FURTHER NOTES ON THE GEOLOGY OF PALESTINE, WITH A
CONSIDERATION OF THE JORDAN VALLEY SCHEME.

BY WILFRID H. HUDLESTON, M.A., F.R.S., F.G.S.

PART I.—INTRODUCTION AND DESCRIPTION OF THE FORMATIONS.

Since I had the honour of delivering an address to the Association rather more than two years ago, on the geology of Palestine,* this subject has been largely before the public, both in connection with the Jordan Valley Canal scheme, and also with the efforts of the Palestine Exploration Fund to extend our geological knowledge of that country—efforts which resulted in the expedition of Professor Hull and party, whose conclusions have lately been published in the form of a popular narrative entitled “Mount Seir.” I venture, therefore, to draw your attention once more to this far off land, where the geological conditions are so markedly different to those which prevail in this part of Europe. The geology of Palestine partakes partly of Syrian, and partly of East African features, and it is necessary to consider both those regions when we are dealing with the physical conditions of an area somewhat limited in extent. Just as Israel of old was alternately the prey of the Assyrian and of the Egyptian, so does the land of Israel, using that term in its widest acceptation, exhibit here its Syrian, there its East African affinities.

In addition to the very interesting narrative of Professor Hull, we have had some valuable communications from Sir J. W. Dawson contributed to the ‘Geological Magazine,’ relating more especially to Egypt and the Isthmus of Suez; whilst the elaborate monograph of Professor Zittel and his coadjutors on the Geology and Palæontology of the Libyan Desert has been most ably reviewed by Mr. G. J. Hinde, also in the ‘Geological Magazine.’ There have been several notices likewise, during the past two years, in the public press with reference to the Jordan Valley Canal scheme, to say nothing of a paper on that subject read at the British Association meeting in 1883, by Mr. Trelawney Saunders, before the Geographical Section. Hence there is no lack of material to draw from: the chief difficulty is, what to select, and where to begin.

* ‘Proc. Geol. Assoc.,’ Vol. viii, p. 1 *et. seq.*

On the whole it seems best to arrange the subject geologically, taking the separate formations in order from below, and afterwards to consider the features of the Wady Arabah and the Dead Sea basin. By so doing we shall be in a position to judge of the merits of the Jordan Valley Canal scheme.

Schists, gneiss, granite and porphyries.

In journeying up the Nile the first place where the older crystalline rocks are seen is at Assouan, which bears about 300 miles S.S.W. from Mount Sinai. In such a distance considerable differences may well occur, yet I apprehend that throughout the Arabian chain of Egypt there are many conditions of similarity between its granites, porphyries, &c., and those of the Sinaitic peninsula. Moreover the descriptions of the Assouan rocks by Sir J. W. Dawson will also possibly apply to those of the Soudan generally, in whose arid wastes our poor soldiers are struggling with physical conditions that are more dangerous than any foe; and such physical conditions are largely due to the rock formations.*

Fig. 1.—(Copied by special permission from the 'Geol. Mag.,' 1884, p. 439).

RELATIONS OF CRYSTALLINE ROCKS AND NUBIAN SANDSTONE AT FIRST CATARACT—

- (m) Older Crystalline Series (Laurentian).
- (n) Second Crystalline Series (Arvonian).
- (o) Nubian Sandstone.
- (p) Dykes of Granite and Diorite.
- (q) Dykes of Felsite and Basalt.

The above is copied from Sir J. W. Dawson's section, which

* It was mentioned incidentally that, according to Russegger's map, all the Nile cataracts occur where the river is passing over such crystalline areas, whilst the more tranquil stretches of water belong to the system of his Nubian sandstone.

exhibits a lower crystalline series penetrated by dykes of granite and diorite, on which reposes a second crystalline series penetrated by dykes of felsite and basalt. The bedding of the latter is represented as being nearly horizontal. The crystalline schists of the lower series are well exposed in the railway cutting, where the beds are seen to be almost vertical with a nearly east and west strike. These consist of micaceous and hornblendic schists in great preponderance, with very little gneiss. All these schistose beds are both seamed and intercalated with red granite veins, and it is interesting to learn that the principal Egyptian quarries were situated in a huge granite dyke at the north end of the ridge, though there are other ancient quarries in granite, diorite, and sandstone in several places in this vicinity. I believe that Sir J. W. Dawson has placed specimens of these rocks in the hands of Professor Bonney for further description; but it would appear from what he says that the red rock of Syene is a granite rather than a syenite.

What he tells us about the second crystalline series is, however, the most remarkable. In the locality described, this second or upper series is not represented as being more than 100 feet thick, but consists of two horizontal bands of porphyry enclosing layers of laminated and gneissose rock. The dykes of granite and porphyry do not ascend into this series, but it is traversed by dykes of felsite and basalt. It was only natural that Dawson should refer the lower crystallines to the Laurentian of Canada, and our ex-President would be delighted to hear that the second series is correlated with his Arvonian.

Dawson considers that the folding and crumpling of the lower or Laurentian series gave rise to the emission of masses, veins, and beds of igneous and aqueo-igneous material, penetrating and overlapping the upturned Laurentian strata. He thinks that the porphyries of Mount Hor may belong to this second series, which in more northern countries is represented by the Arvonian or Huronian. It is because of the apparent parallelism of Dawson's second crystallines with some of the rocks of the Wady Arabah that I have quoted his observations at some length, but we must bear in mind that beyond the fact that they are older than the Nubian sandstone, using that term in its widest extent, the actual age of the porphyry series is practically unknown. Mere litho-

logical conditions we have been taught over and over again, on the highest authority, are not to be accepted as proof of age in the case of erupted rocks. Hence, when we bear in mind that no trace of any fauna older than the Carboniferous has been hitherto discovered in these regions, we must pause ere we accept as pre-Cambrian the porphyries and associated beds of the second crystalline series.

Passing over the little-known region of the Arabian chain, we next have to consider the "crystallines" in the lofty region of the Sinaitic peninsula. North of Jebel Mûsa, Professor Hull delineates a considerable area as being occupied by what he calls "metamorphic" rocks, viz.: granite, gneiss, and various kinds of schist, whilst the remainder of the mountainous triangle, south of Gebel Mûsa, together with the whole of the granitic region of the Mount Seir range, right up to Mount Hor, is grouped under "ancient igneous and volcanic rocks." He thus makes no marked distinction, like M. Lartet, between the ancient porphyries of Mount Hor and the granites of the Mount Seir range. In his "Abstract"* Professor Hull says, "The ancient rocks . . . consist of granite, gneiss, porphyries, and more rarely metamorphic schistose rocks, together with volcanic rocks, consisting of agglomerates, tuffs, and beds of felspathic trap. He is disposed to concur with Lartet in considering the gneissose and granitoid rocks to be of Archæan (Laurentian) age, as they are probably the representatives of those of Assouan." The granites and porphyries are traversed by innumerable dykes of porphyry and diorite, both throughout the Sinaic (*sic*) mountains, and those of Edom and Moab; and he considers it probable that the volcanic rocks which are largely represented along the base of Mount Hor, and in the ridge of Samrat el Fedan near Es Safieh, are contemporaneous with those dykes. He confirms previous observers that none of these dykes penetrate the Desert or Nubian sandstone, and he gives no encouragement to the notion that there are any volcanic rocks of comparatively recent date which could have up-lifted the saddle of the Arabah.

At present it is not easy to say how far the presumed metamorphic area of the Sinai peninsula corresponds with Sir J. W.

* 'Quarterly Statement, Palestine Exploration Fund,' July 1884, p. 162.

Dawson's lower crystalline series at Assouan ; but it is evident that the granite dykes of that region have here assumed such enormous proportions as to be in masses rather than in dykes ; yet everywhere themselves riddled by dykes of porphyry and diorite. The second crystalline series seems to be represented throughout Sinai and Mount Seir, by an acidic group of volcanic rocks, consisting of agglomerates, tuffs, and beds of felspathic trap, which are certainly of pre-Carboniferous age. Their precise mode of occurrence and actual relation to the granitic and metamorphic group will probably be made more clear in future publications.

The Desert and Nubian Sandstone.—In my Address it was mentioned that what was there called the "Nubian" Sandstone appeared under three stratigraphical aspects : "1st, where it is seen to rest on the crystalline rocks, as in the Wady Nasb ; 2nd, where its actual base is not visible, as in the eastern cliffs of the Dead Sea ; and, 3rd, where it is underlain by the *Glandarius*-limestone, as in the Lebanon ranges."*

The Nubian Sandstone may henceforth, most probably, be broken up into three divisions of very different age, though the precise boundaries have yet to be defined. Again we must commence in Egypt, under the guidance of Dawson and Zittel.

In the Nile valley, at Silsilis, the "Nubian" Sandstone succeeds the Cretaceous beds in descending order, and apparently conformably, whilst we have already seen that about 40 miles further south, viz., at Assouan, it is thoroughly unconformable to the crystalline rocks. In the Silsilis outcrop are the celebrated quarries for the stone of the Egyptian temples. Between Silsilis and Assouan there is a re-appearance of limestone, or two distinct sandstones. It would be very interesting if this should turn out to be a representative of the Wady Nasb limestone ; but it is more likely to be a temporary repetition of the overlying Cretaceous. Dawson considers that *Dadoxylon*, the only fossil hitherto discovered, points to a palæozoic origin, and he suggests that this may be a palæozoic deposit, the upper part of which has been *remanié* and mixed with early Cretaceous beds. However, Prof. Zittel will hear of no such compromise as regards Egypt. That

* 'Proc. Geol. Assoc.,' Vol. viii, p. 18.

author, after showing how the regular bedding and the thin bands of soft clay, &c., in the sandstone have been favourable to the production of blocks and monoliths, states that he has no doubt this Nubian Sandstone of the Lybian desert is of Cretaceous, probably of Cenomanian age, and he further declares that the so-called *Dadoxylon* is an Araucarian of Mesozoic affinities. This kind of wood has just been described in the *Palæontographica* under the generic term of *Araucarioxylon*. Finally, he says that these beds must not be confounded with strata of similar petrographical characters in Palestine, the peninsula of Sinai, and Abyssinia. He would restrict the term "Nubian Sandstone" to Nubia and the Lybian desert. At present we must be content to accept these views of Zittel as regards Egypt, though not altogether without reserve.*

Coming now to the Sinai peninsula, there can be no reason to doubt that the Upper Sandstone which overlies the Wady Nasb limestone may be fairly regarded as the local representative of the Nubian Sandstone of Russegger. Professor Hull's experiences quite bear out this view. The fact of there being two very distinct faunas in the Sinai peninsula has been a matter of certainty ever since the discoveries of Mr. Holland. Hull's party have traced the lower or Carboniferous series much further than previous explorers, since they show an important Carboniferous zone in the flanks of Mount Hor and right into the mountains of Moab; but even here Professor Hull was partly anticipated by Lartet, who noticed traces of corals in the Sandstone near the junction of the Wady Haimeh with the Wady Akabah similar to some collected from Sinai and from the vicinity of Nasb.†

However, Professor Hull has now gone to the length of constituting this into a separate formation under the title of the "Desert Sandstone." Along with the overlying limestone it forms a strip on the borders of the crystalline rocks, and is about 400 feet in average thickness. Throughout the sandstone areas of the peninsula, and still more on the eastern side of the Arabah in the mountains of Edom, some of the most striking scenery is produced

* He quotes amongst other things the wood of *Nicolia* from these beds, said by Dawson to be probably a mistake.

† *Geol. de la Pal.*, p. 117, quoted in '*Proc. Geol. Assoc.*,' Vol. viii, p. 20.

by cliffs of "Desert Sandstone" resting on granite and porphyry, sometimes repeated by faults, thus forming a double or treble escarpment. Mount Hor itself is said to be formed of reddish sandstone and conglomerate rising in precipitous walls of natural masonry, tier above tier, with its face to the west. The base of the cliff of sandstone rests upon a solid ridge of granite and porphyry, and the summit of the sandstone is somewhat in the form of a rude pyramid. In Hull's geological map this is coloured as belonging to the Desert Sandstone, though no mention can I find of any fossiliferous limestone being associated with it. In places, also, this Desert Sandstone appears to rest upon a massive agglomerate of volcanic origin, formed of blocks of trap, granite, and porphyry. This was recognized by Lartet under the name "Pondangue de Djebel Haroun." If the Sandstone really does overlie it, this puddingstone must be of pre-Carboniferous age, and may be Pebidian.

Now let us turn our attention to the upper sandstone once more. Wherever any fossils have been found, either at the foot of the Tih escarpment or elsewhere, these are Cenomanian. Hence there is a considerable geological gap, and some will be disposed to ask, where are the Trias, the Jurassic, and the Neocomian? South of the Lebanon it seems to me that there is no reliable trace of any of these systems, and we must conclude that the Cenomanian rests directly on the Carboniferous; so that where there is no intervening limestone with fossils it would be very difficult to distinguish between the two. There can be no doubt that the Cenomanian, or base of the true Cretaceous, possesses a wider overlap than any other series of beds—I might almost say, in the world. Even in our own country there is one little spot in the neighbourhood of Chudleigh where Upper Greensand of Haldon type reposes directly on the Culm Rocks, now held to be Lower Carboniferous. This upper sandstone, then, is the one which presents such a marvellous series of variegated beds, and though the red of Edom is partly due to its red granites, yet to this rock also it owes much, and nowhere can these peculiarities be better studied than in Petra itself. It is this sandstone, no doubt, which forms the eastern shore of the Dead Sea.

There remains, then, the Lebanon division of the *soi-disant* Nubian Sandstone, and this in all probability is really newer than

either of the others, being well up amongst the Cretaceous Limestones. Probably Sir J. W. Dawson was not far from the mark when he referred the lignitiferous zone of the Lebanon to the same horizon as the beds at Edfou on the Nile, which he says are above the Nubian Sandstone, and where borings made for coal have ascertained the existence, in clays and sandy beds, of carbonized wood, striated leaves and stems resembling those of reeds. All this tends to show that at more than one place a sandy lignitiferous zone has been proved in beds of Cretaceous age well above the Cenomanian. On the whole, then, our Nubian Sandstone seems to resolve itself into three perfectly distinct formations, though both the higher ones form part of the Cretaceous system.

Cretaceous and Nummulitic Limestones.—Considerable progress has been made towards differentiating these two formations, which, however, are connected by physical and stratigraphical ties. The Cretaceous beds are the most important factors in Syria, whilst in Egypt those of Eocene age are much the thickest. In the Libyan Desert, according to Zittel, above the Nubian Sandstone come strata of marl, clay, and limestone, with rock-salt and gypsum, fossil wood and shells; then grey laminated clays, sometimes black, but always bituminous and gypsiferous, and on the top of all snow-white bedded limestone, or earthy chalk. This frequently forms vertical walls bordering the summits of hills and plateaus. Some of the Gasteropods bear a certain resemblance to Eocene forms, but the presence of *Ananchytes ovata* and *Ventriculites* clearly defines its geological horizon. I have quoted this description at some length in order that the Libyan Cretaceous may be compared with that of the Lebanon and Palestine already detailed in my previous paper. In the Egyptian area there is far less limestone than in Palestine, and the beds are probably thinner. The abundance of rock-salt, gypsum, and bitumen in both areas is noteworthy.

This last circumstance reminds me of the geological position assigned by Lartet to the rock-salt and gypsiferous marls of Jebel Usdom at the south end of the Dead Sea. In concluding that they formed part of the Cretaceous rocks of that region, he could quote the abundance of similar materials in the Cretaceous of other areas; hence there was no *prima facie* improbability in this mass of rock-salt and gypsum being of Cretaceous age. None of Lartet's party, however, were able to ascend to the top of this

singular hill, and he had to be content with drawing his conclusions from what he could see at a distance. Professor Hull was more fortunate in obtaining evidence, and this seems to be almost the only instance where he has found it necessary to correct the deductions of the French geologist.

Of course nearly every author gives a picture of Jebel Usdom, and there is an effective one by Hull, showing a cliff of rock-salt with its joint-planes curved, owing to the weight of the superincumbent beds of gypseous marl. It has always seemed to me like a glacier overwhelmed by its moraine; the sides are so steep that no Europeans ever scaled them before Messrs. Hart and Laurence. These gentlemen observed that the upper surface was not at all like the limestone strata of the Cretaceo-nummulitic formation, but was, on the contrary, composed of shales and marls with gypsum and selenite much broken and not consolidated. Hull concluded that it formed a portion of the ancient deposits of the Dead Sea basin in connection with the 600ft. level.

In other respects the development of the Cretaceous rocks in Palestine has been so well described by Fraas and Lartet that it would not be easy to add to our information in this respect without a somewhat minute and circumstantial survey. As regards the Nummulitic limestones, we learn from his map that Prof. Hull regards the western edge of the limestone region as belonging to this series all the way down from Mount Carmel to Beersheba, and probably he will give us the evidence on which the assumption is founded. It would seem as though the country of the Lower Hills or Shephelah was included in this Nummulitic area. Besides the well-known outliers on the Samaritan hills, two small ones near Jerusalem are indicated, and a larger one much further south, whilst the whole of the sweep coloured as Miocene (?) in the sketch-map accompanying my Address is set down as Nummulitic.

Those who wish to know something about the Eocene rocks of this region should again consult Zittel. Just as is the case in Palestine, so also in the far more important deposits of the Lybian desert there is no sharp demarcation line between the Chalk and the Tertiary Rocks, but the chalky sediments of the older Eocene follow those of the Upper Chalk with hardly any variation in their characters. And yet palæontologically the boundary between the

Chalk and the Eocene is clearly defined, notwithstanding the continuity of marine deposits. Professor Zittel had never observed either in or above the oldest nummulitic bed a single characteristic Chalk fossil, neither did he find a Nummulate in the Chalk strata.* This I conceive to be a further proof that a sudden change of fauna, without material break of a stratigraphical or lithological nature, is evidence of important physical changes having occurred somewhere outside the area. In other regions, notably in our own, these physical changes were of such magnitude as to have separated the Secondary from the Tertiary period.

By way of concluding this subject of the Cretaceous-nummulitic limestones I may observe that the two groups are faulted together in the very remarkable mountain of Jebel Attâkah over against Suez. Sir. J. W. Dawson† gives a section of this, partly after Le Vaillant. A good opportunity is here afforded for comparison; and what is still more important, the intermediate character of each series is well brought out. In this connection Dawson observes that "the Cretaceous here consists of hard limestones, not, in so far as I know, found in the Nile Valley, but comparable with those seen further east and north in Judæa and the Lebanon, while the Eocene beds appear to be less highly developed and less purely calcareous than on the Nile. The structure of Jebel Attâkah, in short, appears to afford a clue to the apparent anomalies of the distribution of the Cretaceous and Eocene in Egypt, Arabia, and Syria."

Post-nummulitic rocks.—These may be taken in two divisions. 1. Those outside the Dead Sea basin. 2. The deposits of the Dead Sea basin itself. The latter subject is best studied in connection with the stratigraphy of Palestine and the Arabah (see part ii.).

It is, of course, well known to those who have paid any attention previously to the subject that the great physical break which fell upon these regions took place towards the close of the Eocene period. After that all was changed, and a marine area became a continental one.

There seems yet to be considerable difference of opinion as to

* 'Geol. Mag.,' 1884, p. 177.

† *Ib.* p. 390.

the precise age of the newer beds, but whether Miocene, Pliocene, or Pleistocene, they all date from a time when the leading features of these regions had been stamped upon them. The siliceous deposits of Northern Egypt which contain the fossil trees are considered by Zittel as certainly of Tertiary, and possibly of Miocene age. They include seven dicotyledonous forms, and are probably the first of their kind at present known from that part of the world. At any rate, there would seem to be none in the Cretaceous lignites. Zittel also in his map marks some of the deposits about the isthmus of Suez as of Miocene Age, but there still seems to be considerable difference of opinion amongst authors upon this point.

As the isthmus of Suez is a place of paramount importance from a geognostic point of view, we will pause here for a short time before again entering Palestine proper. The elevations in the isthmus are very moderate; the Chalouf cutting between Suez and the Bitter Lakes has a maximum of 26ft.; between the Bitter Lakes and Lake Timsah the elevation is 25ft., and between Timsah and Menzaleh 60ft., this latter representing the present height of land between the Red Sea and the Mediterranean. The "Isthmian Deposits," as Dawson calls them, are in his opinion later than the Miocene. They occupy the highest land just north of Ismailia—thin-bedded grey limestones with vermicular holes resting on marls, sands, and clays, mostly destitute of fossils, but with some layers holding freshwater shells, especially *Ætheria Caillaudi*, which is also found in the Chalouf cutting.

The same author concludes that a branch of the Nile discharged, not into a marine estuary, but into a saline lake, or a lake sometimes salt and sometimes fresh. The greater part of the Isthmian deposits resemble those of the elevated terraces of the Dead Sea, and they must have been laid down at a time of continental elevation, when the Isthmus was represented by a wide extent of land. As regards the date, he considers that between the Miocene and the Recent there are two continental periods to decide upon, that of the Pliocene and that of the later Pleistocene, or Post-Glacial. It is evident from these statements that Sir J. W. Dawson regards the Glacial period in this area as having been one of submergence, though on what evidence I have not been able to learn. However, he reiterates his views that in the first or second con-

tinental period, or in both periods, the Nile discharged into the Arabian desert at the head of the Red Sea.

These conclusions as to the continental and semi-desert nature of the Isthmian area during a long period of time are of importance in helping to explain the immense difference between the faunas of the Red Sea and Mediterranean, a difference which neither the supposed Glacial submergence, nor the more recent submergence to which I shall presently refer, has in any way effected, as far as we can see. There is another consideration, however, which these conclusions suggest. If this Isthmian area was a large evaporating basin in Pliocene and Pleistocene times for the waters of the African highlands, it is just possible that such a continental area may have extended as a comparatively low-lying tract throughout the space now occupied by the Serbonian Gulf, and thence northward as a wide fringe in the direction of the Syrian highlands; at any rate as far north as the Bay of Acre. It has always seemed to me that we must look in this direction rather than in the direction of the Gulf of Akabah for that physical connection which biologists say must at one time have existed between the waters of the Jordan valley and those of a great African drainage. If the evaporation of the Jordan valley system were stopped, and the rains which fall on the slopes of Hermon could accumulate until the Dead Sea basin was full, the overflow would take place across the pass of Jezreel, and the lake so formed would empty itself into the Bay of Acre by some of the channels which run through the plain of Esdraelon. In this way that "ancient river, the river Kishon" may, and indeed must have had an antiquity and an importance which was possibly impressed upon the Scripture writer in a sort of retrospective vision. At present, of course, such a river would simply discharge into the Mediterranean; but in Pliocene time, if my surmise about the northward extension of the Isthmian area is correct, it may in some way or other have come into contact with the Pliocene Nile. I prefer the earlier date, because of the evident remoteness of the connection.

Reverting once more to the neighbourhood of Suez, I must now draw your attention to the recent submergence which this area, and far more than the mere isthmus has undergone. When Professor Hull returned about a year ago (in February, 1884),

the *Standard* announced that he had traced the ancient margin of the gulfs of Suez and Akabah to a height of 200ft. above their present level; that the whole country had been submerged to that extent, and had been gradually rising since, and that, in his opinion, the Red Sea and the Mediterranean were connected at the time of the Exodus. In the 'Quarterly Statement of the Palestine Exploration Fund,' issued in the following April, we are told that "the Professor is of opinion that at the time of the Exodus there may have been a continuous connection of the Mediterranean and Red Sea." However, Hull himself writes (*vol. cit.*, p. 137), that his previous statement in the *Standard* (and also in the *Times*) was merely an hypothesis towards the solution of a real difficulty, viz., the actual position of the passage.

He expresses an opinion that the physical relations of the land and the sea at the time of the Exodus were not the same as now; the only feature unchanged is the conspicuous Jebel Attâkah.* At the same time he admits that there must have been continuous land across the isthmus to the north of the Bitter Lakes, and he wishes to modify his statement to that extent; but south of that position the case was different. At present there is a land way straight across by Chalouf, so that the Israelites could have crossed into Arabia Petræa without the aid of miracle. All he contends for is that there is no evidence to show that at the time of the Exodus in 1491, B.C., the land extended from the head of the Gulf of Suez to the Bitter Lakes. This is rather a curious way of putting the question, as the *onus probandi* certainly rests with those who maintain that the physical features are changed. However, he now admits that the maximum submergence was more ancient than the period of history, and that the ancient sea-beds, or terraces, up to the 200 feet level, along the Gulfs of Suez and Akabah, with shells and corals such as now exist, represent times that are more remote. He argues, however, that at the time of the Exodus the Red Sea might well have extended northwards as far as the Bitter Lakes (requiring a submergence of only 26 feet), and thus formed a barrier to the escape of the Israelites.

In reference to this question of submergence, both Dawson and

* Already referred to in connection with the Cretaceo-nummulitic beds. See *Supra*, p. 86.

Hull allude to the unmistakable evidence which is afforded at about the 200 feet level in the limestone rocks above Cairo, which is bored by *Pholades*. The sand beds, with large *Clypeasters* on the opposite side of the Nile, also are held to indicate the position of this sea-bed. Long ere the foundations of the Pyramids were laid, says Professor Hull, the sea had receded to a level perhaps not very different from that at which it stands to-day. Does Professor Hull then consider that the foundations of the Pyramids were laid after the children of Israel crossed the Red Sea?

PART II.—THE WADY ARABAH AND THE DEAD SEA BASIN.

The original views of Professor Hull on the physical history of the Dead Sea, &c., were enumerated in a lecture given about two years ago.* This is a point of some interest, because we shall thus be enabled to see how far Professor Hull's opinions have been modified by his recent experience. It was felt in some quarters that M. Lartet's views could only be combated by a trained geologist, and Professor Hull was selected as the champion of the River theory in opposition to the Lake Basin theory. He then said, "This great fissure is the key to the physical formation of the whole region, because it gave origin to a river which once flowed down from the mountains of Lebanon southwards through the gorge of the Arabah into the Red Sea in a remarkably straight line, running north and south for a distance of over 250 miles. This is now the Jordan. The depression of the valley continuing through the succeeding Pliocene epoch, the district of the Ghor and the Jordan Valley was converted into a lake which ultimately extended from the southern end of the Dead Sea, northwards nearly to Lake Merom. This lake would then have had a length of 160 miles, and an average breadth of ten miles. During the 'Pluvial' period, which succeeded the 'Glacial,' the waters probably reached their maximum elevation, and continued to flow southward through the gorge of the Arabah and the Gulf of Akabah into the Red Sea; but from the increasing dryness of the climate they gradually decreased, and the surface of the lake became contracted, and ultimately reduced to its existing limits.

* 'Physical History of the Dead Sea, the Jordan Valley, and Palestine.' A lecture delivered in Dublin, 2nd March, 1883.

During the lowering of the surface the remarkable terraces noticed by most travellers had been formed, ranging up to 750 feet, and even higher. They appear to be undoubtedly old lake margins, and indicate the successive levels at which the lake stood. The 750 feet terrace very closely corresponds to the summit-level of the gorge of the Arabah."

Such were Professor Hull's views in 1883. With reference to the concluding statement that the 750 feet terrace closely corresponds with the summit-level of the gorge of the Arabah, I would observe that the summit-level of the Arabah is 2,000 feet above the surface of the Dead Sea. How, therefore, it can "very closely correspond" with the 750 feet terrace calculated from the present surface of that sea is not by any means easy to understand; there is a difference of nearly 1,300 feet to account for.

Another point to which I demur is, the absolute certainty that during the overflow of the "Pluvial" period the waters should continue to flow southwards through the gorge of the Arabah and the Gulf of Akabah into the Red Sea. I have already shown that, if the same relative levels were preserved all round, such overflow would pass out through the Vale of Jezreel. Accepting the most recent calculations as accurate, the height of land in Jezreel is only 285 feet, whilst that of the Arabah is 660 feet; hence, if we were to set that "ancient river, the river Kishon" in full flow once more, the saddle of the Arabah would still be 375 feet above the surface of the Jordanic lake. This position is shown at *x* in Fig. 3, p. 93.

These are points to which we may recur again in considering the Jordan Valley Canal scheme, but at present we are more deeply concerned with the results of the recent geological expedition to that region, and the extent to which M. Lartet's views have been confirmed thereby.

We must commence with the stratigraphy and physical structure of the Arabah, and for purposes of illustration I submit a copy of Hull's cross-section, ten miles north of the head of the gulf (Fig. 2, p. 92), and the longitudinal section by Major Kitchener of the eastern side of the Arabah throughout its entire length (Fig. 3). This is a very fine piece of work,* and sets at rest for ever the questions

* The drawing is by Sergeant-Major Armstrong.

FIG. 2.—CROSS SECTION OF THE WADY ARABAH ABOUT 10 MILES NORTH OF AKABAH (HULL).

(Copied from the 'Quarterly Statement of the Palestine Exploration Fund,' July, 1884, by special permission of the Council.)

FIG. 3.—LONGITUDINAL SECTION OF PART OF THE WADY ARABAH (KITCHENER AND ARMSTRONG).

(Copied from the 'Quarterly Statement of the Palestine Exploration Fund,' October, 1884, by special permission of the Council.)

- A. Head of the Gulf of Akabah. B. Point where the Sea-level line cuts the Dead Sea Basin. x. Level corresponding to the height of Jezreel. y. Position of the highest terrace marl, about 1400 feet above Dead Sea.

of level in the long valley between the Red Sea and the Dead Sea, besides supplying an admirable *coup d'œil* of the eastern flank of one of the most extraordinary fissure-valleys in the world—a valley, too, which tradition and the present difficulties of access have invested with a sort of mysterious charm.

You are, of course, pretty well aware by this time that the great Dead Sea fault, recognized by Von Buch, Hitchcock, Lartet, and others, clings to the eastern shore of the Dead Sea. The fault must be concealed beneath the Dead Sea itself, so that no actual juxtaposition of the strata can be observed, and its position is laid down inferentially. Such, however, is not the case throughout the Arabah, as the position of the fault was made out and laid down on the map in six or seven places, one being about ten miles north of Akabah (see Fig. 2), and another near the water-shed, in both which places the limestone of the Tih is faulted against the old “porphyritic and metamorphic” rocks. The section near the water-shed or saddle is taken across the Arabah near its widest part, which is about opposite Mount Hor, and displays courses of limestone rising in steps to the table-land of the Tih on the west, the beds being represented as having a slight dip to the west. Two shallow valleys, filled with gravel, occupy the middle space, separated by a limestone *massif*, and then the limestone is represented as curving over towards the east against the main fault at the roots of the eastern mountains. A number of parallel faults on this traverse serve to repeat the porphyries and granites of Mount Hor with their cap of Desert and Nubian Sandstone, the whole surmounted by the Cretaceous limestones in the far east—all represented as dipping away from the fault.

The above sections are, of course, diagrammatic, but they bring out very clearly the fact that the main fault clings to the roots of the eastern mountains, and may be regarded as in alignment with the position already assigned to the Dead Sea fault. These dislocations date in all probability from the first upheaval of the seabed towards the close of the Nummulitic period, and from the fact of their being in alignment with the great hollow between Lebanon and Anti-Lebanon, it is probable that the whole belongs to one great system, which is continued down the Gulf of Akabah, and probably into the Red Sea itself. It is by no means unlikely, therefore, that the waters of the ocean cleared away a large portion of

the *débris* resulting from such a crush at the time when its floor slowly emerged into the atmosphere, and that what is known as subaërial denudation is only to be credited with modifications on a smaller scale. Professor Hull now concurs with Dr. Lartet in thinking that the waters of the Jordan valley did not flow down into the Gulf of Akabah, after the land had emerged from the sea. "The disconnection of the inner and outer waters was very ancient," he says, "dating back from Miocene times." This, of course, amounts to an entire abandonment of the River theory which formed such a conspicuous feature in his Dublin lecture two years ago.

But we have to deal with two sets of phenomena in discussing the Jordan-Arabah problem; first the agencies which produced the longitudinal hollow, and, secondly, the agencies which produced the irregularities in the floor of that hollow, and possibly these two sets of phenomena may be of somewhat different age. The subject is one of extreme interest, dealing as it does with the possibility of a sinking-in of the earth's crust at intervals along certain lines of fissure—an explanation so distasteful to most stratigraphists. Fortunately the theory of ice-excavation is hardly applicable to the Dead Sea basin any more than it is to the depths of the Gulf of Akabah. There remains the alternative that such places were originally holes in the ocean floor, and perhaps there may be other explanations which do not occur to my mind at the present moment. Nevertheless, the main point is now conceded by all, viz., that the present watershed between the Dead Sea basin and the Gulf of Akabah is one of high antiquity, whether Miocene or later; and any theory which attempts to explain the very peculiar phenomena connected with the Dead Sea must always be in accord with this now settled question.

In my previous paper I gave a view of the Arabah from Mount Hor (after Lartet), and here (Fig. 3) we have a view of Mount Hor from the Arabah (after Kitchenner and Armstrong). Before proceeding any further, let us consider this most important section, which will enable us to summarize much of the information previously acquired. The following is Sergeant-Major Armstrong's description of the entire section:—

"The Wady Arabah extends from the head of the Gulf of Akabah to the south end of the Dead Sea, and is 112 miles long. The width of the valley at the foot of the hills, from Akabah

to near the lowest point of the watershed, averages about six miles.

"A series of low ridges, called Er Rishah, of about 150 feet above the plain, runs obliquely across the valley at this point, forming a length of ten miles. Opposite Mount Hor the valley widens out to thirteen miles, and gradually narrows in to six miles at the south end of the Dead Sea—the same width as that at Akabah. The sectional line is drawn from the Gulf at Akabah through Wady Arabah, representing the lowest depression to the southern end of the Dead Sea.*

"The lowest point of the watershed (660 feet above Gulf of Akabah) is computed to be 45 miles from Akabah, and 29 miles further north the sea-level point is reached (B of fig. 3).

"The sketch of the outline of the hills on the eastern side of the valley is given relative to the calculated heights as noted.

"Those on the western side (not shown on section) range about 1,900 feet above sea-level."†

Turning our backs to the west, and with our faces towards Mount Seir, which may be accepted as a general term for the Idumæan and Midian ranges, but more especially for that portion near Akabah, let us endeavour to summarize some of the information previously acquired, whilst noting such additional points of interest as our time will allow.

Immediately in front of us, on the upthrow side of the great fault, and opposite the Fort of Akabah, are what Major Kitchener calls the bold granite mountains of Midian, intersected by valleys that have thrown up a mass of *débris* into the main valley, forming a semicircular fan-like ramp up to the mouth of each wady. The character of the granite of this particular district is best described by Milne, who, as I mentioned in my previous paper, accompanied the late Dr. Beke in search of the true Mount Sinai. Some of these granite peaks will doubtless represent the Jebel el Nur, or Mountain of Light, which they ascended in hopes of finding, in some Midianitish volcano, the spot where the Law was delivered. Hull says that the name Jebel el Nur is given in reference to the prevailing red colour of the granite hereabouts.

* The northern portion of the section has been omitted in Fig. 3.

† 'Quarterly Statement,' Oct., 1884, p. 221.

The elevations would seem not to be so great as previous writers have supposed.

Before studying the range of Edom in its northward extension, a glance at the composition of this portion of the floor of the Arabah should be taken. At the lowest part of the valley, Major Kitchener tells us, the soil is soft and loamy; the remainder of the broad bed is sand and *débris* from the hills, the latter doubtless being largely augmented from the fan-like ramps at the mouths of the several lateral valleys. Hull says that the bed of the valley, sloping up from the sea margin to the base of the mountains behind Akabah, is formed of loose gravel, in which were found recent sea shells and pieces of coral, and further up the valley such marine remains were found at an elevation of 130 feet. On the whole, he is disposed to place the line of the raised sea-beach at about 200 feet, that being the degree to which the shores of the Gulf of Suez were depressed, as previously noted. Further up, the surface is variously covered by loam, gravel, and blown sands, which are often piled in great dunes. Occasionally the limestone rock appears in isolated bosses and ridges, as is the case along part of the watershed about 45 miles north of Akabah. Hull's party were four days in travelling those 45 miles.

Directing our attention once more to the eastern mountains, when we are clear of the purely granitic region, a very curious kind of effect is produced by cliffs of "Desert Sandstone" resting on granite and porphyry, and repeated by faults. Attention has been drawn to this in the cross sections. These sandstones form massive walls in the lateral valleys which are themselves deeply excavated. The interest of the whole region culminates in the masses on the flanks and rear of Mount Hor, which is itself a pyramid of Desert Sandstone on a pedestal of porphyry, the features being much complicated by north and south faults parallel to the main one. At the back of the whole, the grey range of Cretaceous Limestone constitutes the most elevated plateau of Edom, looking down upon the pinnacle of Mount Hor itself. This is the cold grey background of limestone hills so often spoken of by travellers as affording a contrast to the reds, purples, and blues of the Cenomanian (Nubian) Sandstone in the gorge of Petra. Thus a *coup d'œil* from the neighbourhood of the watershed gives us almost the entire vertical section of the Palestine formations from the granites and por-

phyries to the uppermost Cretaceous. North of this, the range of Edom continues to fall towards the 3,000 feet plateau of Moab. Hence the watershed of the Arabah corresponds in position pretty nearly with the maximum height of the Edomite range.

Having crossed the limestone floor of the watershed, with its overlying sands and gravels, we descend northwards towards the Dead Sea depression, and become involved with the deposits of that area, described by the Royal Engineers as marls, sands, and gravels on a limestone floor. It was here that the party sent out by the Palestine Exploration Fund people made those observations which, more than anything else, have induced Professor Hull to abandon his river theory in favour of the independent basin theory of M. Lartet. The occurrence of terraces of marl, gravel, and silt, cut through by existing streams, were noticed in the Arabah, about 100 feet above the sea-level (*y* of Fig. 3). "The beds of marl were observed to be enclosed by higher ground of more ancient strata in every direction, except towards the north, where they gently slope downwards towards the borders of the Ghor, and become incorporated with the 600 feet terrace."* This elevation is 1,400 feet above the present surface of the Dead Sea. The marls were observed to contain semi-fossil shells; two species having been determined as *Melania tuberculata* and *Melanopsis Sauleyi*.

From the nature of the ground it is next to impossible that these lacustrine or fluvio-lacustrine deposits should have resulted from the banking up of any temporary lake, and hence there can be but little doubt that we must carry the successive Jordanic lakes of Conder, mentioned in my previous paper, a step higher, viz., to 1,400 feet above the present surface of the Dead Sea. It may be interesting to note, as bearing on this subject, that the marls of the Jordanic lakes are not so unfossiliferous as M. Lartet supposed. Tristram says, for instance, with regard to this very *Melania tuberculata*, "that it occurs living in various streams, and semi-fossil in great numbers on the marl deposits by the Dead Sea. On the shores of the Lake of Galilee dead and bleached specimens are very common."†

We also learn from the same author that *Melanopsis buccin-*

* Hull in 'Quarterly Statement,' July, 1884, p. 164.

† 'Fauna and Flora of Palestine,' p. 196, quoted by Hull, 'Mt. Seir,' p. 100.

oidea is very common in almost all the streams of Palestine, and found sub-fossil in the old marl deposits by the shores of the Dead Sea. *Melanopsis costata* also is very abundant in Lake Huleh, the Lake of Galilee, and the Upper Jordan, and is found in immense quantities in a sub-fossil state round the Dead Sea. Altogether Tristram enumerates five species of *Melania*, and about a dozen species of *Melanopsis*, as characterising the fresh-water system of Palestine. *Melanopsis Saulcyi* is now somewhat restricted in its habitat. On the whole, out of 17 existing species of *Melaniadæ* four have been found sub-fossil in the marls. When the various terraces, beginning with the 1,400ft. terrace, have been subjected to more searching examination the number of sub-fossil species is likely to be increased. As none of the *Melaniadæ* inhabit the waters of the Dead Sea, it is a matter of some interest to know exactly the lowest level at which these shells have been found *in situ* in a deposit unquestionably lacustrine.

If we recapitulate the levels of the Jordanic lake, we find that an overflow would take place now through the depression of Jezreel at 285ft. above sea-level. This height is projected on the section (Fig. 3), and is marked by the letter *x*. Such a state of things would make the area an ordinary fresh-water lake with a maximum depth of 2,860ft., and an overflow into the bay of Acre. The height of such a lake would be 1,577ft. above the present surface of the Dead Sea; and we may fairly believe that terraces of marl may be looked for in the Dead Sea basin at any point below 1,550ft. At present the highest known is at the 1,400ft. level, and this is indicated on the section by the letter *y*. This high-level terrace (*y*), as we have seen, is partly traceable into much lower terraces. There is a very fine series of these terraces above the descent to the Ghor, consisting of beds of white marl and silt, about 1,050ft. above the present level of the Dead Sea and 15 miles to the south of it.* From this level the sinking in of the basin becomes rapid in a northerly direction, somewhat similar to the rapid sinking in of the Jordan Valley between Upper and Lower Galilee.

Time will not permit me to continue these references to the lower terraces. For a study of these I would especially refer to Captain Conder's works.

We now come to the consideration of a very curious problem, a

* Hull, 'Mt. Seir,' p. 106.

problem not difficult of solution so long as the river theory prevailed, but one which is far more obscure now that we have to deal with an independent basin of high antiquity. Prof. Hull is not the first person who has put to himself the question, "Since this sea has no outlet, what has become of the materials that have disappeared?" To this question he promises a detailed reply in a future volume on the physical history of the Ghor and of the Jordan Valley. That the difficulties are great, if we had merely to consider the Ghor itself, none would doubt, but when we have to consider the case of the deep lateral wadies also the case becomes extremely complex. Most of these wadies are gorges of erosion, which have their origin in the high table-lands of Palestine, Moab, and Edom, and the amount of material excavated and removed may probably be estimated by the volume of the gorges themselves. The marls and silts may account for some of this matter. The bulk of the material removed must consist of carbonate of lime, and much of this will be carried off in a state of solution. But when once the waters of the Jordanic lake sank below the level of the gap at Jezreel all dissolved matter must either have been precipitated or else have remained in solution. There is just one other possibility which has frequently presented itself to my mind, and from what he says subsequently the same idea has presented itself to Prof. Hull, viz., that the bottom of the Jordanic fissure has not always been perfectly watertight.

This is a subject of supreme interest, and one which of itself might well occupy a whole evening, so that there is no time to discuss it now. I will merely remark on the possibility of some connection between the waters of this fissure and the steam power necessary for the production of the three large volcanic areas that lie to the east and north-east of the Lake of Tiberias, besides the numerous smaller basaltic flows on either side of the Jordan Valley. Water is as necessary to a volcanic vent as it is to a steam engine. Nor are there other instances wanting of the connection between great fissure-valleys and volcanoes. I quote some passages bearing on the subject from the most adventurous narrative of modern geographical research, viz., Mr. Thompson's journey through the Masai country :—

"Ngiri proved to be the dried-up bottom of a great lake, which formerly had occupied this region, and doubtless had supplied

Kilimanjaro with the water that seems to be such a necessary element in volcanic activity. It lies at a level of 3,550ft. and there are still numerous indications of its former condition in the shape of ponds, marshes, and swamps, fed by springs.”*

But a still closer case in point is supplied by the existence of a meridional trough with a string of charming lakes, some fresh, some salt, lying about a degree to the east of Mount Kenia, another East African volcano. This system is represented as having no surface communication with the sea. The lowest point is Lake Baringo, 3,217ft. above sea-level, which Mr. Thompson said was quite an inland basin, and not salt.† Of course it may be objected that this lake-filled meridional trough is high above sea-level, and that the waters of its lakes may escape through underground fissures to lower levels, and thus into river-basins which drain directly into the sea. I admit that the analogy with the Jordan Valley fissure is not absolutely complete; at the same time it is worthy of consideration.

PART III.—THE JORDAN VALLEY CANAL SCHEME.

It may have been thought by some that I have been rather long in coming to this portion of my story, but the fact is that we have been studying this subject inferentially throughout the whole of Part II., so that you know the main points with reference to the Arabah, or southern section of the proposed canal, already. We must now consider the northern section.

There was a good deal of discussion on this subject in 1883. At that time there were, I believe, two companies formed, one under the Duke of Marlborough, the other under the Duke of Sutherland. It is evident that neither of those noble Dukes had ever read much on the subject, or they would not have given their sanction to such a project; at least with any idea that it could have been carried out! One of the surveying parties was at Akabah in December, 1883.

The idea of a Jordan valley canal is by no means a new one, as it was advocated by Captain Allen, R.N., in a work published in 1855, entitled ‘The Dead Sea: a New Route to India.’ His views were submitted to Government at the time. It is not a little

* ‘Proc. Royal Geogr. Soc.’ for 1884, p. 698.

† *Ib.*, p. 703.

singular how he, as a naval man, spoke unfavourably of the then rival Suez Canal scheme on account of the bad approaches, both on the side of the Red Sea and of the Mediterranean, as compared with the advantages of the port under Mount Carmel. He appears to have made light of the difficulties of excavation, having thought that, if the line of the canal were marked out and shattered by explosions, the pressure of the sea would do the rest. A more childish idea was probably never put into print. But since the subject has been mooted once more, and persons of some standing and responsibility, such as Mr. Trelawney Saunders, have, to a certain extent, advocated the scheme of a ship-canal, let us see what would have to be done. Admitting that there is an excellent harbour under the shelter of Mount Carmel, what are the works that would have to be executed? The distance in air-line from this port to the Jordan valley, over the depression of Jezreel, is estimated at 26 miles, and the extreme height of land is 285 feet. Canon Tristram estimates the mean depth of the cutting at 200 feet; but supposing it to be 180 feet—and it could hardly be less—what does a cutting 26 miles long and 180 feet deep mean? The deepest cutting on the Suez Canal is said to be about 65 feet, and this portion is very short. Remember, too, that, in order to flood the Jordan valley, the canal must be both wide and deep, for, unless a very large quantity of water was admitted, evaporation and other causes would still defeat the project. But let us suppose the first part of the scheme executed, and the waters of the Mediterranean admitted into the Jordan valley to the present level of the sea, there would be an inland sheet of salt water 140 miles long and about 10 miles wide, which, according to Mr. Trelawney Saunders, would greatly benefit Damascus, and bring Jerusalem within 10 miles of the sea-water. For this very doubtful advantage the remarkable scenery and physical peculiarities of the Dead Sea, with all its ramifying valleys, would be for ever destroyed, and the most curious feature on the surface of the earth obliterated. A unique fauna, as Canon Tristram pointed out at Southport, would also be destroyed, along with some most interesting sites. But there are other considerations. It was suggested that the admission of so much water into a space previously only occupied by air might upset the equilibrium of the earth's surface. I do not

quite profess to understand the calculations on which this is based, but there is another possible result which should not be overlooked, viz., that the immense pressure of water in the great fissure might force the liquid through some of the old cracks, and thus renew volcanic activity with most destructive effect. It would be much better for the people of Damascus to be content with a railway than to run the risk of setting the Ledja and the Hauran ablaze once more.

There would not be much difficulty, I apprehend, in taking a railway across the vale of Esdraelon and thence through the trough of Jezreel. I have not seen any levelled section, but deduce the following from the map of the Palestine Exploration Fund. From the port of Haifa to the gorge of the Mukutta (Kishon), seven miles pretty level; then comes the gorge of the Mukutta, between three and four miles long through limestone, on passing which the landlocked plain of Esdraelon is reached. Seven miles through this plain would bring the line to the bifurcation of the two branches of the river, near Ludd, 180 feet above sea-level. From this point to the watershed is three miles, a rise of about 100 feet more. This gives 21 miles to the watershed, with easy gradients for a railway, whilst the canal at this point would require a cutting 285 feet deep to the surface of the water, without reckoning for the depth of the water itself. From the watershed at El Afûleh to the Mediterranean level in the valley of Jezreel (Jâlud) is three miles and a half, giving a fall of about 1 in 65, but probably this sharp gradient might be obviated. If a flush canal were made, it would terminate here, and the waters of the Mediterranean would flow down the valley of the Jâlud in a ceaseless torrent, probably for ages, before the great Jordanic inland sea was full. The surface of the plain of Esdraelon consists in the main of soft post-tertiary deposits, but it is not easy to say at what depth limestone, and even basalt, would have to be encountered. From the sea-level line in the valley of the Jâlud to the bridge at Beisan is 11 miles. Here the depression is about 500 feet below the sea, giving a very easy gradient. Beyond this point the line would probably turn due north up the Jordan valley, in the direction of the gorge of the Yarmuk, flowing in from the east. As we have now entirely left the route of the proposed canal, there

would be no interest in following this hypothetical railway in the direction of Damascus; but I may mention that these wonderful gorges of the Yarmuk, where the limestone and basalt are in juxtaposition, and where there are some of the most wonderful waterfalls in the world, were being surveyed last spring with a view to a possible railway. To give an idea of the extraordinary chasms, I may mention that in one place the upper edges of the plateau are from one to two miles apart in air-line, while the bed of the river is 1,400 feet below them.

But if there are difficulties in the way of a flush canal about 25 miles in length across the plain which separates Galilee from Samaria, these shrink into nothing compared to the difficulties of the southern section, with which you are already acquainted, a cutting 74 miles long, with a maximum depth of 660 feet to the surface of the water, through hard limestone overlain by marls and gravels. Who in his senses would have anything to do with such a scheme? The average depth of the cutting could not be less than 260 feet, making due allowance for the long stretch of moderate elevation near Akabah. The width is the only factor in the calculation that I cannot venture to supply. An ordinary canal with locks would be a great collapse after the magnificent interoceanic schemes we have heard of; but even this, I apprehend, would be no easy matter to effect on an adequate scale, and in a country with such a precarious supply of water.