crosses a low pass at the height of 1120 feet above sea-level, where the chert-bearing limestones crop out from beneath the Derna Limestones.

The plain of Merj is an alluvial plain exceeding 50 square miles in area; it is bounded on the south-east by an escarpment of the Derna Limestone resting upon the chert-bearing limestone. The town of Merj (generally regarded as the ancient Barca¹) is situated on a small rise, due to the outcrop of a Priabonian limestone. The plain is bounded on the south-east by a long straight cliff, which has a trend of 52°, and is continued south-westwards along the plain of Silene. This long scarp is formed mainly of Derna Limestone: the cherty limestone is exposed beneath that rock in the north-eastern part of the scarp, near Bigratah. The beds are here dipping south-westwards so that the chert-bearing limestone disappears below the surface; the beds then become horizontal, and then dip south-westwards to a low syncline, of which the axis meets the scarp south-south-east from Merj. Some 5 miles south-west is another low anticline; it is followed by another syncline, and the dip continues to the north-east as far as the wide breach in the fault-scarp made by the Wadi Jebril. So far as I could tell from a distant view, the beds again dip south-westwards, become horizontal, and then the scarp becomes quite low. A higher scarp could be seen behind it, and, judging by its white face, it may also be formed of Derna Limestone.

The long cliff that forms the south-eastern boundary of the plains of Merj and Silene has the aspect of a fault-scarp, for it is remarkably straight in direction; the only projections from it are talus-fans opposite the wadis; there are no spurs or outliers, such as would be expected in an escarpment due to denudation; and its course is not affected by the changes of dip in the limestone.

That this hill-line is a fault-scarp is also shown by the palaeontological evidence. The limestone at the wells of Merj contains *Pecten arcuatus* Brocchi, *Lucina* cf. *pharaonis* Bellardi, and *Vulsella crispata* Fischer, and, according to Mr. Newton's determinations, is therefore Priabonian. The characteristic nummulite of the Wells of Merj is identified by Mr. Chapman as *N. gizehensis* var. *lyelli*, whereas the species in the cream-coloured limestone of the Merj scarp is *N. gizehensis typica*. Hence the evidence of the foraminifera agrees with that of the mollusca, that the limestones at Merj, which occur at levels ranging from 835 to 850 feet, belong to a higher horizon than the limestone at the level of 1000 to 1240 feet in the hills, 2 miles south of the town.

¹ Barca, however, was at Ptolemeta, according to Smith & Porcher, 'History of the Recent Discoveries at Cyrene' 1864, p. 4, and G. Dennis, 'On Recent Excavations in the Greek Cemeteries of the Cyrenaica' Trans. R. Soc. Lit. ser. 2, vol. ix (1870) pp. 141, 156.

(f) Merj to Ptolemeta.

To determine the succession of the rocks in this part of Cyrenaica, a traverse was made from the plateau-scarp south of Merj to the coast, near its ancient port, Ptolemais or Ptolemeta.

The relations of the rocks between the plain of Merj and the Wadi Hamema, through which we descended to the shore, are uncertain, as, owing to a misadventure, I had to return to Merj by a night journey. The general section from the plateau south of Merj to the sea at Ptolemeta is illustrated by fig. 3 in Pl. XLII.

The coastal plain near Ptolemeta consists of dunes along the shore, of large delta-fans before the mouths of the wadis, and of wide sheets of alluvium in the intervening depressions. The delta-fan, by which the track from Merj to Ptolemeta reaches the coastal plain, rises to the height of 340 feet. The rocks above it are chert-bearing limestones and marls, belonging to the Apollonia Limestone Series, which continue up to the level of over 940 feet. The rocks are dipping northwards, in places as much as 25° , the steep dip being doubtless due to the proximity of the Tokra Fault, although there may be parallel faults which I did not detect.

The rocks crossed during the ascent on to the plateau from the shore (see Pl. XLII, fig. 3) begin above the delta-fan, at the level of 340 feet, with a dark-grey, compact, dolomitic and siliceous limestone. The rock is succeeded above by a chalky granular limestone with some black grains, which microscopic examination shows to be glauconite. This rock, at the height of about 440 feet, includes an oolitic band, in which Mr. D. P. Macdonald has recognized well-preserved echinoid spines, nullipores, and foraminifera. A similar rock occurs in the chalky limestone at Wadi Nagr, west of Derna.

This rock is succeeded by a compact, unfossiliferous, chalky limestone with a rough granular surface. Mr. Macdonald describes it as containing some calcite crystals and occasional grains of quartz.

Then follows, at the level of from 500 to 550 feet, a series of compact chalky limestones with some grains of glauconite. Mr. Macdonald found in the chalky base some *Globigerinæ*, sponge-spicules, and a holothurian plate. The rock includes some layers of marl and nodules of chert.

At the level of 620 feet the track crosses a small col into the Wadi Hamema, which has beheaded the gully followed by the route to Ptolemeta. At this level and up to over 650 feet, the rock is a siliceous limestone with abundant chert-nodules. The matrix of this rock, according to Mr. Macdonald, consists of a close calcareous paste with some grains of quartz and glauconite, and it also contains *Globigerina* and a holothurian plate. The chert-bearing rocks are exposed up to the height of 950 feet.

The northern part of this series of beds consists of chalky limestones like those of the Wadi Nagr, and they belong to the upper portion of the Apollonia Limestone Series. The limestones from the level of 500 to 600 feet containing the large chert-nodules represent the lower part of the same series.

The divide between the Wadi Hamema and the plain of Merj, at the level of about 1100 feet, is formed by some shelly limestones from which Mr. Newton has identified the Miocene *Anadara turonica*: whence we may infer that the Apollonia Limestones, which are exposed in some dry cisterns, are overlain by Miocene beds. The simplest explanation of the occurrence of these beds in this position would be that they were deposited unconformably upon the Apollonia Limestones; but I saw no evidence of their actual relations.

The cherts are also exposed on the northern slopes of the divide, between it and the Pleistocene loams of the plain of Merj. Some of the shelly beds near the pass may belong to the Slonta Limestones, which are certainly exposed at Merj, as shown by both mollusca and foraminifera.

The Priabonian or Slonta Limestones occur at the wells of Merj at the level of only 850 feet, while the Derna Limestone rises in the face of the plateau 2 miles to the south to the height of 1240 feet. The Slonta Limestones at Merj must, therefore, have been lowered either by a fault or by a sharp fold; and the general evidence is clear that the movement was a fault.

(g) Merj to Benghazi.

The journey from Merj to Benghazi being hurried, there was only time for a general determination of the rocks close beside the route. The track crosses the Merj alluvium for $2\frac{1}{2}$ miles to the south-west and then a low ridge of limestone about 6 miles wide, which separates the plain of Merj from the still larger, but less regular, plain of Silene. This limestone ridge rises to the height of about 1130 feet, or about 300 feet above the plain of Merj. The rock is not well exposed, being covered by a red soil and *Thuya*-scrub; but at 4 miles from Merj there are exposures of a limestone with large nummulites, which no doubt belongs to the Derna Limestones, and is continuous with the rocks that bound both sides of the plain of Merj. I could find no chert, except one or two artificial flakes which had probably been carried there. From the summit of this limestone ridge there is a slight fall to the plain of Silene, over which we marched for 30 miles. Its north-eastern part is higher than the plain of Merj; but it slopes gradually to the south-west, and the outlets of its streams are doubtless in that direction. It is less level than the plain of Merj, consisting rather of undulating steppes covered with a loamy soil, and passing into the limestone downs gradually on all sides, except where it meets the Merj fault-scarp. The surface is wind-swept, and numerous vertical columns of dust travelled across it. The stream banks consist of alluvium, which weathers like loess; they stand up in low vertical cliffs, and the streams, when they run, are interrupted by small waterfalls. The chief deposit is a brown loam, interstratified occasionally with beds of limestone-gravel. A well at Mletania has been sunk through the alluvium to the depth of 135 feet, and

it is situated only a mile from the border of the plain, there about 6 miles wide. Much of the ground has been cultivated, especially in depressions where soft loam has been collected as rain-wash. Near the shrine or marabut of Ahmeda, the loam is covered with slabs of secondary limestone showing that the alluvium is thinner there; and blocks of limestone resembling the Derna Limestone occur on a ridge, which projects from the downs into the western side of the plain. The surface of this ridge is littered with slabs of efflorescent limestone.

I could find no exposure of the chert-bearing limestones there; but, after crossing the nummulitic limestones for a couple of miles, we found that chert-nodules became abundant and then cherty limestones appeared on the surface. The first specimens of these cherts were much altered by secondary action, and the cherts were chalcedonic. At Smuta there is an outcrop of a shelly siliceous limestone, near the ruins of a Roman fort. The fossils found are, however, unfortunately indeterminable.

After crossing the watershed between the plain of Silene and the direct drainage north-westwards to the Mediterranean, we observed that the country became more irregular, owing to the numerous, deep, stream-cut ravines. The rock at the edge of the plateau overlooking the coastal plain contained many casts of shells, but no determinable fossil was collected. Beneath the shelly limestone occurred a limestone breccia, including pebbles of black limestone. A steep gully leads from the plateau to the coastal plain, near the ruin of an old fort, at the height of about 450 feet above the sea, and some 16 miles east from Benghazi. The face of the plateau has been much denuded, but presents the aspect of a fault-scarp. The rocks at its foot are pinkish and white compact limestones, containing fragments of *Scutella* and a thick massive *Clypeaster*. As the camels had already gone some distance ahead, I was unable to collect any complete specimens, though the sketches of some of the fossils indicate that the beds are Miocene, and probably Middle Miocene. The *Scutella* Limestone is exposed farther west in bosses, polished by wind erosion. Nearer Benghazi, these Miocene limestones are covered by a younger limestone, of which the characteristic shell has been determined by Mr. Newton as *Ceras-toderma edule* (Linn.), and the rock is either late Pliocene or more probably early Pleistocene in age. The older limestone was still visible occasionally in depressions in the coastal plain, and in the solution-cauldrons occupied by the Garden of the Hesperides and the cave known as the River of Lethe. Nummulites have been recorded from this limestone by the Archduke Ludwig Salvator,¹ and G. B. Stacey called the rock a 'Tertiary limestone.'² The specimens collected there do not contain nummulites, but a virletiform *Ostrea*, which suggests the Helvetian age of the rock.

¹ 'Yacht-Reise in den Syrten 1873' Prag, 1874, p. 52.

² 'On the Geology of Benghazi, Barbary,' Q. J. G. S. vol. xxiii (1867) p. 384; he collected some fossils in the limestone which were not specifically determined, and found *Cardium edule* on the surface (*ibid.* p. 386).

Near Benghazi the lower limestones have sunk beneath sea-level, and the beds exposed around the town are recent dune-limestones containing common Mediterranean shells, such as *Glycymeris glycymeris* (Linn.), *Codakia pecten* (Lam.), *Ostrea edulis* (Linn.), *Cheliconus mediterraneus* (Hwas), etc. Behind the dune-limestones and the dunes to the north of the town are wide sheets of alluvium, which has been deposited in lagoons that are still flooded at intervals and used as salt-pans.

IV. CLASSIFICATION AND CORRELATION OF THE CYRENAICAN Rocks.¹ (Continued on p. 598.)

The field evidence, including a preliminary determination of some Echinoids, suggested during the traverse of Cyrenaica the following classification of the rocks:—

Pleistocene.	Various alluvial deposits, coastal limestones, etc.										
Miocene	<table> <tr> <td>{</td><td><i>Scutella</i> Limestones, east of Benghazi, and Gubah-Birlibah Limestones.</td></tr> <tr> <td>{</td><td>Cyrene Limestones (Aquitanian).</td></tr> <tr> <td>{</td><td>Slonta Limestones.</td></tr> <tr> <td>{</td><td>Derna Limestones.</td></tr> <tr> <td>{</td><td>Apollonia (chert-bearing) Limestones.</td></tr> </table>	{	<i>Scutella</i> Limestones, east of Benghazi, and Gubah-Birlibah Limestones.	{	Cyrene Limestones (Aquitanian).	{	Slonta Limestones.	{	Derna Limestones.	{	Apollonia (chert-bearing) Limestones.
{	<i>Scutella</i> Limestones, east of Benghazi, and Gubah-Birlibah Limestones.										
{	Cyrene Limestones (Aquitanian).										
{	Slonta Limestones.										
{	Derna Limestones.										
{	Apollonia (chert-bearing) Limestones.										
Lower Kainozoic.											

The most surprising geological result of the journey was the comparative rarity of Miocene beds. They are so well developed in Western Egypt, as at Siwa and on the coast near Mersa Tobruk, that the prevalent opinion in recent years (see p. 576) had been that Cyrenaica was mainly composed of Miocene rocks. The subsequent study of the collections has, however, even lessened the area that in the field I was disposed to assign to the Miocene, as the species of *Amphiope*, a genus especially found in that system, has to be referred back, owing to its associated fossils, to the Eocene.

The correlation of the rocks of Cyrenaica depends upon the fossils, mainly mollusca, foraminifera, and echinoids, upon which reports have been prepared by Mr. R. B. Newton, Mr. F. Chapman, and myself.

The oldest rocks exposed occur in the Tokra fault-scarp, east of Benghazi; they are somewhat lower than the chert-bearing limestones, but no determinable fossils were obtained from them.

¹ Owing to the varying nomenclature of the Middle and Lower Eocene Kainozoic Series, the following synopsis may be convenient for reference:—

Miocene	{	Tortonian	} Vindobonian.
		Helvetian	
		Burdigalian or Langhian.	
Oligocene		Aquitanian (often included in the Miocene).	
		Stampian or Rupelian	} Tongrian (sometimes used to include Stampian).
		Sannoisian or Ligurian	
		Priabonian or Ludian (sometimes included in the Oligocene).	
Eocene {	Upper.	Bartonian.	
	Middle.	Parisian (Lutetian); Mokattam Series of Egypt.	
	Lower.	Londonian or Ypresian; Libyan Series of Egypt.	
		Suessonian, Thanetian or Landenian.	

III. Lists of Fossils.

[illegible]

LISTS OF FOSSILS (*continued*).

Echinoidea.	Horizon.	Ain Sciahat.			[Tongr. = Tongrian. Helv. = Helvetian. Langh. = Langhian.]
		Cyrene Lime-stones.	Slonta Lime-stones.	Derna Lime-stones.	
<i>Clypeaster biarritzensis</i> , var. <i>trotteri</i> nov.	U.E.	×			
<i>Fibularia luciani</i> (Lor.)	M.E.	...	...	×	Foot of Cyrene Escarpment.
<i>Scutella tenera</i> Laube	Tongr.	...	×	...	Labruk ; Bir Hu.
<i>Amphiope duffi</i> , sp. nov.	...	...	×	...	Sidi Rof Diasiasia.
<i>Amphiope</i> sp.	...	×			
<i>Echinolampas chercherensis</i> Gauth.	U.E.	...	×	...	Slonta Limestones near Labruk ; Safsaf ; Cyrene ; below Ain Sciahat ; Cyrene to Slonta ; Messa ; Wadi Gharib.
<i>Echinolampas discus</i> Des.	Aq.	×			
<i>Hypsoclypeus hemisphericus</i> (Greg.)	Helv.	...	...	...	Birlibah.
<i>Hemiaster scille</i> Wright	Aq. to Langh.	×			
<i>Schizaster ederi</i> , sp. nov.	...	×			
<i>Sarsella lamberti</i> , sp. nov.	...	×			

Holothuroidea.

Hobothuria plates were recognized by Mr. D. P. Macdonald in the chalky limestone of the Apollonia Series west of Ptolemeta, and in the Derna Limestones near Merj.

Ostracoda.

	Horizon.	
<i>Loxocoena cyrenaica</i> , sp. nov.	M.E.	} Wadi Nagr. <i>Clypeaster</i> Bed east of Ain Sciahat.
<i>Cythere striato-punctata</i> (Rom.)	M.E.	
? <i>Cythere wetherelli</i> Jones	U.E. to Ol.	

Cirripedia.

[*Balanus concavus* Bronn | Miocene. | Gubah.]

Mollusca.

Pleistocene.	Bonmansur, south of Derna.	Plain east of Benghazi.	West of Ptolemeta.
<i>Hygromia sordulenta</i> (Morelet)	×		
<i>Helicella tuberculata</i> (Conrad)	...	×	
<i>Ostrea edulis</i> Linn.	...	×	
<i>Glycymeris glycymeris</i> (Linn.)	...	×	
<i>Glycymeris pilosa</i> (Linn.)	...	...	×
<i>Cardium tuberculatum</i> Linn.	...	...	×
<i>Cerastoderma edule</i> (Linn.)	...	×	
<i>Mactra stultorum</i> (Linn.)	...	×	
<i>Jagonia pecten</i> (Lam.)	...	×	
<i>Loripes lacteus</i> (Linn.)	...	×	
<i>Cerithium</i> cf. <i>vulgatum</i> Bruguière	...	×	
<i>Columbella rustica</i> (Linn.)	...	×	
<i>Cheliconus mediterraneus</i> (Hwas in Bruguière)	...	×	

Mollusca (*continued*).

Miocene.	Gubah.	Cave of 'River Lethe.'	Plain east of Benghazi.	Between the plain of Merj and Wadi Hamana.
<i>Alectryonia plicatula</i> (Gmel.)	×			
<i>Alectryonia virleti</i> (Desh.)	×	×		
<i>Gigantopecten ziziniæ</i> (Blackenborn)	×		×	
<i>Anadara turonica</i> (Dujardin)	×			×
<i>Strombus coronatus</i> (Defrance)	×			

Aquitanian.	East of Shrine, east of Slonta.	Ain Sciahat, above camp.	Ain Sciahat.	Brlilbah.	West of Labruk.	
<i>Ostrea cf. caudata</i> Münster	×					
<i>Ostrea crassicostata</i> Sowerby	×					
<i>Spondylus cisalpinus</i> Brongniart		×				W. of Lamludeh.
<i>Pecten vezzanensis</i> Oppenheim			×			
<i>Pecten cf. pasini</i> Meneghini			×	×		
<i>Æquipecten zitteli</i> Fuchs	×				×	
<i>Æquipecten camaretensis</i> (Fontannes)		×				
<i>Æquipecten scabrellus</i> (Lam.)		×				
<i>Æquipecten haueri</i> Michelotti		×				
<i>Oopecten rotundatus</i> (Lam.)		×			×	Wadi Umzigga.

Priabonian.	Mersa Susa.	Kuft Narbeh, north of Wadi Firyah.	Near Slonta.	North of Slonta.	Messa.	Wells at Merj.	South-west of Merj.	
<i>Ostrea cf. ventilabrum</i> Goldfuss			×	×		×	×	Near Bint, E. of Derna.
<i>Pecten arcuatus</i> (Brocchi)	×	×	×		×	×	×	Near Bint, E. of Derna.
<i>Æquipecten cf. deletus</i> (Michelotti)								Derna.
<i>Æquipecten cyrenaicus</i> , sp. nov.								Above camp at Ain Sciahat.
<i>Vulsella cf. crispata</i> P. Fischer							×	
<i>Vulsella eydari</i> Oppenheim			×					
<i>Spondylus</i> sp. (cf. <i>rouaulti</i> d'Arch.)				×				
<i>Trachycardium cf. granconense</i> Oppenheim	×							
<i>Lucina cf. pharaonis</i> Bellardi		×	×	×		×		Pass N. of Wadi Khumas.
<i>Lucina cf. nokbaensis</i> Oppenheim								Wadi Nagra, first camp west of Derna.
<i>Corbis lamellosa</i> (Lam.)			×					
<i>Maetra cf. fourtaui</i> Cossmann								Pass N. of Wadi Khumas.
<i>Cordita</i> (cf. <i>aenticostata</i> Lam.)								Pass N. of Wadi Khumas.
<i>Euspira possaguensis</i> Oppenheim								East of Ain Hafra.
<i>Ampullina crassatina</i> Lam.								Lamludeh.
<i>Rostellaria cf. ampla</i> Sol.								West of Shrine of Sidi Abdullah; south-east of Messa.
<i>Gisortia gigantea</i> (Münst.)	×							
<i>Vasum cf. frequens</i> Mayer-Eymar				×				

Parisian.

Ostrea sp. (cf. *O. gigantea*) Near Ain Sciahat.

They probably represent part of the Lower Eocene or Libyan Series of Egypt. The chert-bearing Apollonia Limestones also yielded no determinable molluscs or echinoids, but their infraposition to the Derna Limestone shows that they correspond to the chert-bearing Upper Libyan Limestones of Egypt. They are succeeded above by the Derna Limestone, which is shown by its beautifully preserved foraminifera to be the equivalent of the Lower Mokattam Limestone in Egypt, and is therefore of Middle Eocene age. The Slonta Limestones, a stratified series above the Derna Limestone, according to Mr. Chapman's identification of the fossils, are also Middle Eocene. But Mr. Newton reports that the mollusca are Priabonian, which is regarded either as the uppermost series of the Eocene or the lowest of the Oligocene.

The evidence of the echinoids agrees with that of the mollusca. One of the most characteristic beds in the Slonta Series yielded many specimens of *Echinolampas*; but I have been unable to recognize among them any specimen, either of *Echinolampas crameri* or of *E. africanus*, the characteristic Upper Mokattam species: the Echinolampids certainly have Upper rather than Middle Eocene affinities.

The supposition that the Slonta Limestones may represent the Upper Mokattam stage is, on the other hand, supported by some stratigraphical considerations. Thus, at or near the top of the Slonta Limestones is a widespread horizon containing reef-building corals. The specimens obtained were casts, and they have not yet been closely examined; but the development of the reef-corals at this horizon must be due to a shallowing of the sea in Cyrenaica, and this change may have been contemporary with the growth of the reefs of *Orbicella* and other corals in the Upper Mokattam Beds of Egypt.

The Upper Mokattam Beds in Egypt are succeeded by freshwater and terrestrial deposits, and the only quartz-pebbles found in Cyrenaica, except along the coast, were obtained at Gasr el Migdum, in a bed a little above the coral-reef horizon. This pebble-bed, and the marl containing flattened stem-like fragments that forms the springs at Cyrene and Messa, may represent a stratigraphical break corresponding to the Egyptian freshwater beds; and there is clearly a gap in the succession at or a little above this horizon, since no representative of the Lower Oligocene (Tongrian) was found. The Slonta Beds are succeeded by the Cyrene Limestone, which is referred to the Upper Oligocene (Aquitanian).

If the reef-coral limestone in Cyrenaica is on the same horizon as that of Egypt, then the Slonta Beds would be Middle Eocene, and the gap in the succession in Cyrenaica would include both the Upper Eocene and the Lower Oligocene.

That the Derna Limestone is Middle Eocene is undoubted. It is overlain by a hard or rough-weathering limestone, some layers of which contain so many echinoid-plates and spine-fragments as to suggest for it the name of the Echinoid Limestone. Some of the plates came from regular echinoids, but I unfortunately did not collect sufficient for generic determination. Above this Echinoid Limestone is a soft white marl containing *Fibularia*

luciani; hence this bed and the underlying Echinoid Limestone may both be included in the Middle Eocene. The *Fibularia* Bed is succeeded by a series of limestones which, so far as I saw, were resting conformably upon it. These limestones include the white to cream-coloured nummulitic limestone, in which have been excavated the tombs of the northern necropolis of Cyrene. Mr. Chapman refers the foraminifera in this rock to the Middle Eocene. It does not, however, contain the typical *N. gizehensis* found in the Derna Limestone, but the variety *lyelli*; and that variety is also found in the brown-weathering, stratified limestones at Slonta. There and elsewhere the variety *lyelli* is associated with Priabonian, or at least Upper Eocene, mollusca and echinoids.

I am therefore forced to the conclusion that the Slonta Limestone should be included in the Upper Eocene, and regarded as Priabonian. This view involves the correlation of the hard, brown-weathering limestones of the Slonta Downs with the soft, cream-coloured, nummulitic limestone of the northern necropolis of Cyrene. But, as the two formations both occur between the Cyrene Limestone and the Derna Limestone, and as they both contain the same variety of nummulite, they must be approximately on the same horizon. The difference in their lithological characters is probably due to the beds at Cyrene having been deposited farther from land. The occurrence of the variety *lyelli* may be due to its survival, owing to favourable bathymetric conditions.

The identification of the Slonta Limestone as Upper Eocene and Priabonian introduces one important difference between the stratigraphical succession in Egypt and in Cyrenaica. The coral-limestones of the two countries must be at different horizons; but what is more remarkable is that the great gap in the succession in Cyrenaica would be later than that in Egypt, if the usually accepted age of the *Palaemastodon* Beds of Egypt be correct. The date of that fauna has been the subject of considerable discussion. According to Dr. Andrews,¹ these *Palaemastodon* Beds are Bartonian; Prof. Depéret,² on the other hand, from the resemblance of Andrews's *Ancodon gorringei* from the Fayûm to the *Brachyodus cluai* from the Ebro Valley, holds that the Fayûm Beds are Oligocene, and belong either to the base of the Stampian or to the top of the Sannoisian. Dr. P. Oppenheim³ has since reaffirmed his acceptance of the Eocene age of the Fayûm beds, and says that they are at the highest, Ludian, that is, Priabonian.

If Dr. Andrews's and Dr. Oppenheim's conclusions be correct, then the marine deposits ended in Egypt at the close of the Middle Eocene or Parisian (Lutetian), while the sea still covered Cyrenaica, which only emerged in the Lower Oligocene. But, if Prof. Depéret be right, the gap in the marine succession of deposits in Cyrenaica occurred at the same time as in Egypt.

¹ C. W. Andrews, 'A Descriptive Catalogue of the Tertiary Vertebrata of the Fayûm, Egypt' British Museum, 1906, pp. ix, x.

² Ch. Depéret, 'Sur l'Âge des Couches à *Palaemastodon* du Fayoum' Bull. Soc. Géol. France, ser. 4, vol. vii (1907) pp. 193-94; also *ibid.* pp. 455-56.

³ P. Oppenheim, 'Observations sur l'Âge des Couches à *Palaemastodon* du Fayoum' Bull. Soc. Géol. France, ser. 4, vol. vii (1907) pp. 358-60.

Some of the evidence of the Cyrenaican fossils is consistent with Prof. Depéret's view that the Egyptian mammalian beds are later than the dates usually accepted: thus *Pecten arcuatus*, the most widespread mollusc in the limestones ascribed to the Priabonian, is also found in the Tongrian; and the *Amphiope*, found at several localities, is not an Eocene genus. Its presence led me in the field to regard the beds containing that genus as, at the earliest, Tongrian; but the evidence of the associated nummulites and mollusca, as also the Upper Eocene aspect of the accompanying Echinolampids, renders it advisable to regard the presence of *Amphiope* as due to an unusually early occurrence of that genus. Otherwise, though the acceptance of *Amphiope* and *Pecten arcuatus* as Tongrian would approximate to Prof. Depéret's views, it would increase the difference between the dates indicated by the foraminifera and by some of the other fossils.

It may be suggested that the simplest explanation of the conflict of evidence is that the specimens were mixed after they were collected. The mixture was however Nature's, not mine; for some of the fossils which indicate different dates were cut from the same hand-specimen.

It therefore seems probable that, because of varying bathymetric conditions, there was an intermingling of the Middle and even Lower Eocene foraminifera, *Nummulites curvispira* and *N. gizehensis*, with Upper Eocene mollusca; but, on the reappearance of *N. gizehensis* it was represented by var. *lyelli*, the nummulite characteristic of the limestones at Slonta and of the soft limestone excavated into the tombs at Cyrene.

The distribution of the chief nummulites in question is as follows (with their range in the corresponding horizons in Egypt and adjacent parts of Asia, quoted from Dr. Blanckenhorn's table ¹):—

		Dr. Blanckenhorn's Table.
Cyrene Limestones.	{ <i>Nummulites subramondi</i> and <i>Operculina libya</i> .	Lower Oligocene. { <i>N. intermedia</i> and <i>N. biarritzensis</i> .
Slonta Limestones.	{ Coral-limestone— <i>N. beaumonti</i> . Limestone of the Cyrene Tombs and <i>Echinolampas</i> Beds of Slonta— <i>N. gizehensis</i> var. <i>lyelli</i> , <i>N. curvispira</i> , <i>N. subdiscorbina</i> , <i>N. intermedia</i> , and <i>Operculina libya</i> . <i>Fibularia</i> Limestone— <i>N. curvispira</i> . Echinoid Limestone— <i>N. subdiscorbina</i> and <i>N. gizehensis</i> var. <i>viquesneli</i> .	Upper Mokattam. { <i>N. subdiscorbina</i> and <i>N. beaumonti</i> .
Derna Limestones.	{ <i>N. gizehensis</i> , <i>N. curvispira</i> , <i>N. chrenbergi</i> , and <i>N. rouaulti</i> .	Lower Mokattam. { <i>N. gizehensis</i> , <i>N. curvispira</i> , <i>N. beaumonti</i> , and <i>N. subdiscorbina</i> .
Apollonia Limestones.	{ <i>N. subdiscorbina</i> .	Upper Libyan.
		Lower Libyan. { <i>Operculina libya</i> , <i>N. biarritzensis</i> .

¹ 'Neues zur Geologie & Paläontologie Ägyptens, II. Das Paläogen' Zeitschr. Deutsch. Geol. Gesellsch. vol. lii (1900) facing p. 406.

The *Nummulites* and *Operculina libyca*, which lived from the Lower Libyan to the Miocene, have therefore a somewhat variable range in age, and their distribution must be influenced by bathymetric conditions.

Above the Priabonian or Upper Eocene rocks of Cyrenaica there appears to be a gap in the succession, as the next beds recognized belong to the Upper Oligocene or Aquitanian. The limestones of Wadi Umzigga and Birlibah contain *Lepidocyclus elephantina*, which Mr. Chapman assigns to the Middle or Upper Oligocene (Stampian or Aquitanian); the mollusca from the same limestone are identified by Mr. Newton as Aquitanian: hence the rocks may be accepted as Aquitanian. They are, therefore, of nearly the same age as the limestones at Cyrene, which are the best representatives in Cyrenaica of the Aquitanian Series.

At Gubah, west of Wadi Umzigga, the rocks are Miocene, and probably Helvetian; and as I found an Echinoid of that age near Birlibah, there are apparently Miocene outliers on the *Lepidocyclus* Limestones.

The Miocene rocks were not once seen resting directly upon the older rocks. They form the plains at the foot of the Tokra scarp, east of Benghazi; but there they have been faulted down against the Lower Eocene beds. Some shelly limestones, from which Mr. Newton has identified the Miocene *Anadara turonica*, occur on the divide between the plain of Merj and the wadis leading to the coast near Ptolemeta. They lie upon the Apollonia Limestone. The Gubah Limestones are also probably faulted down against the rock which forms the plateau near Zawiah Charrah; but we obtained no definite evidence as to their relations, as we had been asked to travel quickly and with special care to avoid arousing suspicion during that stage of the journey.

The sequence of rocks in Cyrenaica is, therefore, more varied and complex than was anticipated. The Miocene rocks, instead of occupying the whole country, are sparsely represented, and Cyrenaica consists essentially of a vast block of Eocene limestone. This rock is capped by some outliers of Oligocene and Miocene; while some Miocene limestones have been faulted against its western foot, and it is fringed by low-level, marine, Pleistocene limestones.

The suggested classification and correlation of the Cyrenaican beds and their relations to those of Egypt, Tunis, and Malta, are shown in the table on p. 602.

The stratigraphical succession in Cyrenaica differs, therefore, from that in Egypt and Tunisia, owing to the continuity of the marine rocks in Cyrenaica and their deposition farther from land. The most striking feature in their lithology is the paucity in mechanically-derived sediment—a fact brought out clearly by a careful study of a series of microscopic sections made by Mr. D. P. Macdonald. The series must include nearly 3000 feet of strata, which consist of limestones almost entirely composed of organically formed material. There are occasional beds of limestone-breccia,

	Cyrenaica.	Egypt.	Central Tunisia.	Malta.
PLEISTOCENE.	{ Sand-dunes, lagoon-clays, alluvium and delta-fans. Calcareous tufa of Derna. <i>Cerastoderma-edule</i> Limestone, east of Benghazi.			
MIOCENE.	None.			
Upper—Tortonian.	{ <i>Scutella</i> Limestones at the foot of the Tokra scarp.	Limestones with <i>Scutella</i> , <i>Clypeaster subplacumarius</i> , <i>Ostrea virleti</i> , etc. of Siwa and Marmarica.	Sandstones and conglomerates with <i>Ostrea crassissima</i> , <i>Pecten fuchsii</i> .	Upper Coralline Limestone.
Middle—Helvetian.	{ Gubah Limestones.		Coarse white sandstone with <i>Scutella subrotunda</i> .	Greensand.
Lower—Burdigalian	None.			{ Blue Clay. Upper <i>Globigerina</i> Limestone.
OLIGOCENE.				
Upper—Aquitanian.	Cyrene Limestones at Cyrene, north-east of Slonta, Labruk, Lamludeh, Biribah, Wadi Umzigga, etc.	<i>Lithothamnion</i> Limestones of Aradj, and basalt of the Fayûm.	White sandstone of G. Gebil.	Lower <i>Globigerina</i> Limestone.
Lower—Tongrian.	None.			Lower Coralline Limestone.
EOCENE.				
Upper—Priabonian.	{ Coral - limestone at Wadi Firyah, Labruk, etc. Tomb Limestone at Cyrene and <i>Echinolampas</i> Bed at Slonta — with <i>Nummulites</i> <i>gizehensis</i> var. <i>lyelli</i> . <i>Fibularia</i> Limestone at Cyrene. Echinoid Limestone. Cave Limestone with <i>N. gizehensis typica</i> and <i>N. ehrenbergi</i> . The Chert - bearing Series.	{ Coral - limestone of the Fayûm: limestones and marls near the Pyramids. Limestones and marls, with the typical Nummulite Limestone. White limestone with chert-nodules.	Clays and sandstones with <i>Pecten arcuatus</i> , <i>Echinolampas cheriterensis</i> , <i>Clypeaster biarritensis</i> .	
Middle—Mokattam Series.	Derna Limestone.		Marls with <i>Echinolampas goujoni</i> and <i>Ostrea bogharensis</i> .	
Lower—Libyan.	Apollonia Limestone.	Limestones and marls of Farafra and Khargah.	<i>Globigerina</i> Limestones with chert-nodules and <i>Nummulites rollandi</i> . Nummulite Limestone with phosphatic chalk.	

but I only remember finding quartz-pebbles once, and sand-grains in the limestone are rare. Some of the limestones are argillaceous, or include layers of marl; and this material is composed of a very fine clay. We saw no representatives of the terrestrial and freshwater deposits of Egypt, or of the abundant sandstones and clays found in the corresponding rocks of Tunisia.

The Cyrenaican limestones must have been deposited mainly in water of moderate depth. The rocks which indicate the deepest water are the fine-grained chalky *Globigerina* Limestones, which form the upper part of the Apollonia Limestones, west of Ptolemeta, and are also exposed at the Wadi Nagr. During the deposition of the Slonta Series the sea was shallower near Slonta than at Cyrene, for elastic material becomes more abundant as the beds are traced southwards; hence land doubtless existed in that direction, and if no considerable river discharged on that coast it need not have been far away. The widespread coral-reef limestones near the top of the Slonta Series indicate a shallowing of the sea, and the area may have been raised above sea-level during Lower Oligocene times; for the Slonta Series of Priabonian age is apparently succeeded by Aquitanian limestones.

Another gap succeeded the Aquitanian; for the next beds are shallow-water Middle Miocene limestones, which are widely developed on the coastal plains east of Benghazi, and are preserved in occasional fragments on the summit of the Cyrenaican plateau.

The Cyrenaican sequence resembles the Maltese in the persistence of marine conditions. The Maltese beds, however, began later, as the oldest is Tongrian, while the latest is Tortonian. The *Globigerina* Limestones of Malta were probably laid down in deeper sea—Sir John Murray's estimate for them is 1000 fathoms—than any in Cyrenaica; but the chalky limestones of the Apollonia Series were probably formed in water not much shallower. The long continuity of a variable marine series is a feature common to the geology of both Malta and Cyrenaica.

V. THE TECTONIC GEOLOGY.

The two essential facts in the structural geology of Cyrenaica are, that pre-Kainozoic rocks are unknown there¹; and that all its rocks are marine limestones, which, although raised in places to 2500 feet above sea-level, are, except in the vicinity of the main fault, still horizontal or inclined in broad shallow folds. The country, therefore, has no resemblance either in composition or in structure to the Atlas Mountains. It is essentially a block of Eocene Limestone, capped by some outliers of Oligocene and Miocene, and flanked by Pleistocene. The Eocene rocks, which form the great mass of the country, resemble those of Egypt; but I saw no representative of the Bartonian and Oligocene terrestrial deposits found in Egypt, as in the Fayûm.

¹ The most likely position for Cretaceous rocks is on the lower part of the Tokra scarp.

Cyrenaica may, therefore, be described as a plateau formed by a westward extension of the Eocene limestones of Egypt, and capped by outliers of the Maltese beds.

The Miocene rocks, which, on the coast of Western Egypt, are but little above sea-level,¹ occur in Eastern Cyrenaica at the height of 1100 to 1800 feet; and, while the base of the Derna Limestone,

Fig. 4.—Sketch-map illustrating the tectonic relations of Cyrenaica.

which is correlated with the Lower Mokattam Beds of Egypt, lies close to the sea-level at Derna, it disappears beneath it farther east. Westward, on the other hand, the Derna Limestone at Mersa Susa extends from about 500 to 1100 feet above sea-level, it

¹ They are marked on Dr. Ball's map of Mersa Matruh up to the height of about 200 feet.

rises in the Wadi Khumas to the height of nearly 1800 feet, and its base is from 1000 to 1100 feet above sea-level near the plain of Merj. The main dip is, therefore, from Western Cyrenaica eastwards into Egypt; hence the Cyrenaican plateau may be regarded as the western limb of the Egyptian geosyncline, of which the centre is occupied by the Oligocene basin on the west of the Fayûm.

In Cyrenaica, faults are more important than folds. That some of the main geographical features of the country were due to faulting was suggested by Spratt.¹ He attributed the sharp bends of the coast, as at Ras el Tin, the Syrtis, and the Bay of Salum, as also the variations in the level of the plateau, to the influence of faults. This suggestion was repeated by Dr. Hildebrand² in 1904. The general aspect of the country, as seen from the sea, appeared consistent with this hypothesis, which was confirmed by the facts discovered during our march.

The faulting happened so long ago that the actual faults are hidden; for the scarps have been worn back, and the fault-lines covered by talus. The existence of the faults was, however, proved east of Benghazi and near Merj, for in both cases younger rocks have been lowered against older members of the Cyrenaican sequence. The Gubah Limestones have probably also been faulted down against the Eocene limestones.

I expected to find that the step-like descent from Cyrene to the coast was due to two parallel step-faults, the upper cliff at Cyrene being the scarp of one of them. The upper cliff is, however, an escarpment. The platform at its foot is not a repetition of the rock (the Cyrene Limestone) of the upper plateau, but an outcrop of an older, harder limestone, which has resisted denudation. The lower cliff, however, if we judge from the evidence collected near Mersa Susa, is doubtless a fault-scarp; for Mr. Newton has identified the fossils collected on the coastal plain at the foot of the cliff (for list, see p. 597) as Priabonian in age, and they are lying at the foot of cliffs of Lower Eocene chert.

The faults of which I obtained definite evidence may be classified into three main groups, the relations of which are shown in fig. 1 (Pl. XLII) & text-fig. 4 (p. 604).

The first group trends approximately east and west, and forms the scarps seen from the sea behind Mersa Susa, and near Derna. In both cases the evidence for the existence of the fault rests on the identification of the Priabonian limestones at the foot of the cliffs, and lying against the Lower Eocene rocks. It appears probable that the coast-line east of Ras al Hilil may be due to the same fault; and it appears natural to suggest that the long straight lines of the coast in Marmarica, and of the north and south sides of Crete, may also have been determined by faults with the same general trend. (See map, fig. 4.)

The fault east of Derna, which appears to determine the position

¹ T. A. B. Spratt, 'Travels & Researches in Crete' vol. ii (1865) App. iv, pp. 375-76.

² G. Hildebrand, 'Cyrenaika als Gebiet künftiger Besiedelung' 1904, p. 7.

of the coast between that port and Ras el Tin, trends about 20° to the south of east. It thus approximates toward the direction of the powerful faults which, as shown by M. Deprat,¹ formed the islands of Eubœa, Andros, and Tinos, and separated Eubœa from the mainland of Greece by the rift-valley of the Talanta and Euripo Channels.

The members of the second group of Cyrenaican faults trend from south-west to north-east. They give rise to the scarps that bound the plains of Merj and Silene, as Upper Eocene limestones at Merj occur at a lower level than the Middle Eocene limestones of the plateau to the south-east of the town. The Merj fault-scarp is parallel to the Tokra fault-scarp, down which we descended on to the coastal plain about 16 miles east of Benghazi. The hills are formed of Lower Eocene rocks, and that the limestones at their foot are Miocene is clear from the large Clypeasters and Scutellas exposed on the wind-swept surfaces. The Tokra fault must have a downthrow of at least 1500 feet. This fault-scarp trends towards Ptolemeta, but its precise course is uncertain. The position accepted for its northern continuation on the map (fig. 4, p. 604) is based on the Admiralty Charts, Eastern Mediterranean (2158 B, corrected to 1907) and Benghazi to Derna (1031, corrected to 1900); but, according to Camperio,² the fault-scarp may pass nearer to Tokra, for his map marks the high plateau as reaching nearly to the shore and ending to the east of Tokra in a steep descent which trends from about west-south-west to east-north-east. The Admiralty Charts, however, represent the scarp as passing farther inland on a fairly straight course, from its position east of Benghazi to Ptolemeta. The International Geological Map of Europe (Sheet D VII, 1905) agrees more closely in this respect with the Admiralty Chart than with Camperio's map.

The Tokra scarp, as above accepted, is parallel to the Merj scarp and is in line with the sharp division in Western Crete between the Jurassic rocks and the metamorphic area south of Kanea. The downthrow of the faults would no doubt be on opposite sides in Crete and Cyrenaica; but the coincidence of direction is remarkable, especially as the continuation of this line into Asia Minor separates the downthrown Kainozoic area of the Smyrna district from the metamorphic rocks of the highlands to the south-east of Smyrna and Ak Hissar. This line across Western Crete and from Smyrna to Ak Hissar is almost at right angles to the direction of the Eubœan faults.

The third group of Cyrenaican faults trends approximately north and south. It includes the Gubah Fault, the continuation of which may form the headland of Ras al Hilil. The evidence from this fault supports Spratt's suggestion that the sharp bends of the coast on the western sides of Bomba Bay, of the Bay of Salum, and perhaps

¹ J. Deprat, 'Étude Géologique & Pétrographique de l'Île d'Eubée' Besançon, 1904.

² 'Carta Economica della Tripolitana & Cirenaica,' published by the Società di Esplorazione commerciale in Africa, Milan, 1883.

too of Abu Shaifa Bay and Kanais Bay, are also due to faults. The abrupt western ending of Crete along a north-and-south line, and the conspicuous headlands with the same trend, such as Cape Littinos and the western shore of the Gulf of Morabella, may also be due to north-and-south faults. (See map, fig. 4, p. 604.)

The throw of some Cyrenaican faults is very great. The fault behind Mersa Susa had a movement of approximately 1500 feet, and the Tokra fault had a downthrow to the west of at least the same amount. The movements, though extensive, are probably of recent geological date. The best evidence obtained as to their age is from the Tokra scarp. Limestones with *Cerastoderma edule* extend over the coastal plain nearly to the foot of that scarp. I did not see them along the fault-line, but their range inland was probably bounded by it. As the *C. edule* Beds are late Pliocene or early Pleistocene, the fault-scarp was probably formed before the deposition of these beds; it was certainly later than the *Scutella* Limestone, which is probably of Middle or perhaps Upper Miocene age.

The faults are not necessarily of one age, but they were probably all part of a connected series of movements which apparently began later than the Helvetian and earlier than the *Cerastoderma-edule* Beds. These deposits represent a marine transgression of late Pliocene and early Pleistocene age, which can be recognized in many widespread localities on the northern coasts of Africa. If the Tokra scarp be a continuation of that in Western Crete near Kanea, the south-west to north-east faults would be earlier than those which trend east and west and have determined the northern coast of Cyrenaica; and the fact that we did not find the *Cerastoderma-edule* Beds along the northern coast gives slight support to that hypothesis. Negative evidence from a hurried examination of so small a proportion of the coast is of little weight, but the fact may be mentioned in order to direct attention to this point. The *Cerastoderma-edule* Beds occur on the western coasts of Egypt; and, if they are absent from the northern coast of Cyrenaica, then the faults, by which the last remnant of the land-connexion between Africa and Crete foundered beneath the Mediterranean, took place after the deposition of the early Pleistocene limestones. The land-bridge to Crete would moreover have been limited in width to the area between Ptolemeta and Mersa Matruh, where M. Pachundaki has found the *C. edule* Beds.

Cerastoderma edule is widely distributed in Algeria and Tunisia, and is referred by M. Georges Rolland¹ to the Upper Pliocene; but, as its main distribution is post-Sicilian, it is safer to regard the *C. edule* Limestone in Cyrenaica as early Pleistocene, the age accepted for it by Dr. Blanckenhorn² and by M. Pachundaki.³

¹ 'Géologie du Sahara Algérien & Aperçu géologique sur le Sahara, de l'Océan Atlantique à la Mer Rouge.' Chemin de Fer Transsaharien (French Government Report), Paris, 1890, pp. 194-95.

² 'Neues zur Geologie & Paläontologie Ägyptens—IV. Das Pliocän- & Quartärzeitalter' Zeitschr. Deutsch. Geol. Gesellsch. vol. liii (1901) table facing p. 308.

³ 'Contribution à l'Étude Géologique des Environs de Marsa Matrouh (Marmarique)' Revue Internationale d'Égypte, vol. iv (1907) pp. 4 & 6.

Though important earth-movements in this area have apparently happened as late as the Pleistocene, they appear to have ceased before historic or even Palæolithic times. The sea-level cannot have been notably altered at Derna since the date of the Palæolithic camp at Bonmansur. I saw no recent raised beaches along the coast; and there are no distinct signs of recent subsidence. Stacey has referred to modern subsidences at Benghazi, while F. W. & H. W. Beechey have referred to indications of the recent advance of the sea seen during their surveys of the ancient Greek ports of Tokra, Ptolemeta, and Mersa Susa. The evidence even at these localities seems, however, to show that there has been no marked displacement of the shore-line since classical times. The sea has no doubt encroached at Benghazi and Mersa Susa,¹ but its advance at both places may be explained by ordinary coastal abrasion, with subsidences due to solution of limestone. The *Glycimeris* Limestones at Benghazi and Ptolemeta would suggest a slight emergence of the land, and not a subsidence; but they may have been storm-beaches and dunes subsequently separated from the sea by silting.²

The ancient wharf at Ptolemeta, according to the Beecheys' map, is now 150 yards from the shore-line, but the intervening beach is probably due to silting. At Mersa Susa there has been a slight encroachment of the sea near the ancient theatre; it has, on the other hand, receded at the old harbour, probably through silting, for the ruins of the ancient piers appear to stand at exactly their original level. The maps of Mersa Susa, Tokra and Ptolemeta, revised from the Admiralty Chart by Smith & Porcher,³ show that there has been no serious change of sea-level since the building of those ancient towns by the Greek colonists, who began the colonization of Cyrenaica about 620 B.C.

VI. THE WADIS, AND POSSIBLE VARIATIONS IN PLEISTOCENE CLIMATE.

The preceding evidence shows that Cyrenaica is a block of Eocene, Oligocene, and Miocene limestones, which was uplifted in Upper Miocene times (if the Gubah Limestones be Helvetian) and subsequently isolated by the foundering of the surrounding areas. The first subsidences in the Lower or Middle Pliocene formed the Tokra scarp and the Gulf of Syrtis, for the Cretaceous rocks—as at Tripoli—are separated from the sea only by Pleistocene deposits. The

¹ The most definite evidence of the advance of the sea is at Benghazi. G. B. Stacey writing in 1867 quoted Arab testimony that horse races had been held 50 years previously, inside the reef where the water was now 5 feet deep; and he states that the ruins of buildings were to be seen at low water on the reef: Q. J. G. S. vol. xxiii (1867) p. 384. The present brackishness of the wells at Mersa Susa has been regarded as evidence of encroachment of the sea or subsidence of the land by George Dennis, 'On Recent Excavations in the Greek Cemeteries of the Cyrenaica' Trans. R. Soc. Lit. ser. 2, vol. ix (1870) p. 144.

² That the shore has receded at Benghazi is remarked by F. B. Goddard, 'Researches in the Cyrenaica' Amer. Journ. Philology, vol. v, No. 17 (1884) p. 51.

³ 'History of the Recent Discoveries at Cyrene' 1864, pl. i.

great tract of lowland, extending from Egypt to the south of Cyrenaica through the Oases of Siwa and Aujila, may have sunk at the same time, or it may not have been raised by the Miocene uplift to the same extent as Cyrenaica.

The maps of Cyrenaica, as for example that in Dr. Hildebrand's 'Cyrenaika' pl. iii, represent the country as descending to the south in two steep steps; one of these steps is situated 25 miles south of Slonta; the other is much farther south, and it separates the Libyan Plateau from the lowland of the Wadi Fareg and the Oases of Siwa and Aujila, of which the former certainly and the latter probably are below sea-level. This representation suggests that the southern boundary of Cyrenaica consists of one or two faults, of which at least the southern is connected with the foundering of the Siwa-Aujila depression. The Slonta Arabs, however, assured us that the country passes gradually downwards into the Aujila plain; and if so, the Aujila district probably did not share the Miocene uplift, which increased gradually northwards.¹

The predominant dip of the beds in Northern Cyrenaica is northward, and this direction continues as far south and west as the Wadi Khumas and Messa. In Central and Southern Cyrenaica the predominant dip is southward, and it is probably the same in South-eastern Cyrenaica. The main dip-slope, due to the Upper Miocene movements, was therefore to the south. The consequent rivers would, therefore, have carried whatever drainage there may have been down the southern slopes of Cyrenaica through the Wadi el Bah westwards to Benghazi, and through the Wadi el Ajara el Remla eastwards to the Bay of Bomba. Along the line of our traverse the most conspicuous drainage is to the north, although at Slonta and Silene we crossed streams beginning with a southward course, and the northern margin of the plateau has been notched by numerous gullies cut by obsequent streams. The wadis in Northern Cyrenaica are now deep cañons forming the most picturesque features in the scenery. Although some of the limestones, such as the typical rock of the Derna Limestone, are very soft, the cliffs of the wadis are sometimes vertical. These cañons, such as the wadi west of Mersa Susa (named by Smith & Porcher the Wadi Lebaiath, but my guide called it the Wadi Dimi-ell), the Wadi Jebail, and the great Wadi Derna, are so large that they inevitably suggest the question, whether they were not excavated by great perennial rivers, when the country had a better water-supply and heavier rainfall than at present.²

¹ The evidence of the Arabs (see p. 586) agrees with the conclusion in Dr. Hildebrand's text, *op. cit.* pp. 151-152: 'We do not yet know how the whole Libyan plateau rises towards the north, whether it rises in terraces, whether it slopes up gently, or whether our Cyrenaica is placed on it like a dome. Only one thing almost all travellers have united in stating, that Cyrenaica gradually sinks to the south and at last loses itself in the Libyan Desert.'

² Corresponding to Dr. Blanckenhorn's 'Pluvial Period' in Egypt, 'Neues zur Geologie & Paläontologie Egyptens—IV. Das Pliocän- & Quartärzeitalter' Zeitschr. Deutsch. Geol. Gesellsch. vol. liii (1901) p. 393 & table facing p. 308.

The occurrence of boulders 3 feet in diameter embedded in an old sheet of silt at the mouth of the Wadi Nagr, and of others lying on the bed of the wadi west of the Wadi Susa, shows that the floods have been of great power. Nevertheless, there does not seem to me any adequate evidence of a greater rainfall in Cyrenaica in historic times.¹ Northern Africa no doubt had a better rainfall than at present, at the time of the glaciation of parts of North-Western Europe: for the cyclonic systems, which now traverse Europe from west to east, would then have followed a more southern path. But that meteorological factor appears to have benefited Algeria and the Atlas Mountains rather than Cyrenaica, for even the older parts of the deep Cyrenaican wadis present the characteristics of cañons cut in an arid country. Nevertheless, it is probable that the wadis were cut at a time of heavier rainfall than at present, for very little excavation is now taking place in them. In some of the valleys, such as the Wadi Khumas north of Slonta, various facts show that there cannot have been any flow of water down the ravine for some years past. Thus plants of several years' growth stand on the lowest part of the channel; traces of cultivation, which must have been several seasons old, remain undisturbed on sheets of clay in depressions of the river-bed; footpaths have been worn clear of pebbles; and slight ridges of earth have gradually accumulated across the dry river-bed. Just above the lowest part of Wadi Khumas the valley contracts to a narrow gorge, which is filled with trees and shrubs, and I could see no flood-marks upon them. There can have been no heavy flood through this outlet for at least several decades. Below this point, however, a large tributary comes in from the north, from the neighbourhood of Messa; and the traces of recent movement of coarse gravel and the absence of shrubs from the river-bed, show that water had flowed across that river-bed within the last year or two. In the Wadi Jeraib some patches of rolled shingle with only young vegetation give evidence of some flow in a recent season; but the amount cannot have been considerable, for lower down the wadi the evidence of the flow had disappeared.

There is no evidence of any considerable deepening of these wadis in recent years. The largest cedars that we saw in Cyrenaica were in the Wadi Jeraib, where they are growing almost level with the river-bed, and chariot-tracks in the lowest part of the same wadi show that the bed has not been appreciably lowered since Roman times. Chariot-tracks worn in the limestone in other localities also show that the wadis have not been materially deepened since the Roman occupation. The gravel-platform at Bonmansur in the Wadi Derna may have been partly worn away since its occupation by Palæolithic man; but even there it is quite possible that no appreciable change has taken place since his time.

¹ The conditions of existing rainfall and water-supply are stated in the Expedition Report, pp. 5-6, 9-10, and in the Report by Mr. M. B. Duff, pp. 38-44. The most reliable rainfall records available, those at Benghazi from 1891 to 1894, are included in the table opposite p. 46.

There does not seem to be the slightest physiographic evidence of any considerable change in the rainfall or water-supply of Cyrenaica since the days of the Greek colonization in the seventh century B.C.; and the evidence furnished by the classical descriptions of the country, as also the waterworks erected by the Romans, indicates that the country was then under the same climatic conditions as at present.

J. P. Thrige, in his '*Res Cyrenensium*' 1819 (2nd ed. 1828), has collected the classical records respecting Cyrenaica, and they indicate that the climate of the country was much the same in ancient as in modern times. There were probably more trees under the Romans, as they were then more carefully preserved; but the characteristic products of the province, such as wool, honey, wax, and corn, are indicative rather of moorlands with a limestone soil, than of a humid, wooded country. Plagues of locusts, insects characteristic of arid plains, devastated the land then as they do now; thus, in the year 125 B.C. they came in such swarms that accumulations of their bodies along the shore are said to have caused a pestilence. Other visitations are recorded, and they were so constant a danger that a law, quoted by Thrige (paragraph 80),

'made it obligatory for the people to wage an annual war against locusts, destroying first the eggs, then the brood, and ultimately those that had grown up, and imposed a penalty for negligence.'

The waterworks, which are the most conspicuous remains of the Roman occupation, also show that the country suffered from a scanty water-supply. Water was stored with great care, and Cyrene received a supplement of water from some artificial roofed reservoirs at Safsaf, about 6 miles distant in a straight line. The capacity of these reservoirs was measured by Dr. Trotter; the largest is about 960 feet long, 16 feet wide, and 12 feet deep; and the whole of them would have held about 1,500,000 gallons. If Cyrene had had a population of 15,000, the Safsaf reservoirs would have provided an allowance of only a gallon per head per day for three months. It would not have been worth while building a long stone aqueduct to carry so small a quantity, if a considerable supply had been available at Cyrene.¹

Again, ancient Ptolemeta, according to Beechey,² had no springs, and was dependent for water upon an aqueduct: whereas, if there had been a reliable rainfall, wells in the ground behind the town would have yielded a considerable supply.

The ruins of ancient Greek and Roman buildings near all the

¹ It may be suggested that at the date of the first Greek colony the country had a wetter climate than at present, and that the Roman water-supply works mark the effort of the later colonists to maintain their hold over the country despite the increasing desiccation; but I can find no support for this suggestion, either in the classical literature, or in the physiography of the country.

² F. W. & H. W. Beechey, '*Proceedings of the Expedition to explore the Northern Coast of Africa, from Tripoly eastward*' 1828, p. 361. See also R. M. Smith & E. A. Porcher, '*History of ... Discoveries at Cyrene*' 1864, p. 66.

chief existing springs show that 2000 years ago those localities were the most important centres in the country, and that considerable springs were no more numerous than they are now. We saw no evidence that the springs had much larger volumes in classical times; and that the springs at Cyrene are as abundant as ever is asserted by the 'Mediterranean Pilot' (4th edit., vol. ii, 1905, p. 325). The country, moreover, in classical times suffered from famines following drought, as still happens occasionally, as just before the visit of Bruce to Benghazi in 1766.¹

That the region to the south of Cyrenaica was arid in classical times is shown by the fact that Cyrenaica was the starting-point of caravan-routes to the Oases of Aujila and of Siwa, through which then, as now, passed one of the chief caravan-routes from Cyrenaica into Egypt. That these routes traversed a desert country is evident from the statement of Strabo,² according to whom, behind Cyrenaica and the Syrtis, is a very sterile and dry tract in the possession of the Libyans; and Aujila and Ammon (that is, Siwa) were then oases well supplied with water and productive of palm-trees. How little the geography of Cyrenaica has altered since the time of Strabo is shown by his statement that the country behind the coast produces trees for the width of 100 stadia,³ and then for another 100 stadia the land is only sown, but from excessive heat does not grow rice. Hence, the tree-belt in Cyrenaica was then about $11\frac{1}{2}$ miles wide, and to the south of it was a belt, also $11\frac{1}{2}$ miles wide, of treeless plains producing dry cereals. The forests may have been thicker in classical times than they are now, but the forest-belt was apparently no wider.

That Cyrenaica in pre-classical times had a heavier rainfall seems to me probable from the aspect of some of the old valleys, which, from their curves and shape, I should suspect to have been carved during a period of greater rainfall; but this period, though doubtless Pleistocene, was probably pre-classical, and even earlier than the time of the people who made the stone implements which are scattered abundantly in several districts of Cyrenaica.

VII. THE COMPOSITION OF THE SOILS.

A series of analyses of the soil of Cyrenaica by Dr. J. Trotter is tabulated in the Report of the Expedition (pp. 28-36). As that report may not be easily accessible, some of the analyses are here reprinted. Nos. I-III illustrate the sedentary soils; nos. IV-XI the transported soils.

¹ R. L. Playfair, 'Travels in the Footsteps of Bruce in Algeria & Tunis' 1877, p. 285.

² The Geography of Strabo translated by H. C. Hamilton & W. Falconer, vol. iii (1857) p. 294.

³ The stadium, according to Smith's 'Dictionary of Greek & Roman Antiquities' (1845, p. 344) is 606 feet 9 inches English. 100 stadia = therefore about $11\frac{1}{2}$ miles.

ANALYSES OF CYRENAICAN SOILS.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.
Organic matter, etc....	5.21	5.35	8.30	6.80	8.49	5.29	7.70	6.59	7.51	3.90	7.67
Iron oxide	4.15	6.79	4.58	5.72	6.91	{ 16.88 ² }	{ 6.30 }	1.64	5.01	5.83	3.40
Alumina & soluble silica	8.45	14.11	7.21	5.62 ¹	5.90 ¹			9.76	8.50	11.55	5.82
Lime	1.43	28.72	25.68	1.14	1.50	2.11	1.14	31.70	1.40	1.00	54.37
Magnesia	.05	.28	.04	.04	.51	.05	.31	.07	.09	.07	.09
Phosphoric anhydride	.14	.12	.16	.14	.13	.18	.19	.13	.11	.20	.79
Sulphuric anhydride	.06	.04	.10	.07	.03	.03	.04	.04	.05	.05	.26
Potash	.63	.13	.14	.47	.23	.33	.28	.51	.83	.71	.34
Soda	.23	.49	.75	.70	.41	.68	.77	.63	.84	.58	1.91
Insoluble residue	79.65	43.97	53.04	79.30	75.89	74.45	77.29	48.93	75.66	76.11	25.35
Totals	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

¹ Alumina only.

² Iron oxide and alumina.

- I. A red loam from Gasr el Harib, plateau above Derna.
II. Above the Fountain of Apollo, Cyrene.
III. Near the Fountain of Apollo, Cyrene.
IV. Plain below the Fountain of Apollo.
V. Near the wells at Merj.
VI. North side of the Plain of Merj.
VII. South side of the Plain of Merj.
VIII. Ptolemeta.
IX. Plain of Silene.
X. Plain of Benghazi.
XI. Brown loam, from Derna.

VIII. SUMMARY OF CONCLUSIONS.

Cyrenaica is a plateau of Eocene limestones ranging from the Lower to the Upper Eocene, and capped by limestones referred to the Aquitanian and the Miocene. The predominant dip is to the east, so that the Miocene limestones found on the plateau in Eastern Cyrenaica occur close to sea-level on the western coasts of Egypt. The Cyrenaican plateau may, therefore, be regarded as part of the western limb of the great syncline of Western Egypt.

The plateau has been isolated and fractured by a series of faults of late Kainozoic date. The position of the northern coast of Cyrenaica is determined by these faults, and the Tokra scarp separates the main plateau from the coastal plain east of Benghazi. The Tokra Fault is on the same line as an apparent fault in Western Crete.

The faults may be divided into three groups:—(1) those ranging east and west along the northern coast; (2) those trending from south-west to north-east, including the Tokra scarp and the parallel scarp which bounds the plain of Merj; and (3) the north-and-south faults which have determined some of the chief bends in the northern coast of Cyrenaica and Western Egypt. The three series are connected with the faults which have broken up the land of Ægea and formed the rift-valleys that have separated Eubœa from the mainland of Greece.

The rocks of Cyrenaica are limestones composed almost entirely of organic material. They contain occasional quartz-grains and some very fine clay. The limestones have been deposited in a clear sea, and usually in moderately deep water, though at the top of the Slonta Limestones there is a bank of coral-reef limestone. The limestones range from shallow-water deposits, down to those formed at a depth approaching 1000 fathoms.

The rocks may be classified as follows:—

Pleistocene	Alluvial deposits, etc.
Miocene	Gubah Limestones.
Oligocene	Cyrene Limestones.
Eocene.....	{ Slonta Limestones. Derna Limestones. Apollonia Limestones.

The geological history of the country begins with the deposition of the chert-bearing Apollonia Limestones, which may be correlated with the Libyan or Lower Eocene Series of Egypt. The sea probably deepened to nearly 1000 fathoms, at which depth were deposited some chalky limestones with *Globigerina*. A re-elevation of the sea-bed led to the formation of limestone-breccias and conglomerates. Then followed another subsidence, during which were formed the cream-coloured limestones of Derna. This horizon is characterized by the typical form of *Nummulites gizehensis*.

The Derna Limestone was succeeded by a marly limestone containing *Fibularia luciani*, followed by the deposition of a rough-weathering massive limestone containing many echinoid fragments. This rock was succeeded by the deposition of the stratified Slonta Limestones, which are represented near Cyrene by a soft cream-coloured nummulitic limestone containing *N. gizehensis*, var. *lyelli*. This rock appears to pass southwards into the harder brown-weathering Slonta Limestones, which were formed in shallower water. The Slonta Limestones contain Priabonian mollusca and an *Echinolampas* Bed, in which the common species is referred to *E. cherichrensis* Gauth., of the Priabonian of Tunis. The deposition of the Slonta Limestones was brought to an end by a stratigraphical break, and the next series begins with a glauconitic marl containing many rolled limestone-fragments. This bed passes upwards into the yellow Cyrene Limestone, characterized by the abundance of *Operculina*. That limestone is referred, from the evidence of the molluscs and echinoids, to the Aquitanian. These beds are best developed above the Fountain of Apollo at Ain Sciahat, Cyrene.

Miocene rocks occur at Gubah, where they have been let down by faults, and along the coastal plain east of Benghazi, where they lie at the foot of the Tokra scarp. The country appears to have been uplifted after the Middle Miocene, and to have become part of a wide land which extended northwards and included Crete and the Ægean Sea.

The land was afterwards broken up by great subsidences, which left Cyrenaica as a horst, bounded by the fault-scarps on the north and west, isolated from Crete, and sinking slowly southwards to the Siwa-Aujila depression.

The river-valleys in Northern Cyrenaica belong to an obsequent system, the formation of which was probably started during a period when the rainfall was heavier than at present; but there appears to be no evidence of any appreciable change in the climate or water-supply of the country since the date of the Greek colonization, which began about 620 B.C.

EXPLANATION OF PLATE XLII.

Fig. 1. Geological map of Cyrenaica, on the scale of 20 miles to the inch, or 1 : 1,267,200.

2. Section from Benghazi to Derna.

3. Section from the Merj fault-scarp to the sea near Ptolemeta.