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MEMOIR ON THE GEOLOGY OF THE SOUTH-EAST COAST OF ARABIA. CARTER. 1851.

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Rev. W. K. Kerr
Harbour Chaplain
Bombay
1869.

Geological Memoir on the South-East Coast of Arabia.

Oct. 185

by H. J. Carter Esqre
H. E. I. C. Medical Service Bombay

From the Bombay Branch Royal Asiatic Society's
Journal for January 1852.

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Indian Institute, Oxford.
Presented
by the
Rev. W. B. Keer
April 1885.

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Memoir on the Geology of the South-East Coast of Arabia.

By H. J. Carter, Esq., Bombay Medical Service, formerly Surgeon of the H. C. Surveying Brig "Palinurus."

[From the "Journal of the Bombay Branch of the Royal Asiatic Society," Jan. 1852.]

Presented October 1851.

The matter contained in this "Memoir" was chiefly collected during the late Surveys of the South-east Coast of Arabia, by Captain Sanders* and Lieut. Grieve, I. N.; much has been contributed by Lieut. Grieve, who latterly had sole charge of the Survey, through specimens and information of parts which I had not an opportunity of examining; and the geology of the Curiyah Muriyah Islands is extracted from the late Dr. Hulton's interesting account of them, taken during the time they were surveyed by Capt. Haines, I. N., now Political Agent at Aden.

Previous to entering on the subject of this "Memoir," I shall premise a few general remarks on the outline of the coasts about to come before us more in detail: this will be followed by a running geological description of them, made more particular where they were actually examined; and, finally, a short review of all the facts which have been brought forward.

Although I have only mentioned the South-east Coast of Arabia, I shall begin from the Straits of the Persian Gulf, follow the South-eastern Coast and its islands to the Straits of Bāb el Mandeb, and then, crossing over to Berbera, pursue the African Coast from this point, with its islands, to Socotra. I have not much to offer of the former or latter coasts, but what little I have will, I think, be found interesting, in connection with the South-east Coast of Arabia.

Beginning, then, from Ras Mässändäm, which is the name of the western promontory of the Straits of the Persian Gulf: the mountains which form this have been fretted into innumerable irregularities, and rapidly rise from 400 feet, which is the height of the small island called Mässändäm, at the extremity of the Cape, to 2000, then 3000, and

* It is but due to state, to the memory of this able surveyor and excellent officer, who died at sea near Malta on the 14th August last, that I received the greatest kindness from him during the time I had the good fortune to be under his command.

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subsequently, as they progress in a semi-circular direction, south-eastward, to 6000 feet above the level of the sea, which they are at a point some miles inland opposite Măskat ; leaving in their course a comparatively flat country between their lower hills and the sea, which is called Bātănă. This flat country extends to within fourteen miles of Măskat, after which the land, which is raised up into a confusion of ridges and hills, with scarped precipices, presents an irregular sea-cliff on to the neighbourhood of the Devil's Gap ; and inland a succession of elevations, which end in the ridge just mentioned. This ridge, which is about forty miles from the sea opposite Măskat, is, as before stated, about 6000 feet high, and goes by the name of Jibal Fălläh. Proceeding southwards, it gradually approaches the coast, and terminates at the Devil's Gap, of which it forms the northern boundary : it is there 6228 feet high.* The Devil's Gap is the outlet of a great valley, which ramifies up among the mountains of Oman. From its southern boundary another ridge arises, which attains a height of 4400 feet† within eight miles of the sea, and descends to the latter in two or three precipitous cliffs. This ridge is continued on south-eastwards, to terminate in Jibal Jallān, which is about 3900 feet high,‡ and about twenty miles inland from the south-eastern coast : it is the southern extremity of the great mountainous chain of Eastern Arabia. From its eastern side a group of mountains extend towards Ras el Hăd, or the eastern extremity of Arabia, to which we shall come presently, and its subsidence in the other directions will be mentioned by-and-bye.

The eastern extremity of Arabia, commonly called Ras el Hăd, is truncated, and presents a coast facing due east, about twenty miles in extent. This is accompanied by a sea-cliff about one hundred feet high, which is about the general level of the land here.

Turning this extremity to the south-west, we get no more sea-cliff for a great distance, and after passing opposite the termination of the great chain to which I have alluded, the land soon subsides to a general level of from 50 to 100 feet above that of the sea, without any mountains interiorly, or towards the south-west, but presenting a continuity of low undulating hills, of a sandy-looking aspect, and a light brown colour, as far as the eye can reach. This continues on to opposite the island of Masira, where the mainland sinks to the level of the sea, the only place on the coast where this occurs unbacked by mountains.

The island of Masira, which is opposite this port, is rocky and mountainous, and in its highest part not more than 600 feet above the level of the sea.

* Chart ; Lieut. Grieve. † Idem. ‡ Idem.

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After Masira, the mainland begins to rise again, and a sea-cliff first commences at a Cape called Ras Kăbret, in 19° 57′ N. lat. and 57° 48′ E. long. The land, however, on the western side of the bay, called Ghobat Hăshish, which is a little to the north of Ras Kăbret, is 80 feet above the sea,* and goes on increasing in height, until it attains an altitude of 480 feet† at Ras Markās, which is close to Ras Jăzirăh. On account of the coast here running north and south for 100 miles, and therefore cutting its general direction, which is N. E. and S. W., at an angle of 45°, we not only see that the land rises towards the S. W., but that it rises also towards the south.

From Ras Jăzirăh onwards, the coast gradually increases in height to 800 feet, which it is about the centre of Curiyah Muriyah Bay; and in its first part is, from its height and whiteness, very similar to the cliffs between the North Foreland and Beachy Head. But as we approach the south-western horn of Curiyah Muriyah Bay, its outline and horizontality become disturbed, and suddenly it attains a height of 4000 feet, which it preserves, more or less, on to the Yaffai mountains, at the Straits of Bāb el Mandeb.

Opposite Curiyah Muriyah Bay are five small islands, which in point of size are hardly more than the tops of so many mountains. They are about twenty miles off shore, and the largest and highest, which is Hăllăniyah, has a point 1645 feet above the level of the sea. There are also two or three still smaller opposite Hisn Ghorab, about sixty miles south-west of Makalla.

The chief features of the land between Curiyah Muriyah Bay and the Straits of Bāb el Mandeb are, that here and there it is more or less tabular in its outline; more or less broken into mountainous peaks; more or less interrupted by ravines; five times by great valleys; and once (in the Bay of El Kămmăr) by an intervening tract of low land forty to fifty miles in breadth, which, running S. W. and N. E., seems to cause a natural division into two parts of the mountainous ridges of which this elevated tract is composed. Throughout, this high land is more or less scarped upon the sea or the maritime plain, which latter is seldom more than ten miles in breadth.

Its color is for the most part white, particularly where it is weather-worn, and here and there black or brown, where it is confronted by, or mixed with, rocks of an igneous origin.

Having thus given a brief outline of a part of the North-east and the South-east Coasts of Arabia, let us now proceed to the composition of their rocks.

* Lieut. Grieve. † Idem.

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Returning to Ras Mässändăm, which, as before stated, is the western promontory of the Straits of the Persian Gulf, and the northern extremity of the chain of mountains which extends along the North-eastern Coast of Arabia from the Cape just mentioned to the neighbourhood of Ras el Hăd, we find this promontory, taken generally, to be mountainous, and fretted out into innumerable irregularities, which have given rise to the formation of as many coves, creeks, inlets, islands, islets, and rocks. Ras Mässändăm, the extremity of an island by the same name, is 400 feet high, and the next portion of the Cape is about 1500 feet, and but a few miles further inland these mountains rise to 3000 feet. At first sight they no doubt appear like black basalt, from their color, and hence have been described as such by Captains Wellsted and Whitelock, and have always been considered igneous rocks. Pliny calls them the Eblætian mountains, probably from the Arabic *iblis*, the devil; but latterly this promontory and its islands have been inspected by Lieut. Constable, of the Indian Navy, who has kindly shown me rock specimens from them, which prove that they are all composed, not of black basalt, as before suspected, but of jet black and dark black grey limestone, interstratified and veined with white and pinkish brown calc-spar. The jet black limestone is of a fine compact structure, and breaks with a smooth conchoidal fracture, like lithographic limestone, but the lighter colored varieties are more coarse, and break with a rough fracture. The calc-spar, which is in strata of eight to ten feet thick, is columnar, or vertical, in its crystallization, and traversed horizontally by wavy lines, like that from Gibraltar: some of it is of a dazzling whiteness, and of a massive saccharoid crystalline structure. I was informed by Lieut. Constable that the whole of these mountains here are of a similar composition, and that they are horizontally stratified, the strata in some places being thinner and more schistose than in others.

Proceeding southwards, this chain of mountains, as I have already stated, curves inland, and leaves a low country in front of it, called Bătănă, which is without sea-cliff, on to a point fourteen miles north of Măskat. It is from this point that my own observations commence. To the north of it, as far as the eye can reach from an elevation of 600 feet, nothing is seen but a low shore, shelving up very gradually to the mountains inland, each shelf presenting a scarped surface, possessing a chalky appearance, which gives a general whiteness to the whole district, and from which I inferred that it was but a continuation of the same limestone formation as that of the sea-cliff on which I was standing when I made these remarks.

This limestone formation, as it occurs in the vicinity of Măskat, I

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have already described in our Journal;* but for the sake of not breaking the continuity of the present description, I will repeat a paragraph or two of it here, leaving the reader to go to the paper itself for further information on the subject, which it would be as well that he should do at once, if possible, as he will there find, in the geological description of the neighbourhood of Mäskat, an account of the limestone formation in this locality, and a description of the different igneous rocks which have come to the earth's surface in this part of Arabia, all more or less typical of what we shall hereafter frequently meet with on the south-eastern coast.

In summing up the few observations contained in the paper to which I have alluded, it is stated, p. 125,

"That the limestone formation, limiting the group of igneous rocks at Mäskat, both north and south, commences (from below upwards) with a deposit of the same kind of pebbles (viz. coarse and fine-grained diorites, basalts, petrosilex and quartzites), lying in both places on the fundamental rock of the locality; passing into a sandy grit; then into a silico-calcareous deposit; then presenting the remains of marine animals, (small ostreiform Gryphæa,) these increasing in number with the calcareous material (chiefly consisting of minute and small Foraminifera); the increasing purity of the limestone, interrupted in each instance by a pink-colored deposit, that at Ras Ghissa (south of Mäskat) chiefly consisting of the remains of small Foraminifera, and that of the formation at Darzit (north of Mäskat) of a thin series of gypseous, marly, and arenaceous strata; then a compact yellowish or fawn-colored limestone (presenting a variety of shells and corals), terminating the series at both places, and almost entirely composed of the accumulated remains of polythalamous animals."

The following are the fossils which I found in this formation, and which I shall insert here, as they are not mentioned in the paper to which I have referred:—

FORAMINIFERA.

Nummularia.— *N. obtusa.* Sow. (Pl. xxiv. fig. 14, Grant's Geol. Cutch. Geol. Trans. Vol. VI. 4to.) *Loc.* Mäskat. *Obs.*—The specimen containing these nummulites was brought to me by the late Capt. Newbold, who saw a bed of them in the limestone formation at Mäskat. I cannot say from what part of the series it came, but the fact is sufficient to prove that this formation, if not the whole, is a part of the "Nummulitic Series."

* Vol. III. No. xiii. p. 118.

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Operculina, d'Orb.— *Species?* Test white, porcelainic, sub-circular, equilateral. The largest about $\frac{1}{4}\frac{1}{8}$ inch in diameter. Consisting of three whorls, each whorl thickened on the external edge; spire irregular, chambers numerous, increasing regularly from a central cell projecting on both sides; the divisions of the chambers distinct externally. *Loc.* Mäskat. *Obs.*—This species abounds in the silico-calcareous sandy part of the formation of Mäskat, just before the latter passes into compact limestone. It is now, even, common on the South-east Coast of Arabia, and exists in a large bed, mixed with fine sand, in twenty-five fathoms of water, opposite the village of Takah. Other fossilized species of Operculina occur with it at Mäskat, even so low down as the grit where the first organic remains begin to appear.

ECHINODERMATA.

Spatangus.— *Species?* Subovate. Length $1\frac{4}{7}$ inch, breadth $1\frac{2}{7}$ inch, thickness $\frac{3}{7}$ inch. Notched anteriorly, truncated and overhanging posteriorly, with the vent in the upper part, from which a ridge extends on to the genital pores. Ambulacra four, sunk in grooves, slightly truncated, the two posterior shorter than the two anterior ones. Base sub-carinated in the centre, mouth bilabiate, near the margin. *Loc.* Mäskat. *Obs.*—From the pink stratum which abounds with the Operculina above mentioned.

ZOOPHYTA.

Caryophillia.— *C. cornigera?* Lam. *Loc.* Mäskat. *Obs.*—This species is very like *C. Anthophyllum*, (Lam. et Ellis, Tab. 29,) but has rounded extremities and contracted stellæ at the ends of them.

Agarica, Meandrina, Astrea, and Scyphia (Goldf.).

CONCHIFERA.

Gryphæa.— *Species?* (Cast of lower valve, imperfect.) Length $1\frac{4}{7}$ inch, breadth $1\frac{2}{7}$ inch. Deeply carinated; irregular, wavy, or lobed towards the circumference, and expanded, particularly towards the right side. *Loc.* Lower sandy part of aqueous strata, Mäskat.

——— 2d *Species?* (Lower valve, incomplete.) Length $1\frac{2}{7}$ inch, breadth $\frac{3}{4}$ inch. Deeply carinated, expanded, plane towards the circumference; smooth externally, presenting concentric striæ; uncinated, like *O. Uncinata* Desh. (Coq. For. Envir. de Paris, Tome 1, Tab. 18, Figs. 7—11.) *Loc.* Mäskat. *Obs.*—This and the foregoing species abound together, and are more or less ostreiform.

GASTEROPODA.

Natica.— *Species?* (Cast, incomplete.) About 2 inches long. First and second whorls depressed. *Loc.* Mäskat. *Obs.*—Imbedded in a

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yellow calcareous stratum, or granular deposit, consisting of minute Foraminifera.

The limestone forming the upper part of this formation, north of Măskat, is much more pure and compact than any that I arrived at in tracing the strata from below upwards on the south side of this town; and, from the distance of the top of the formation from the fundamental rock in the former situation being much greater than in the latter, I am inclined to think that the section I took on the south side of Măskat was incomplete, and that the upper compact strata had there disappeared.

From the sandy nature of the deposits in which the small Foraminifera abound in this formation, and the sandy base of the genuine specimen of nummulitic rock which the late Captain Newbold found at Măskat, as well as from the loose silico-calcareous or calcareous sand in which all the nummulites I have ever seen, from Egypt, Sindh, and Cutch, have been imbedded, I am of opinion that this is the part of the Nummulitic Series in which their remains are to be sought, and not so much in the compact and purer limestone above, where I had always fancied they were to be found; and when, in connection with this, I consider that the bed of Operculina already mentioned, opposite Takah, which contains the largest living specimens of Foraminifera I have met with, is mixed with fine sand, and that I have always observed their tests to be more numerous in sandy bottoms than in more subtle and plastic deposits, I am not so surprised that these delicate shells should not occur in the finer material of which the compact limestone of the Nummulitic Series is more or less composed, and where I had expected most to find them.

Passing on from the commencement of the sea-cliff at the end of the plain of Bātănă, to the town of Măskat, we soon step from the limestone formation, here all at once raised to 600 feet above the sea, on to the bed of igneous rocks, in the midst of which Măskat is situated.

These are spread over an area of about ten miles long, and three miles broad, and are chiefly composed of serpentine, which is limited on the coast, and inland by a yellow-colored limestone formation, (the one just mentioned). Their ridges and summits are sharp and peaked, and seldom exceed 400 feet in height, and their sides and valleys soil-less and barren.

"The serpentine is for the most part of a dark brown colour, and interspersed with small laminated crystals of diallage *chatoyante*. When taken from a depth, it is tough, and not easily broken; but on

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the surface crumbles and breaks into rectangular fragments, the sides of which are more or less coated with green and variegated serpentine, steatite, or calcareous spar. In some parts it is of a light brown color, and earthy, while in others it is darker, more compact, and more waxy or crystalline. It is exactly the same as that of the Lizard Point, in Cornwall."

Here I must correct a misapplication of terms; the "serpentine," following Bronguiart's "Classification et Caractères Minéralogiques des Roches,"* should have been termed "euphotide." It presents the same varieties as that of St. Kevern, and the Lizard, in Cornwall, viz. Euphotide felspathique, and E. ophiteux (Bt.), that is, a rock composed of compact felspar, with isolated crystals of diallage, more or less serpentiniferous, just as diorite (Bt.), with which we shall presently see it is connected, is composed of two ingredients, viz. felspar and hornblende.

The northern extremity of these igneous rocks is composed of diorite, and the limestone formation rests upon it, while between the diorite and the euphotide is a bed of green steatitic clay, out of which oil jars, water jars, &c. are manufactured.

Passing over these igneous rocks to the limestone cape called Ras Ghissa, which limits them to the south of Mäskat, we follow the coast from this point on to the cape called Ras el Häd, at the eastern extremity of Arabia, and of this part I know nothing further than what I have frequently seen from the sea, and what Lieut. Grieve, who surveyed it, has kindly communicated to me.

From Ras Ghissa the limestone formation is continued on for thirty or more miles in an extremely broken condition, being raised in ridges one after another, having their white fractured surfaces towards the north-east, and their original surfaces sloping in the opposite direction; consequently the sea-cliff which faces them is also extremely irregular. After the distance mentioned, the formation loses its ridge-like character, and passes into round and isolated hills, and the great inland ridge approaches the sea to form the northern boundary of the Devil's Gap, which, as before stated, is 6223 feet above its level. There is here a break, and no cliff for a few miles, until the ridge, which forms the opposite or southern boundary of the opening of the valley, commences, and this, attaining a height of 4400 feet not above eight miles from the sea, presents, as may be conceived, an immense mural surface in this direction.

From the summit of the ridge here, which is called Jibal Jäbär, the

* See Dict. des Sciences Naturelles, Art. "Roches."

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land descends to the sea in two or three gigantic cliffs, and is thus scarped the whole way to the town of Soor, where the coast line, turning still more to the east, leaves the scarped ridge to pursue its course southwards, and terminate in the mountains of Jallān. Lieut. Grieve states (Priv. MS.) that "the Jibal Beni Jābăr rise abruptly from the sea to a height of about 3000 feet," near a deep narrow valley called Wadi Shāb, about thirty miles N. W. by W. of Ras el Hăd. Specimens from this valley show that this mountainous ridge is composed of limestone, like that of the other parts of the coast. Its scarped bared surface presents a horizontal stratification, and a general light brick-red color, which is the prevailing tint of the limestone formation throughout the whole coast of Southern Arabia, and arises from the presence of more or less red argillaceous earth, which is found in the cavities of the rock, and about the organic remains. When the rock weathers down to these cavities, the earth becomes liberated, and, spreading over the white limestone, gives it the tint mentioned. In some parts it has entered into the composition of the rock itself, which then is of a cream color. Opposite the scarped surface of Jibal Jābăr there are no soundings half a mile off shore, and this is invariably the case on this and the south-eastern coast, where the land rises abruptly from the sea. Wherever it is highest the soundings are deepest, and *vice versâ*.

From the town of Soor to Ras el Hăd, the coast presents a sea-cliff of about 70 feet high, with land rising in shore to 200 feet, but sinking gradually towards the eastward to the level of the sea, which it attains at Ras el Hăd; also several great irregularities along the coast, which have evidently been occasioned by subterraneous influence.

Lieutenant Grieve mentions a singular pit on the top of the cliffs two miles east of Soor, which is 80 yards in diameter, and 60 feet deep; and it is only a few months since that an earthquake took place near Soor, which shook down several houses there. After this pit, come two other similar, but much more extensive depressions, viz. the Khors or Lagoons of Jărāmah and Hăjar. The former, entering by a narrow channel from the sea, is three miles long and two broad, with sides of 50 to 70 feet high, and water ten fathoms deep, making in all a depth of 110 to 130 feet below the level of the surrounding land. Khor Hăjar, which follows this, is not more than half the size, and much more shallow, but of the same kind of depression.

Rock-specimens from the top of the cliffs about two miles from Soor, near the great pit, which were kindly sent me by Lieutenant Grieve, show that they are composed of a fine white saccharoid limestone, which

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has undergone minute fracture, and has had its fissures filled up again by a red colored cement, probably of the same composition as the parent rock. Such a brecciated state is frequently seen on the south-eastern coast, and in all probability has been caused by the shock of some subterraneous explosion or upheaval. At the same time, I have noticed that such rocks are more or less magnesian: the one just mentioned, on a rough analysis, yields about 12.18 per cent. of magnesia, and hardly effervesces at all with acids before it is pulverized. Its Sp. Gr. is 2.72. The specimens from the lower strata of the same cliffs show that they have not been fractured in the same manner, though of the same composition and structure. I think I have also noticed on this coast that the upper strata are those which are most comminutely fractured, while the lower ones are less so, or have escaped it altogether.

The rock-specimens from the sides of Khor Jărāmah are of a coarser structure; and when we arrive at Khor Hăjar, where the cliffs sink to the level of the sea, and are lost under the sand of the plain, there we find them composed of a limestone conglomerate, consisting of pebbles of the older formations, and shells, cemented together by a red calcareous sand, in which there are minute particles of ingneous rocks. In some parts, this cement exists as a rock by itself, without the grosser portions, and appears to belong to a loose miliolitic formation, which we shall find by-and-bye to prevail on the south-eastern coast.

At Ras el Hăd, which is a sandy cape, we have a plain of two or three miles square, connected on its western side with the Khor last mentioned, and on its eastern side forming the northern point of that short piece of coast which, running north and south for twenty miles, terminates the eastern extremity of Arabia. This short eastern face presents a uniform limestone cliff 100 feet high, and of a light yellowish color, with horizontal strata. Specimens from it show that it is composed above of a compact yellow limestone, breaking with a sub-conchoidal, uneven fracture, almost identical with that from the cliffs of Kurachi opposite; also of strata of the same kind of material and structure, containing abundance of small Foraminifera; and a stratum of whitish saccharoid limestone, like that mentioned at the base of the cliffs two miles east of Soor; while another specimen from these cliffs shows that there is a stratum of the kind last alluded to, which contains a considerable quantity of hyaline quartz, in minute grains, indeed an arenaceous limestone; it resembles the fine silico-calcareous strata of the limestone formation at Măskat.

Turning Ras el Khubba, which is the south point of this short piece of coast, we come upon the South-east Coast of Arabia, and lose all sea-

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cliff for upwards of 180 miles. The coast now generally runs N. E. and S. W., and presents nothing but a sandy shore for the distance I have mentioned, and which I will now more particularly describe.

The first thing worthy of notice on proceeding along this coast is a little cape called Ras Rues, which consists of a few hillocks about twelve feet high; this is about three miles from Ras el Khubba. These hillocks are composed of a recent conglomerate, the grosser parts of which are held together by a dirty-looking silico-calcareous sea-sand, and though exceedingly insignificant in appearance, nevertheless they are interesting in a geological point of view, inasmuch as they contain pebbles of all the rocks probably in the neighbourhood. These pebbles consist of diorites, basalt, quartzite, jasper, and portions of the older limestone formation, all smoothly rounded by attrition.

After leaving this cape, and passing along the coast, we arrive opposite the mountains of Jallān, which I have already stated to be the termination southward of the great chain on this side of Arabia. They are about twenty miles inland from the south-east coast, and the highest is about 3900 feet above the sea. On every side, viz. towards Ras el Hăd on the east, and the desert of Akhāf on the west, as well as towards the south-eastern coast, they, like other mountainous terminations, subside more or less gradually, and more or less irregularly, to the general level of the surrounding country. This, towards Ras el Hăd, or the eastern extremity of Arabia, is in coin-shaped mountains, which offer beautiful scarps for the geologist, and are easy of access; towards the south, in low conical or dome-shaped hills of a brown sandy aspect, mixed with dark peaks, probably of igneous matter, such as we shall see a little further on; while towards the west the subsidence is more gradual and regular, to hills of about 200 feet high. Mr. Cole, of the Indian Navy, who travelled from Laskhara, a town on the coast just here, to Măskat, along the western side of these mountains, kindly sent me specimens from the hills near Bădiyah, which town is in the same parallel of latitude as the highest of the Jallān mountains. These specimens show that the same kind of black limestone exists there as that which Lieut. Constable showed me from Ras Măssăndăm; also pieces of fine compact grey lithographic limestone; and of fine argillaceous slate, of blue and black colors. Hence we may infer that the black limestone forms part of the mountains of Oman, both north and south, but whether continuous or isolated remains for future observation to determine.

Some distance after the subsidence of the mountainous chain has taken place towards the eastern extremity of Arabia, and the land in

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this direction has assumed a general level of from one to two hundred feet above the sea, two mountains, close together, and of equal height, being about 855 feet above the plain, make their appearance. These, which are called Jibal Săffān, are close to the cliff of the eastern extremity of Arabia, and of course isolated for some distance from any other mountains. They are, therefore, very remarkable, from their situation, and being coin-shaped, presenting their fractured surfaces towards the west; they also form a fine section, which is easily attainable, so far as it goes, of the strata at this point; the sea-cliff, as I have before stated, being only 100 feet high.

From Ras Rues onward we have no cliff, and nothing on the land remarkable, beyond the low, brown, sandy-looking hills, and isolated dark peaks, dispersed here and there among them, until we arrive at a place called Ras Jibsh, which only differs from the rest of the coast in presenting a few of these dark peaks, which are arranged in a ridge-like form about 100 feet high, made more evident by their being a little above the surrounding country. There are now no longer any mountains to be seen inland, and nothing more than a monotonous extent of brown sandy-looking mounds, from 50 to 100 feet above the level of the sea, as far as the eye can reach in every direction.

The dark igneous peaks which form the cape called Ras Jibsh are probably only a repetition of what we have before seen among the sandy hills, and they are composed of euphotide and diorite, as those at Mäskat. The diorite, however, presents larger crystals of hornblende, which occurs here in a diversity of forms: sometimes it seems replaced by the diallage of the dark euphotide, or by bronzite or hypersthene; while the felspar sometimes passes into labradorite, of a blueish grey color, and presenting minute parallel lines or striæ, which traverse the plane of cleavage. One part of this ridge is composed of a very marked rock, consisting of moderately-sized crystals of black hornblende and grey felspar, in equal proportions, among which is disseminated a small quantity of a beautiful grass-green hornblende: it is not improbable that the black hornblende itself is but a deeper tint of this color.

There is also, close to these igneous rocks, but much lower than the tops of them, a mound of dull red jasper, undergoing fragmental disintegration: this is probably a chertified condition of some aqueous strata, which have been brought up with the igneous rocks.

The immediate neighbourhood consists of the hills I have mentioned, probably limestone, more or less obscured by drift-sand.

Inside the ridge of rocks is a small bay, which now only offers a safe landing for boats, but which is said to have formerly extended a long

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way further inland behind the ridge mentioned, where there still exists a dry lagoonal depression, about two miles square, and 12 feet above the level of the sea. There is also, on the inner side of the ridge, a modern deposit, the upper margin of which is between 20 and 30 feet above the level of the sea. I have already mentioned one at Ras el Hăd, which is raised at least 12 feet above the level of the sea, also a littoral conglomerate at Ras Rues, the upper part of which is about 12 feet above the sea; and here we have a similar deposit, raised 30 feet above it. This kind of formation we shall find frequently on this coast.

From Ras Jibsh south-westwards, the coast presents a still more desolate aspect, if possible, than it did to the eastward of this cape: not a dark mound now appears to vary the color of the land, close to the sea, or as far as the eye can reach interiorly; but as we approach Ras Abu Ashrin, which is in 20° 58′ N. lat., and 58° 44′ E. long., the light brown color of the land ceases, and is succeeded by a tract of white dome-shaped sand-hills, from one to two hundred feet above the level of the sea. These extend inland as far as the eye can reach, and are scarped upon the sea, where their structure is satisfactorily seen. None of these scarps, which correspond to the hills forming part of the line of coast, are I think more than a hundred feet high. The formation consists of a sandy, granular rock, which, when minutely examined, is found to be chiefly composed of calcareous grains, with a small quantity of hyaline quartz, and dark particles, probably hornblende, from the igneous rocks. The latter character is deserving of notice, because, as no dark particles of this kind appear in the older limestone, they serve as a distinguishing mark for this formation when it approaches the latter in appearance. So uniform is it in its granular structure that there is hardly a fossil larger than the grains of which it is composed to be seen throughout the whole deposit. It is more or less stratified, and, though loose in structure, is sufficiently compact to form a good building stone. The thickness of this formation cannot be further ascertained than that which can be learnt from its scarped parts, which at the utmost do not exceed 100 feet. It is so loose on the surface that the upper and exposed part has become disintegrated for some depth, and, assisted by irregular upheavals, the original formation has probably thus been transformed into the dome-shaped mounds which it now presents. In some parts the sand is so subtle that it yields to the lightest weight, while in others it is so caked that it will bear that of a man. At a little distance it has the appearance of mounds of snow. Can these be the "winding sands" which are alluded to in the Khoran

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among which the tribe of Ad are said to have perished? There can be no doubt that they form the south-eastern part of the Desert of Akhāf, and not far from the borders of it where this tribe is said to have settled; and could the gulf of sand at the western extremity of this desert, in which Baron Wrede found a plummet sink to the length of the line attached to it, viz. 360 feet, be the disintegrated sand of this formation, filling some volcanic depression there? There is no doubt that this deposit forms the lowest part of the seaward boundary of the Desert of Akhāf, and it may do so throughout; and that the desert itself extends at first a little inland, and then to the westward, to within 300 miles of the Red Sea, and about 150 miles from the south-eastern coast, where the "Sand-gulf" mentioned is said to be situated. The desert itself is also said to be impassable, and nothing would render it more so than an extension of such sand-hills as those in the neighbourhood of Ras Abu Ashrin.

When subjected to a chemico-microscopic analysis, if it may be so termed, the calcareous particles of which this deposit is composed are found to be nothing more than the remains of minute Foraminifera, the tests of which, having become partially dissolved and re-crystallized, have cemented the whole together; but this having taken place without interfering with the form of their internal cavities, and the latter being filled with the mineral called by Dr. Mantell moluskite (yellow silicate of iron?) allows of the latter being dissolved out by a weak acid, and the origin of the calcareous grains thus ascertained: not only this, but the extreme faithfulness with which the internal cavities are represented admits also of their species being determined.

I have been thus particular in describing this deposit, because we shall find it so widely spread along this coast; and not only here, but extending to the peninsula called Khattyawar, on the coast of India, from whence it is imported into Bombay in considerable quantity, for building and flooring stone; and supplies much the same place that the freestone from Portland does on the southern coast of England. I shall henceforth apply the terms miliolite or miliolitic to this deposit.

At Ras Abu Ashrin the coast sinks nearly to the level of the sea, and continues so for thirty-nine miles, or on to the bay called Ghobat Hăshish, where the same kind of white sand-hills are again met with. I do not think this flat portion extends very far inland before it is stopped by the tract of sand-hills mentioned: indeed I could see that it does not, from the high land of Masira opposite; nevertheless it is the lowest part of the South-eastern Coast of Arabia, unbacked by mountains; and the island of Masira, to which we will now pass over, lies opposite it, about ten miles distant.

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Masira is thirty-five miles long, and varies from four to nine broad, and a chain of mountains runs longitudinally through it, which sends off spurs to the principal capes. This chain is chiefly composed of igneous rocks, and its highest mountain, which is in the northern half of the island, is not more than 600 feet above the level of the sea; while hardly any in the southern half of the island exceed 300 feet. Here and there tracts of limestone present themselves, but these are of small extent, and chiefly raised up upon peaks of the igneous rocks. Besides the main chain, which through its spurs and ramifications extends nearly all over the island, leaving only here and there, on its inner side, some sandy plains, there are other small ridges and rocks, which run more or less round the margin of the island, and others in the southern part of the channel, between Masira and the main land, which make their appearance in reefs and small rocky islets.

To the igneous rocks and the limestone there may be added a modern formation, composed of sea-sand, in which are imbedded shells, corals, and pieces of the older rocks. Let us now turn our attention to a more particular description of these formations.

The igneous rocks are chiefly composed of euphotide and diorite, such as we have before seen at Ras Jibsh and Mäskat, but, in addition to these, there are more or less homogeneous green and black diorites, also basaltic rocks, more or less scoriaceous, or cellular, and amygdaloidal trap, the cavities of which are filled with calc-spar.

The euphotide is seen as usual in conjunction with its companion the diorite, though not, I think, so plentiful. They form the main chain and principal masses in the island. This, which is the older diorite, contains large crystals of hornblende, as at Jibsh, but of a greater variety of colors, such as green, brown, deep dark red, and black, sometimes in equal quantity with the compact felspar, at others preponderating. At the northern extremity of the island, the diorite is of a newer kind, and from its fine structure, homogeneous appearance, and black color, almost resembles basalt: it is here 200 feet above the level of the sea; it forms the islets, too, and is seen in many parts, but as a less plentiful rock. The fine green diorites, and the trap, also form low round hills, of considerable extent, and the cellular and phonolitic basalt much higher hills, with loose portions on their sides, the whole weathering smooth, and of a dark red brown color.

The accessory minerals which I met with were epidote, with calc-spar, and micaceous iron ore, tremolite, hornblende of different colors, and diallage, with its varieties, also copper. The latter mineral exists in many parts of the island, chiefly, I think, among the fine-grained

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green earthy diorites, and low trap hills. I found it in the form of malachite, disseminated and in veins, in the parent rock, and following veins of hyaline quartz which traversed it. In many parts it has been worked, as the excavations and remains of slags and smelting-places in various parts indicate, but the weather-worn state of those I saw would make the time at which they were worked very remote. I have given a short account of these copper veins in this Journal (Vol. II. No ix. p. 400).

From the igneous rocks, let us go to the tracts of limestone. These are of small extent, and for the most part raised on the tops of the older igneous rocks. Beginning at the northernmost end of the island, we find a tract commencing just inside the group of black dioritic rocks which forms this extremity, and from thence extending longitudinally along it for about five miles, making the central ridge or highest elevation of this narrow part of the island. It is scarped towards the west, and slopes into the sand of the sea shore on the eastern side, at the same time that it rises towards the south-west, so that the dip of its strata is towards the east, and that of its strike north-east. For a long way the ridge or upper line of the scarp is not more than 30 or 40 feet above the level of the sea, but at its southern extremity it rises suddenly to about 100 feet. Here it presents a trifid rent, giving rise to three great fissures, which run in different directions towards the sea on each side of the island, respectively. The thickness of the scarps here is from 60 to 80 feet, and their geological section is as follows:—

The upper part of compact limestone, of a whitish yellow colour, cleavable, but breaking with a rough fracture. This is more or less filled with the remains of shells and corals, and extends downwards for 40 feet. It then passes into ten feet of coarse, loose, sandy, silico-calcareous limestone, of a yellow colour, containing numerous shells, and then 10 feet more of the same deposit, traversed by veins of gypsum, after which follows a coarse arenaceous yellow limestone, more or less shelly, which is lost beneath the bottom of the fissure.

Returning to the inner shore of the island, by one of these fissures, I passed, after issuing from it, between the scarp of the limestone ridge on my right hand and the igneous rocks of the island on my left, while the part over which I walked was composed of loose gritty earth of bright red and yellow colours, which seemed to be the finer parts of a jaspidean conglomerate that lay beneath. This conglomerate I thought might be an altered and lower deposit of the limestone formation, which would then make the section of it correspond with that at Mäskat.

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The pebbles of this conglomerate have been so changed by the heat to which they have been exposed, that it is impossible to say what they were originally. In it, also, are disseminated here and there small quantities of malachite, which is the case in the silicious conglomerate of the limestone formation that rests upon the diorite at the village of Darzit, north of Mäskat.

The second tract of limestone we come to, proceeding south-westward, is raised on the top of the main chain of dioritic rocks, in the centre of the northern half of the island. Its surface, which is horizontal, is 400 feet above the level of the sea, and its form very conspicuous from a distance, on account of its horizontality, and the contrast of its light yellow colour with the dark rocks around and beneath it. This tract is of an irregular shape, and about two miles long, by a quarter of a mile broad, and its longest diameter is parallel with the longitudinal axis of the island. The southern extremity of its upper surface or plateau, which is attenuated, and not more than 50 feet wide, is undermined on each side for upwards of 15 feet, which leaves only a support of about 20 feet wide in the centre; other parts on this side of the plateau are similarly worn, while there is nothing of the kind on the other sides. This leads one to infer that these excavations were effected by the waves when this limestone tract might have been rising from the sea. The fact also of their being only on the south-western extremity strengthens this, from the north-eastern part being sheltered by the coast, and the opposite side being directly exposed to the south-west monsoon. The surface of this plateau, which is perfectly horizontal, and the strata of the whole mass parallel to it, is bestrewed with the casts of bivalve shells (Conchacea) in the same manner as the hills about Hydrabad in Sindh, and among these, the casts of large species of the genus *Lucina* are by far the most prevalent in both localities. The following is a geological section of this tract:—

Beginning from above downwards, we have a compact limestone, of a whitish colour, cleavable, and breaking with a rough fracture: this is more or less filled with shells and microscopic Foraminifera, and extends downwards for 100 feet. Then follows a coarse yellow limestone, more or less sandy, which chiefly presents the remains of corals, and occupies about 50 feet; after which comes about 50 feet of loose yellow silico-calcareous sand, and red and green arenaceous clays: the upper two-thirds, consisting of the former, are traversed by veins of gypsum, in all its common crystalline forms; and the latter, consisting of the clays mentioned, forms the base of the series, and rests upon the diorite. I did not perceive a conglomerate here to bear out my inference respect-

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ing its existence at the base of the last tract, which is not exposed. The only fossils obtained were the following:—

Corbula ?— *Species ?* (Cast.) Trigonal, inequilateral, inequivalve. Breadth $4\frac{1}{4}$ inches, height $3\frac{1}{2}$ inches, depth $1\frac{4}{7}$ inches. Thick posteriorly; compressed anteriorly. *Loc.* Masira, from the surface of the plateau.

Spondylus.— *Species ?* (Cast.) Subovate, inequilateral. Breadth $1\frac{1}{7}$ inch, height $1\frac{1}{2}$ inch, and depth $\frac{9}{14}$ inch. Striæ numerous, close together, and thin, the largest bearing small spines. *Loc.* Masira, from the second tract of limestone.

Although I could perceive traces of numberless fossils in this limestone, the only ones that I saw weathered out were the bivales on the plateau, and the one last mentioned.

Adjoining this tract of limestone are two others, which are only separated from it by a deep ravine: they are a little less in size, and slope towards the east with the tops of the igneous rocks on which they are supported. I had not time to visit them.

The next tract I shall describe is by far the most interesting of all, on account of its fossils. Proceeding south-westwards, we come to this about two miles from the plateau. But it is not similarly situated as to height, for its base is barely raised above the level of the sea, from which it is about a mile inland, among the igneous rocks. Like the southwest extremity of the first tract, this has also been raised by a force applied from below, here in the centre of the mass, which has produced a radiated fracture of the whole, and thrown its parts widely asunder, so as to expose a floor beneath, now half a mile or more in diameter. This floor happens to consist of a stratum of small nummulites, which reveals the nature of the limestone tracts hitherto examined, and establishes the existence of the Nummulitic Series on this part of the South-eastern Coast of Arabia.

The limestone, which rises about 100 feet above this floor, is of the same kind as that already described, and the fossils obtained from the inclosed area, which presents a vast variety, are as follows:—

FORAMINIFERA.

Nummulina.— 1st *Species ?* Circular, slightly convex on both sides, thin at the edge. Breadth $\frac{2}{7}$ inch, thickness $\frac{1}{7}$ inch. Horizontal or wavy; surfaces smooth, sloping gradually towards the circumference; presenting when polished a reticulated structure. Splits into halves, and shows a spire, consisting of a great number of whorls, which are divided into small chambers; the whole becoming more dense towards the centre. *Loc.* Masira.

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Nummulina.— 2nd *Species?* Orbicular, doubly convex; Breadth $\frac{1}{12}$ inch, and thickness $\frac{1}{24}$ inch. Surfaces smooth, sloping suddenly to a thin circumference; presenting a reticulated structure, like the foregoing species. Splits in halves horizontally, and exposes a spire, consisting of a great number of whorls, divided into small chambers, the whole structure becoming more dense towards the centre. *Loc.* Masira. *Obs.*—The entire stratum was nearly made up of this and the foregoing species.

ECHINODERMATA.

Spatangus.— 1st *Species?* Conical. Length 6½ inches, breadth 5½ inches, and height 5 inches. Ambulacra four, not depressed, spreading from the centre of the summit of the test, and extending nearly to the margin; grooved anteriorly in the place of the fifth ambulacrum. Genital pores four. Mouth bilabiate, between the centre and anterior extremity. Base oval; carinated in the centre, from the mouth backwards, and covered with small tubercles; bordered on each side by a longitudinal area of smooth polygonal plates. Vent terminal supra marginal. *Loc.* Masira. *Obs.*—The remains of this large fossil were very numerous, and partly filled with the nummulites mentioned.

——— 2nd *Species?* (Incomplete.) Length 2 inches, breadth 1½ inch. Ambulacra five, petaloid, situated in deep furrows, spreading from a point nearer the anal than the oral extremity; the posterior two shortest. *Loc.* Masira.

Cidaris.— *Species?* (A portion only of the test, bearing two big tubercles.) The largest $\frac{1}{12}$ inch in diameter at the base, surrounded by a ring of small tubercles, but none within the circle. *Loc.* Masira.

CRUSTACEA.

Cancer.— *Species?* Carapace sub-elliptical; Diameter 5¼ inches transversely, 4 inches antero-posteriorly. Spiniferous laterally; spines five in number, alternately bifid, extending from the orbits backwards; orbits 2¼ inches apart. Pinchers large, expanded, equal in size, concave on the interior surface, and bordered on the posterior edge by eight tubercles; tail consisting of six segments. *Loc.* Masira.

CONCHIFERA.

Tubicola.— *Species?* (See a description of the tube among the fossils from Hammar el Nafur, further on.) *Obs.*—They abound among the nummulites in Masira, and are very common in Sindh.

The deposit in which these fossils were imbedded bears little trace of them when not weather-worn or disintegrated, so that this might partly account for my having passed them over in the other limestone tracts. Here they abounded all ready to my hand, but being alone

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when I fell in with them, and the sun having set, I could not examine the place so much as I wished, nor bring away so many fossils as I desired, and the next day we removed to a station several miles distant; so that I had not an opportunity of returning to this really garden of fossils, much to my regret.

The last unmentioned tract of limestone in this island is that which forms two mountains 500 feet high, at its south-western extremity. It is a narrow portion, about a mile long, and raised, as usual, on peaks of the diorite. There were no loose fossils about it, and the character of the limestone I have already described. Its base is buried in the debris of the superincumbent mass.

All these tracts are doubtless parts of the same limestone formation, which was once continuous over the island of Masira, but has since been broken up by the eruption of its igneous rocks, and more or less carried away by the action of the waves, during the time that the island has been gradually rising from the bottom of the sea to its present position. The presence of the bed of nummulites, too, in one portion of it, shows also that the whole belong to the Nummulitic Series.

Having now described the two principal formations in the island of Masira, viz. igneous and aqueous, let us turn our attention for a few minutes, before returning to the main land again, to the more modern formations to which I have alluded. These are two in number, one of which, perhaps the latest of the two, is seen in the north-eastern part of the island, where it is about 12 feet thick, and raised about 40 feet above the level of the sea, about a mile from it. It is scarped on its seaward side, and runs parallel to the north-eastern extremity of the island, which is truncated, and on the other side thins off upon the rocks on which it is supported. It is composed of shells, and pieces of coral, from which the animal matter has disappeared, and portions more or less rounded of the limestone and igneous rocks of the locality, all of which are slightly held together by sea-sand, consisting of minute grains of the same kind of material. It lies between the two groups of igneous rocks which form the two angles of this truncated extremity of the island, and is firmly adherent to their sides.

The other formation, which is but a finer deposit of the last mentioned, and perhaps a little older, is considerably elevated above the sea. It may be seen close to the village of Gyren, on the inner side of the south-western half of the island. It only differs from the miliolite of the opposite coast in containing more particles from the igneous rocks, and is raised on the top of some greenstone peaks, about 200 feet above the level of the sea.

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Before concluding my remarks on Masira, I should mention that in the north-east half of the island, a little inland of Ras Jazirăh, there is a small low mound of aqueous strata, projecting from the plain of igneous rocks which exists there. These strata, which have been rendered jaspidean by heat, are in a vertical position, and composed of an extremely fine flinty material of a red or flesh colour, probably originally a fine clay. They are undergoing fragmental disintegration, and the pieces very much resemble leelite. To what formation this belongs I cannot say, but probably not to the limestone formation of Masira, for that rests on the igneous rocks in which this appears to be enveloped. I have mentioned the existence of a similar mound, and similarly situated, at Ras Jibsh.

Returning to the main land, to the bay called Ghobat Hashish, which is opposite the south-western extremity of Masira, and to which we have already brought on the low land behind this island, and the sand-hills from Ras Abu Ashrin, we find the compact limestone again appearing from beneath the miliolite. This is seen on the western side of the bay, where it is about 80 feet high, after which it rises gradually on to Ras Jazirăh, about 100 miles distant, where it is about 480 feet above the level of the sea; and the direction of this part of the coast, being due south, as I have before stated, shows also that the strata gradually rise in this direction, as well as to the south-west, which we shall see presently.

For the specimens and information I possess of this part of the coast I am indebted to the kindness of Lieut. Grieve, who surveyed it in 1847.

Rock-specimens from the west side of the bay of Hashish, and from Ras Sărāb, about twenty-five miles south of it, show that the limestone formation which here emerges from beneath the sand-hills, consists of a fine compact rock, some of which is magnesian, heavy, and of a grey color.

Next comes the little island called Hammar el Nafur, which is about twenty-five miles south of Ras Sărāb, and of all the information which Lieut. Grieve has communicated to me, that from this little island and another cape next to it, called Ras Kariat, with their specimens, are by far the most interesting and important. It is extremely fortunate that this little island should exist just here, at the commencement of the rise of the cliff, which we shall find by-and-bye carried up 4000 feet above the level of the sea far beyond our reach; for from its form and position, together with the cape mentioned, we obtain an unmistakeable geological section of the cliff for 320 feet down from its summit, which is the height of Hammar el Nafur.

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This island is about 400 yards long by 300 broad, and its summit, though flat, is split in all directions. Rock-specimens from it show that it is composed of compact white limestone, and concretionary flints above, the former breaking with a more or less smooth fracture. This is stated to extend down 150 feet, and to present no loose fossils. Then comes 50 feet of white earthy or gritty calcareous deposit, more or less mixed with argillaceous matter, of a greenish white color, in which there are many fossils; and the rest is stated to be greenish white clay, without any; the bottom of the sea everywhere in the neighbourhood being composed of the latter material.

This clay, just stated to be of a greenish-white colour, is meagre to the touch when dry; breaks with an irregular rough fracture; receives a polish when scraped with the nail; does not adhere to the tongue; does not effervesce with acids; does not mix readily with water, but, when once rubbed up with it, remains for many days suspended in it, in an impalpable powder. Before the blow-pipe it dries up, becomes red and porous, and then passes into a black slag. When in combination with more or less calcareous material, it forms an excellent soap.

Having described this clay, I will now add a list of the fossils which Lieutenant Grieve sent me, and with them include those which came from Ras Kariat, nearly opposite, since the strata and fossils of both places are said to be exactly the same, and the specimens confirm this. They are as follows:—

FORAMINIFERA.

Nummulina.— *Species?* Circular, compressed, terminating at the circumference in a thin edge. Breadth $\frac{2}{17}$ inch, thickness $\frac{1}{32}$ inch; surfaces smooth, without any marking; presenting a spire internally, with many whorls, divided into small chambers. *Loc.* Hammar el Nafur and Ras Kariat, in the gritty calcareous deposit below the compact limestone.

Orbilolites?— (Impressions only). 1st *Species?* Oval. Length $\frac{2}{17}$ inch, breadth $\frac{6}{17}$ inch.—2nd *Species?* Circular. Diameter $\frac{3}{17}$ inch. *Loc. idem. Obs.*—Found in the marl passing from the gritty calcareous deposit into the clay.

ECHINODERMATA.

Echinocyamus.— *E. pyriformis* Ag. mihi. (Tab. 22, figs. 19—24, et *Echinoneus placenta* Goldf. Tab. 42, fig. 12.) Sub-pentagonal. Oval. Length $\frac{1}{3}\frac{3}{6}$ inch, breadth $\frac{1}{3}\frac{1}{6}$, height $\frac{1}{17}$. Subtruncated anteriorly, pointed posteriorly; mouth central; vent inferior, and situated a little distance from the margin. *Loc. idem.*

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Echinocyamus.— *E. siculus* Ag. mihi. Oval, depressed. Length $\frac{8}{12}$ inch, breadth $\frac{7}{12}$ inch, height $\frac{4}{12}$ inch. Mouth and vent the same as in the foregoing species; ambulacra five, petaloid, not depressed. *Loc.* Hammar el Nafur and Ras Kariat. *Obs.*—This, and the foregoing species, are numerous in the earthy deposit below the compact limestone, together with the nummulites, which, on the other hand, are scanty, judging from the specimens of the deposit sent to me, but they are probably more numerous in other parts.

Clypeaster.— *Species?* Sub-pentagonal. Length $2\frac{8}{12}$ inches, breadth $2\frac{3}{12}$ inches, height $1\frac{5}{12}$ inch. Summit sub-central, anterior; ambulacra five, petaloid, in furrows, each enclosing a raised area; genital pores four; none posteriorly, mouth sub-central, depressed, surrounded by five tubercles, or projections, with a groove between each, presenting ambulacral pores; vent sub-marginal. *Loc.* Ras Kariat.

CONCHIFERA.

Tubicola.— *Species?* Tube only. Circular. Diameter $\frac{1}{2}$ to 1 inch; slightly increasing downwards. Straight or slightly crooked; sometimes bent at an obtuse angle; length unknown. Wall of tube from the thinness of a wafer to $\frac{1}{12}$ inch; composed of concentric layers, smooth and round internally; uneven, and presenting transverse striæ or rugæ externally. Filled with the material in which they are imbedded. *Loc.* Hammar el Nafur, Ras Kariat, Masira.

Teredo Navalis.— *Species?* Tube, sub-circular. Diameter above $\frac{1}{4}$ inch, increasing slightly downwards to a point, where it suddenly dilates; sub-flexuous; length of specimen $2\frac{1}{2}$ inches, real length unknown. Divided internally above by a transverse septum, which ends below where the tube dilates, (probably close to the animal,) in the two compartments becoming separate syphons, which are in contact in the middle, and entirely separated from the rest of the tube. Wall of tube $\frac{1}{12}$ inch thick; external surface uneven; irregular; striæ arranged longitudinally, and becoming circular where the tube suddenly expands. *Loc.* Hammar el Nafur and Ras Kariat. *Obs.*—The first of these tubes abounds in the earthy limestone or marly deposit with the nummulites, both here and in the island of Masira. They are also very common in Sindh. A specimen of one is figured in Pl. xxi. fig. 1 of Grant's Geology of Cutch, (loc. cit.) where it has been provisionally called "*Serpula? recta*" by Mr. Sowerby.

CONCHACEA.

Lucina.— *Species?* (Cast, imperfect.) Circular, compressed, equivalve, presenting little tubercles in circular depressions on both sides, which

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appear to be impressions of the mantle. Breadth about 2 $\frac{2}{10}$ inches, and length 2 $\frac{2}{10}$ inches. *Loc.* Hammar el Nafur. *Obs.*—This is a facsimile of one of the species of Lucina found commonly about the hills at Hydrabad in Sindh, and like those on the surface of the plateau in Masira. It is a characteristic fossil of the upper part of this series, from which therefore it most probably came in the island of Hammar el Nafur.

GASTEROPODA.

Natica.— *Species?* (Cast, imperfect.) Breadth 4½ inches, and length 3½ inches. *Loc.* Hammar el Nafur and Ras Kariat. *Obs.*—There are several imperfect casts of large Naticæ from the softer limestone of these localities. In Sindh, also, such casts are found, composed almost entirely of large nummulites, together with minute and small Foraminifera. They, therefore, in the absence of the larger nummulites, here serve to establish the nature of the deposit in which they are found; throughout which the shells of Conchifera and Gasteropoda would seem to have entirely disappeared, as in most other parts of the Nummulitic Series with which I am acquainted.

Before proceeding further, it is worth while to compare the strata of the island of Hammar el Nafur and Ras Kariat, on the main land, with a section of the nummulitic strata forming the range of hills at Sukkur, in Sindh. This section was kindly sent me by Dr. Malcolmson, of the Bombay Medical Service, who states in his letter as follows:—"I have been over the Sukkur range of hills to their termination at Daji Kot. There is but little diversity in the whole range, which in no place exceeds 400 feet in height. The whole is one mass of nummulitic limestone, more or less disintegrating. It is, however, strange that the upper strata are in many places *very compact, and contain but few fossils, but are very plentifully interspersed with flints;* some of the flints contained large nummulites. The escarpment of the whole range faces the west. The strata are perfectly horizontal. Some of the limestone is of a cream colour, and forms a good building stone, which wears well, and does not seem to suffer from atmospheric exposure. About twelve miles from Sukkur I found a bed of clay *underlying* the nummulitic limestone, filled with the impressions *only* of shells. [This clay, of which Dr. Malcolmson sent me a specimen, is of the same kind as that at Hammar el Nafur.] The hill is here 250 feet high, and composed entirely, in the lower part, of nummulites, overlaid by compact limestone, containing flints. I traced the out-cropping of the clay for about half a mile."

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Here, then, we have nearly the same strata as at the island of Hammar el Nafur and Ras Kariat, and that too about the same height, viz. 400 feet, composed of *compact limestone* above, then *nummulites* in a *loose disintegrating (gritty ?)* deposit below, and afterwards *clay*.

It is important to establish the exact nature of this series at Hammar el Nafur and Ras Kariat, for the reasons I have before stated, viz. that as the cliff rises towards the south-west we shall soon find these strata elevated beyond our reach, so that when we come to the height of 4000 feet we shall have to assume that they still form the summit there, from their existence at Hammar el Nafur and Ras Kariat; unless we can prove this by the presence of the nummulites themselves, or some other allied fossil. The disintegration of the deposit in which the great mass of nummulites are imbedded I have generally observed to be the case in all the specimens I have seen from Egypt, Sindh, and Cutch. I have not yet seen a compact hard limestone charged with nummulites.

Passing back to the coast opposite the island of Hammar el Nafur, Lieut. Grieve states this to be "low, and to present a range of small dark peaks, rising gradually from the beach." These are probably the tops of low igneous rocks, which we might expect to be near, from the break in the cliff, and the upheaval of Hammar el Nafur opposite it.

The next place from which I have specimens is Ras Kariat, already mentioned. This cape is nine miles south of the island of Hammar el Nafur, and about forty north of Ras Jazirăh. From this point the cliff, which is 280 feet high, and has hitherto been in detatched portions, is extended on continuously to within a few miles of Ras Jazirăh. The upper part of it, like that of Hammar el Nafur, is composed of compact white limestone with concretionary flints, passing below into an earthy gritty one, thence into a marly deposit, and lastly clay. The fossils are the same as those of Hammar el Nafur, and have been described under the list from that island. I received also large portions of radiated and columnar crystallized carbonate of lime, pointed at the circumference, translucent, and of a greenish white colour; they are crossed by transparent wavy lines, as if they had been formed by successive additions, and appear to come from the earthy limestone near the green clay; also specimens of gypsum, of which some of the tubes of the Tubicolæ were made up. The occurrence of gypsum here should not be forgotten, for it exists in the same position at Masira and Măskat, viz. below the compact limestone.

From Ras Kariat the cliff, as before stated, extends on uninterruptedly to within a few miles of Ras Jazirăh, or a little beyond Ras Markas, which is nine miles from the former cape, where they are 480

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feet above the level of the sea. Rock-specimens from this show that the base is composed of a pinkish, compact, sub-saccharoid, magnesian limestone, which slowly effervesces with acids; also a rock of the same kind, but filled with the cavities of small shells, viz. Cardium and Cerithium, containing selenite. The Cardium is oblique, inequilateral. Length $\frac{1}{2}$ inch, and breadth $\frac{3}{7}$ inch. We shall find a rock almost identical with this occurring at Makalla, about 600 miles S. W. of it; the proximity, however, of igneous rocks, which we shall find in both localities, have probably influenced this resemblance, more than the continuity of the stratum.

Lastly, we come to Ras Jazirăh, the end of this portion of the coast, which now suddenly returns, from running N. and S., to its general direction, viz. N. E. and S. W.; and here we have another eruption of igneous rocks. This is confined to the cape, and its immediate neighbourhood, but it presents as complete a picture of such a disturbance as can well be witnessed. The continuity of the cliff, which on either side is uniform, and horizontal as far as the eye can reach, is here entirely broken up by the igneous rocks, and the detached portions of its strata thrown into all kinds of positions, and weathered into all kinds of shapes; while the dark rock appears between or below them, or in separate peaks, among the general wreck. Where the white strata overlie the igneous rock, they are discoloured for some distance, red and black: this would seem to be the passage into the former, just as we saw it in the base of the plateau at Masira, where these coloured strata are composed of red and dark green clays; for the limestone here probably rests on dioritic rocks, as at Masira, and the rupture has been caused probably by their subsequent elevation, and by the effusion, perhaps about the same time, of more igneous matter. Specimens from the island which joins the cape at low water, and from which it takes its name, show that it is formed of a rock belonging to the euphotide and diorite before mentioned, and of which probably the igneous rocks on shore are principally composed. These specimens consist of brown compact felspar, in which there is an equal quantity of sparkling laminated black hornblende, in small crystals; and on the plane surfaces of the specimens an ophiolitic or nephritic deposit, like that seen about the euphotide hitherto met with. On either side of this eruption the cliffs, as before stated, are continuous, and their strata horizontal, as far as the eye can reach, but their whiteness, which hitherto has made them look so much like those on the south-east coast of England, seems here to cease, and to give place to a light yellow tint.

From Ras Jazirăh the cliff is continued on, with the exception of a

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break here and there, (where it falls back and gives place to a sandy plain in front,) to Ras Shaherbataht, and Ras Gharau, which capes are within a few miles of each other. Here the cliff is 800 feet above the level of the sea, and has been gradually rising to this since leaving Ras Jazirāh, a distance of 110 miles. Capt. Haines states that the upper strata here are composed of limestone, below which come "chalk" and flints.* As we approach this cape, we observe that the cliffs begin to present large caverns, which appear to have been solely excavated by the waves; they are very similar to those seen on the Bill of Portland. I could not help thinking that in this way most of the great caverns which we shall by-and-bye see in the mountains have been formed, and which now serve for the habitations of most of the Bedouins who live on the high land of Southern Arabia. At Ras Shaherbataht the same kind of uniformity and continuity of cliff meets the eye on either side, as at Ras Jazirāh, only that it is nearly twice the height; but as we approach the centre of Kuriyah Muriyah Bay a totally different aspect presents itself: here we observe at Ras Shuamiyah, which is about 135 miles from Ras Jazirāh, another and much more extended outbreak of igneous rocks than at the latter point. The cape called Ras Shuamiyah is formed by a dark black-looking igneous rock, and on either side of it black dykes irregularly extend up through the white strata, in some places raising them and running along between them, and in others attaining the summit and flowing along the surface above the cliff, the uniformity of which may well be conceived to have become totally destroyed by this eruption. In some parts it is raised higher than we have hitherto seen it, in others more depressed, while the land interiorly appears to have participated in this, if not in a former more general disturbance; and a few miles further south-west, its irregularities still increasing, brings us to the high land before mentioned, which is 4000 feet above the level of the sea, with the white cliff we have been passing at the upper part of it. This is the eastern limit of the elevated tract of Southern Arabia, and the western limit, on the coast, of the low land or Desert of Akhāf. The south-western part of Kuriyah Muriyah Bay is bordered by the former, which, breaking down towards the extremity of the horn, ends in a granite mountain, 1200 feet high, which forms the cape itself, and is called Ras Nus.

The appearance of this granite mountain probably explains the grand and sudden upheaval of the coast here. It is the first granite we have met with, but we shall soon find that we have come to an immense tract of it, which not only extends along the coast south-westward for several miles,

* Journal Royal Geograph. Soc., Vol. XV.

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but also eastwards, where it forms the greater part of the Kuriyah Muriyah islands, to which we will now direct our attention.

They are five in number, neither of which is more than twenty-five miles from the coast; and the farthest apart are not more than thirty-five miles from each other, while they are all in the same parallel of latitude. The largest, called Hălläniyah, is about seven and a half miles long, and about three and a half broad. The next in size is Soda, which is about three miles long, and two broad. Haski and Jibliyah are each about a mile square, and Gharzaut is hardly more than a large rock.

Hălläniyah is composed of about one-sixth limestone, and the rest of igneous rocks. The limestone occupies the northern part, and forms a cape 1645 feet above the level of the sea; its colour generally is a light yellow to the water's edge, and its strata, though tilted up and displaced where they are in contact with the igneous rocks, are undisturbed at the cape, any further than is caused by their elevation of about fifteen degrees towards the north. The late Dr. Hulton, from whose description of these islands* the following remarks have been extracted, states:—

"About the centre of the island [Hălläniyah] the hills rise into a cluster of pointed spires, the highest of which was computed by trigonometrical measurement at 1510 feet above the level of the sea; and from these, similar hills run in all directions, preserving in most cases the form of interrupted ridges. At the eastern [northern ?] extreme, the land assumes a different state; a perpendicular headland, 1645 feet in height, boldly projects into the ocean, and for some distance to the westward appears a continued mass of table-land, accidentally heaved up, as it were, at the end of the island. With the exception of this high land the rest of the island is chiefly composed of granite, varying somewhat in its structure, and the proportion of its fundamental ingredients, upon which also depends a variety in its colours. The most interesting feature of the granite is the manner in which most of its ridges are surmounted by a dark-coloured rock, allied in its characters to those of the trap order, more especially to greenstone. [The latter is our diorite, and the dark-coloured rock probably euphotide, which we have before seen to accompany it.] This is found passing through the body of the hills in the form of dykes. The same rock is seen abundantly in the form of veins and seams, traversing the granite in all directions. It would appear as though by some powerful internal impulse this substance had been injected into fissures in the granite, produced by the same violent action. To a person viewing it

* Trans. Bombay Geograph. Soc. 1839-40, p. 189.

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from a moderate distance, the distribution gives rise to an appearance of an unusually dark shade running along the summits of the hills, as most of our party at first fancied. These dykes and seams do not follow any general rule in regard to their direction, but are entirely influenced in this respect by the disposition of the granite, which follows no particular course. They vary from a fine vein of a few inches to a stratum of eighteen or twenty feet in breadth. In mineral composition, too, they differ no less materially. Most of it I have stated to resemble greenstone, in the compactness and simplicity of its structure, and hornblende appears to be the predominant ingredient; but by the intermixture of felspar in greater or less quantity, rocks of a very different nature result, still occupying the same relative situation. In some places the felspar is disseminated in the form of distinct crystals, communicating a porphyritic structure; in others quartz is abundantly intermingled, giving it more of a granitic aspect. In the latter there is a tendency in the compound to diffuse itself more extensively through the granite bed, losing its character as a stratum, and entering largely into the formation of the hill itself. In fact, it appears to undergo, by this accession of felspar and quartz, a regular transition to granite itself, and merely differs, as far as the eye can judge, in colour, which, from the presence of hornblende as a subordinate mineral, becomes of a dark speckled hue. . . . . In both this and the prevailing kind of granite, mica, if not altogether wanting, is a very scarce ingredient, and is found chiefly in the light-coloured veins of granite intersecting the granite mountains." There can be no doubt, I think, that this is an altered state of the euphotide already described: the author knew greenstone (diorite); he also knew granite, and trap; and there is no other "dark coloured rock," that I saw, in this part of Arabia, "allied" to greenstone, but "euphotide."*

"The eastern end [northern ?] of the island is that which attains the highest point of elevation, and is composed of a secondary limestone pretty regularly stratified towards the sea. It contains in its substance a few fossil shells, but is not remarkable for anything further than its proximity to the granite, its greater elevation above the sea, and its

* In my "Geological Observations on the Igneous Rocks of Maskat, &c.," (see this Jl. Vol. III. No. xiii. p. 128,) I have stated that Dr. Hulton had not mentioned either euphotide or diorite in his account of the Kuriyah Muriyah Islands, nor did I see any of these rocks at Marbat. But I had not then begun to put together this paper, and therefore had neither read Dr. Hulton's account, nor looked over my specimens from Marbat, with such attention as I have done since, which will account for any discrepancies that may appear in this and the paper alluded to regarding the rocks of these two localities.

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insulated situation. It is nowhere intersected by veins of either granite or greenstone."

I know nothing myself more of this island than that which I have stated previous to quoting Dr. Hulton's description, and have nothing to remark further respecting it than that I would direct attention to the depth of the limestone strata here, which we shall find useful by-and-bye in determining its real depth throughout the neighbouring coast.

The small rocky island of Gharzaut, which is a little N. N. E. of Hăllăniyah, and 200 feet high, is composed "exclusively of granite of a reddish colour, and a fine crystalline structure."

Soda, which is six miles west of Hăllăniyah, presents a peak 1310 feet above the level of the sea. The composition of the hills is granitic, with the same distribution of dark-coloured strata as that noticed on Hăllăniyah, though not quite so conspicuous. "The granite on the eastern end, and on the central part, is of a dark grey colour, with extensive veins of a light colour, traversing it in various directions. That on the western end is a mixture of red and grey granite, in varying proportions, the red preponderating in most localities, and of a fine texture, similar to that of Rodondo [Gharzaut]."

The geological structure of Jibliyah, the highest point of which is about 500 feet, is stated to be "essentially primitive, but with a greater variety in the appearance of the rocks than we found at Hăllăniyah. The outer detached rocks are of similar composition, being formed of a species of dark-coloured granite, in which hornblende appears to enter largely. The island itself is composed of porphyritic syenite, the colours of some specimens affording a rich and diversified appearance."

Haski, the most western of all these islands, and the nearest the shore, presents in its highest peaks an altitude of about 400 feet. "In its geological characters, too, it is nearly similar [to Jibliyah], though the reddish-coloured granite, which is common in Soda, is here found to constitute the greater portion of the island, the remainder being composed of a species of variegated granite and porphyry."

Thus we see that these islands are, with the exception of Hăllăniyah, all composed of igneous rocks, and that, too, chiefly of granite; and we also see that they are all nearly in the same parallel of latitude as the village of Hasek, which is only nine miles north of Ras Nus, the south-western extremity of Kuriyah Muriyah Bay, and which itself, as before stated, is also formed of a granite mountain. Further, if we look at Captain Haines's beautiful chart of Kuriyah Muriyah Bay, we shall not find a sounding of 50 fathoms north of this little chain of islands

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and a line extending from them to Hasek, that is between them and the main land to the north, while immediately south of them and this line the soundings sink to 145 fathoms, and no bottom, showing that there is a great depression on this side, which we also learn by the soundings to be continued westward to Ras Nus, and along the coast as far as Marbat, where the granitic tract ends.

Returning again to the shore, we find ourselves opposite a very different coast to that we have just passed: one now of 4000 feet instead of 800 feet above the level of the sea; and commencing from Ras Nus, where we left off, which is the seaward point of demarcation between the low and high land, we find the granitic tract on shore to commence here, (though at sea it begins much farther eastwards, as we have seen in the Kuriyah Muriyah islands,) and to extend on to Ras Marbat, a distance of forty miles, where it ends. At first it is narrow, and runs along the base of the broken-down table-land, but the latter, soon falling back, gives place to an expansion of it into a low field of igneous rocks, which is about ten miles wide, and terminates at the cape mentioned. This field, which is backed by the precipitous declivity of the table-land, presents an almost uninterrupted uniformity in its lowness, except at one point, near the sea, where an isolated pyramidal mountain of the main land remains, as a type of what once existed over the whole area. This mountain or pyramid, called Jibal Jinjări, which is 1300 feet high, is stated by Captain Haines to present chalk and gypsum in its composition; and so far it is interesting, because we know that these two substances exist in a fixed part of the upper strata of the white limestone series, from what we have seen at the island of Hammar el Nafur and Ras Kariat, where it is only 320 feet above the level of the sea, and from their presence in similar situations in other parts. By chalk here is meant a soft white earthy limestone, or gritty calcareous deposit; there is no genuine chalk on this coast that I have met with, though the former is a close approach to it, and, in the absence of the latter for comparison, might easily pass for chalk.

In the immediate vicinity of Ras Nus the limestone strata, capping the detached and broken-down masses of the table-land, (which in this way here reaches the sea,) are much and variously inclined, while a similar disturbance is evinced by the older igneous rocks of the low plain which follows, from the variety of coloured dykes with which they are veined. I explored about a dozen square miles of these rocks near Marbat, and also ascended the precipice of the table-land at this point, the particulars of which will now occupy our attention.

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The igneous rocks, as before stated, terminate at Ras Marbat in a low plain, which shelters a little bay and village of the same name on its inner side, that is between it and the main land. This plain is about four miles square, and 30 feet above the level of the sea in its centre, from which it gradually slopes on all its free sides to the sea. It is more or less wavy, and here and there interrupted in its continuity by irregular fissures running to the sea, and by projections a few feet above the surface of the granite rocks of which it is composed, while at the bottom of the bay is a group of granite hills, about 100 feet high.

The igneous rocks of this plain and its neighbourhood consist of red and grey granite, red protogine granite with black hornblende sparcely mixed with the chlorite, syenite, euphotide, and coarse and fine-grained diorites, green chlorite brecciated with fine compact brown limestone, and cemented together with calcareous matter; to these may be added gneiss, which appears in vertical strata in the midst of the groups of red and grey granite rocks projecting from the plain.

The red protogine granite appears to be the most abundant; and the grey granite the oldest in appearance, though the line of demarcation between the two is by no means evident, for they seem, so far as I saw, to pass into each other.

The granite hills on the inner side of the plain at the bottom of the bay have been thrown up through fine compact brown limestone strata, which forms a part of them, and from its effervescing so slowly with acids, and its heaviness, is probably more or less magnesian. It also, when minutely examined, presents laminæ of mica, which in some way or other have been transported into it.

I did not see the rich red granite, grey syenite, euphotide, diorites, nor chlorite breccia *in situ*, and therefore only infer their existence here from having picked up pieces of them in different parts of the plain; but there can be hardly any doubt of the fact, for I do not see how they could have come there otherwise.

With these few observations on the igneous tract, which is about ten miles broad, let us pass across to the base of the scarp of the table-land; and, fortunately for our examination of this, there is a dry bed of a great torrent, which empties itself into the Bay of Marbat on the inner side of the granite hills, and which, running along the base of the declivity for two or three miles, completely separates it from the igneous rocks, and exposes its strata unobscured by debris for several feet below the surface of the immediate neighbourhood.

The precipitous face of this table-land here is scarped for about two-

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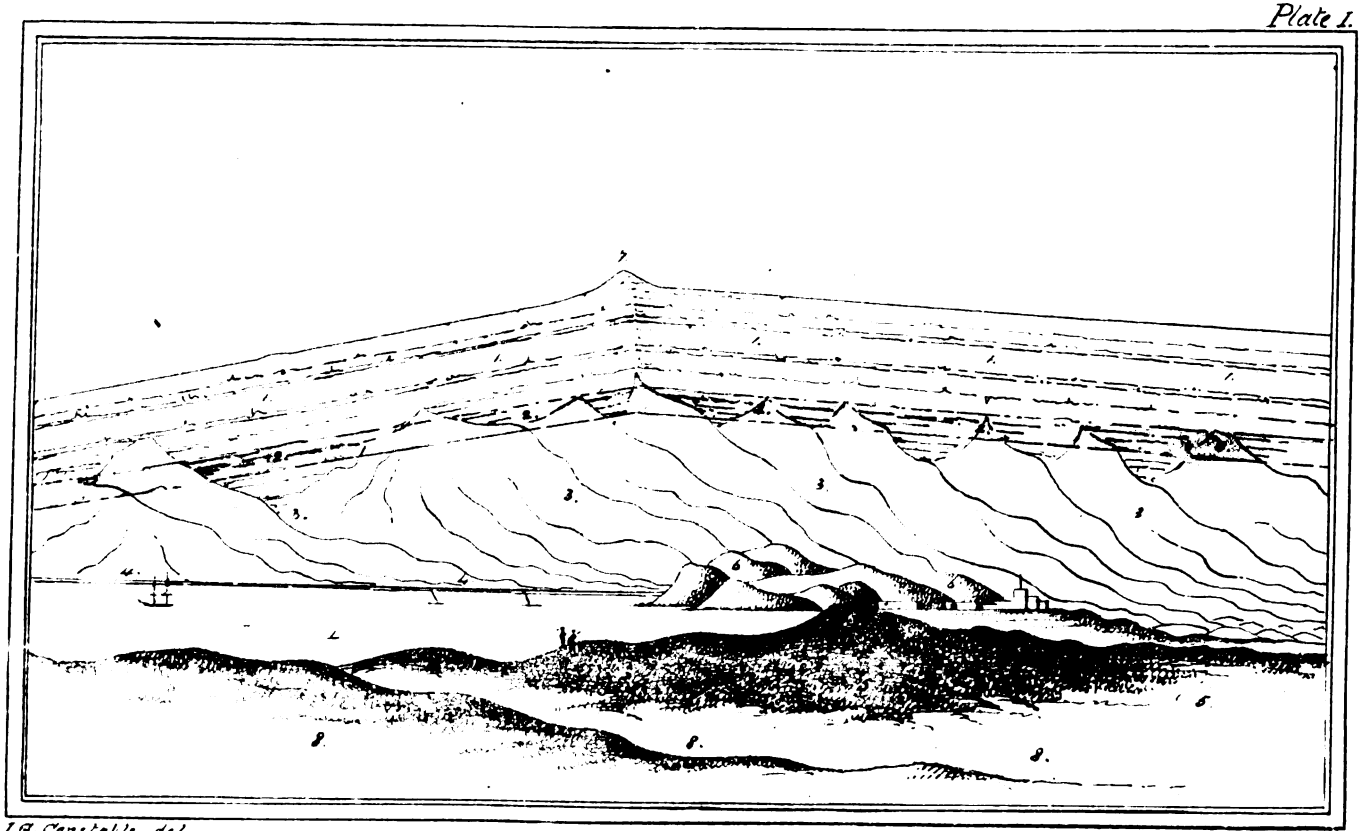
Plate I.



J.G. Constable del.

H.I.C. lith.

MARBAT.

7. Marbat Peak 3400 ft. 8. Granite Plain.

1. White Limestone Series.
2. Argillaceous Series.
3. Micaceous Sandstone.
4. Dark Brown Limestone.
5. Miliolite Deposit.
6. Granite Hills.

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fifths of the way down, and then slopes outwards in ridges, like great buttresses, which, parting from the base of the escarpment, in pointed extremities, expand out to a great extent as they reach the plain below. Commencing, then, from the base of these opposite Marbat, where the escarpment is 3400 feet high, and where the torrent bed before mentioned is 20 feet deep, we have from below upwards the following geological section, viz., coarse micaceous sandstone, of a yellowish brown color, becoming finer as we ascend, for 1700 feet; then passing into argillaceous strata of a red color, which continue for 300 feet; and lastly into white limestone strata, which form the rest of the series, an extent of 1400 feet.

These divisions I will now describe more in detail, and commencing from below, we find the sandstone of a compact gritty structure, becoming finer as we ascend; massive at first, but becoming thinly laminated, and in the upper part of all thicker again, and jointed; breaking with a rough earthy fracture throughout; of an ochrish brown color, and ferruginous aspect below, becoming more yellow in ascending, and then of a dirt-brown color at the top; presenting mica throughout, but more in some parts than in others, though diminishing generally in quantity towards the upper part.

The dirt-brown colored fine deposit of this sandstone passes into the argillaceous division, which presents strata of various colors, but chiefly red. One, a dark red clay stratum, and of a soapy nature, presented an excavation, which the Bedouins told us was made by their women, who came there occasionally to eat the clay; whether from hunger or a vitiated taste I could not discover, but probably the latter.

These red strata pass into white and grey compact limestone strata, more or less thick, more or less fine in structure, more or less lithographic in appearance, above which comes a whitish yellow chalky deposit, more or less argillaceous, from which the Bedouins cut their pipes, and then a white compact limestone again. The latter lies in heaps of bare rocks, weathered into rude architectural-looking piles, 300 or 400 feet high, and two or three miles inland from the summit of the table-land, as seen from below, so that this much must be added to the 3400 feet, which height was obtained by triangulation from a base measured on Marbat plain, where, from what I have stated, the real summit could of course not be seen. We had no means of obtaining the height of this scarp in any other way.

The soil on the summit of the table-land is of a brick-red color, and more or less argillaceous; it seems to come from the cavities and disintegration of the limestone, which, where it is bare, has been

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weathered into sharp undulating ridges, as it is on some parts of the coast, where the sea is washing it away without making any deposit.

The following are the fossils which were obtained from these limestone strata:—

FORAMINIFERA.

Alveolina, (D'Orbigny.)— *Species?* Ovo-spheroidal or melanoid; long diameter $\frac{6}{10}$ inch, short diameter $\frac{4}{10}$ inch. Sulcated longitudinally, in sigmoid lines, which extend from apex to apex, marking the divisions of the chambers, which present transverse parallel striæ, dividing them into compartments. *Loc.* Marbat, from the summit of the formation inland downwards to an unknown extent. *Obs.*—This fossil varies in size below the measurement given. It is a characteristic fossil, and occurs also in great abundance in lower Sindh, near Tatta, where it is well known by the name of "Tomra," and forms the sacred strings of beads worn round the neck by Hindu devotees, and others of that religion. It differs from *Fascicolites* (Parkinson) *elliptica*, Sow. (Grant's Geol. Cutch, pl. xxiv. fig. 17), which on the other hand abounds in the hills of Hydrabad, in being more spheroidal, and exceeds a little in size the largest of those I met with at Marbat.

Operculina, (D'Orbigny.)— *Species?* Discoidal, nautiloid, very thin. Width $\frac{5}{10}$ inch. Surface presenting four whorls, divided into many chambers, which are reflected, and increase regularly from the first to the last cell. *Loc.* White limestone, Marbat. *Obs.*—This little fossil frequently accompanies the foregoing.

Orbitolites.— *Species?* Circular, concave, extremely thin in the centre, abruptly expanding into a thickened rim at the circumference. Breadth 1 inch, thickness at the rim $\frac{1}{10}$ inch. Surfaces smooth, presenting a series of concentric rings, alternately raised and depressed. Internally composed of minute cells, arranged in concentric circles, which are multiplied vertically to four or five tiers deep, as they extend from the centre to the circumference. *Loc.* Marbat. *Obs.*—This fossil, which is not present in the specimens I possess from the summit of the white limestone strata, varies in size below the measurement given. It is a characteristic fossil, and the species and specimens increase in number as we approach the coloured division, where whole strata are composed of them, as we shall see hereafter. The Alveolina and Operculina above described are also found in company with this large Orbitolite. It belongs to d'Orbigny's genus Cyclolina, (Foram. Fos. du Bas. Tert. Vienne, p. 139, Tab. xxi. figs. 22—25,) and its structure has been beautifully figured by Carpenter, (Quart. Jl. Geol. Soc. Vol. VI. pl. vii. fig. 24.) It also occurs in great

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abundance in the Hala Mountains, near the Buran River, in Sindh, together with the spheroidal Alveolina called "Tomra" above mentioned, and an Operculina. All three appear to agree with the three as they are found together in Arabia as to size and outward appearance, but the internal structure of the first and last slightly differs. The cells appear larger in the Sindh Orbitolite, and the whorls more numerous in the Sindh Operculina.

Corbis ?— *Species ?* (Shell, imperfect.) Breadth $3\frac{9}{10}$ inches, length $3\frac{8}{10}$ inches. Cancellated; resembling *Corbis pectunculus*. (Lamarck et Tab. 13, fig. 3—6 Paris Basin Deshayes.) *Loc.* Marbat. *Obs.*— Found in a small block of fine white compact limestone, with individuals of the foregoing fossils.

Inoceramus ?— *Species ?* (Specimen imperfect.) Shell thin, suborbicular. Length $2\frac{1}{4}$ inches, breadth 2 inches. Inequilateral, striated concentrically, cardinal edge of upper valve straight. *Loc.* Marbat. *Obs.*—Found in the block of limestone just mentioned.

GASTEROPODA.

Pileolus.— *Species ?* (Specimen imperfect.) Shell thin, suborbicular, subspiral, involute, with an ill-defined apex. Length $2\frac{1}{4}$ inches, breadth $1\frac{3}{4}$ inch, and thickness $\frac{3}{4}$ inch. *Loc.* Marbat. *Obs.*—Found together with the foregoing fossils. Species of this genus are very common in Sindh, and almost all that I have seen, which, like the present, are chiefly reduced to their casts, have been more or less filled with *Fascicolites elliptica*, and the spheroidal Alveolina before mentioned. They range from one to four inches long, with a proportionate height, and the border of the columella is denticulated.

Carinaria ?— *Species ?* Conical, reflected. Length $\frac{1}{4}$ inch, breadth at the base $\frac{4}{10}$ inch, slightly compressed laterally, striated horizontally, with a ridge or raphe in front. *Loc.* Marbat. *Obs.*—Found with the foregoing fossils.

Trochus.— *Species ?* (Cast, imperfect.) Height about 4 inches, and breadth at the base 4 inches. Spire consisting of nine or ten whorls. *Loc.* Marbat. Found with the foregoing fossils.

Buccinum.— *Species ?* (Cast, imperfect.) Length $2\frac{3}{4}$ inches, breadth $1\frac{1}{2}$ inch. *Loc.* Marbat. *Obs.*—Found with the foregoing fossils, which were also accompanied by casts of olives, but too imperfect for description.

From the colored agillaceous strata I obtained nothing but a rock-specimen of limestone of a lead blue color, almost entirely composed of small orbitolites, but I did not preserve it, not knowing at the time from whence it came.

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Nor did I see anything in the micaceous sandstone worth noting, except a tesselated arrangement of a stratum in the lower part, over which the path passed, leading from Marbat to the base of the table-land. It is on the short plain here which extends outwards from the base of the latter to the border of the torrent bed, and is raised about 30 feet above the level of the sea. At first I thought this was the tiled surface of a floor belonging to some old building, but a few moments' reflection and observation convinced me that it was the cracked surface of the stratum, which must have been formed at the time of its deposit. The cracks had been an inch wide, and had been filled up with a dark ferruginous sand, which contrasted strongly in color with the white coarse-grained quartziferous sand of the stratum generally, and therefore of those parts which it surrounded. This ferruginous deposit or cement had cracked again in its centre, and so the whole of the divisions had become more or less loose and separable. They are of course of various sizes, and of all kinds of polygonal shapes, and about three inches thick: the ferruginous sand not only coats their sides, but their lower surfaces as well, and it is probably owing to the presence of the iron that this remarkable feature has been preserved. It shows us plainly that this part in particular of the sandstone must have been deposited at the level of the sea, where the tide now and then overflowed it (for no cracking could take place under the sea), and that too before the 4000 feet of strata now above it were deposited; and, as the uppermost stratum of the latter contains the remains of animals which must have been deposited in the sea, these cracks farther show that this portion of the sandstone must have gone down at least 4000 feet since they were formed, and have returned to a position higher than that even in which it was first deposited. I took particular care to ascertain the correctness of this by observations made on the spot, and brought away some of the loosened divisions for closer examination; and the total absence of calcareous material in them, connected with their containing particles of mica, and being of the same composition as the sandstone in which they are found, at once places beyond doubt the possibility of their being a subsequent formation. Neither can these divisions, or the sandstone in which they exist, be confounded with any other above it, because there is no other of the kind; and if it had been a portion of the same sandstone disintegrated and re-deposited, it must have contained more or less particles of carbonate of lime, from the detritus of the older rocks, and the sea in which it was re-deposited; for every formation which has taken place subsequently to, above or alongside this sandstone, does contain more or less calcareous material.

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I had not time to examine these sandstone strata much, or probably I might have met with some fossils in them.

Having, then, seen the igneous tract at Marbat, and traced the strata of the table-land to its summit, let us now return for a few moments to the granite plain, where we shall find a modern formation, well worthy of our attention, and which we shall have to trace on for some distance, and indentify with similar ones which we have passed, for it will be some way before we can again get a section of the table-land; and in the mean time we must occupy ourselves with the no less important deposits which lie along its base.

Capping the plain of Marbat, the highest part of which I have before stated is about 30 feet above the level of the sea, is a granular deposit, composed chiefly of particles of carbonate of lime, with which are mixed more or less grains of quartz and hornblende, from the igneous rocks on which it reposes. It is about a yard in thickness, and extends in all directions over the plain to within a mile of the sea. It contains a great number of organic remains, consisting chiefly of casts of small Conchacea. This indeed is the fossil character of the deposit. The houses at Marbat are built with it, and some of the headstones of the graves there are made from slabs of it, which will show that it is of considerable consistence. It fills the inland extremities and crevices of the fissures, which I have stated to extend through this plain to the sea, and there contains very large shells; and adherent to the side of the group of granite hills at the bottom of the bay is a large mass of it, the upper part of which is 30 feet above the level of the sea. Here it presents a vast quantity of corals, with gigantic shells of Hippopus, Ostrea, &c. All these shells have lost their animal matter, and are more or less friable and pulverulent. This formation in its more subtle material closely corresponds with the miliolitic deposit at Ras Abu Ashrin, and when we have proceeded a little onwards from the igneous rocks, we shall find its composition and appearance to be almost identical with it, while at Marbat it more resembles that part of the miliolitic deposit which we have seen resting on the dioritic rocks, near the village of Gyren, in the island of Masira.

Between this formation and the water's edge is a coarser deposit, which overlaps the former, and is composed of rounded gravel from the granite rocks, held together by a whiter matrix than that of the first deposit; and, still nearer the sea, a third, still more white, and apparently more recent, the upper surface of which is about 12 feet above the level of high-water mark.

The fossils obtained from this and the foregoing deposits were:—

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Lucina ?— (Cast.) Breadth 1 inch, height 1 inch. *Loc.* Marbat, in the miliolitic deposit lying on the granite plain. *Obs.*—There were many other bivalves present, smaller than this, but none so numerous.

Venus.— *V. puerpera vel corbis* (Lam.) mihi. (Specimen imperfect.) Breadth 3 inches, height 3 inches. Cancellated, the lines projecting a a little at their points of decussation. *Loc.* Marbat, in the deposit between the latter and the water's edge.

Ostrea.— *Species?* Inferior valve oval. Length 8 inches, breadth 5 inches. Deep, patulent; muscular impression sub-central, lateral; straight posteriorly, convex anteriorly. Impression of hinge concave rhomboidal, wavy, terminated by a straight border anteriorly, and by an ill-defined one posteriorly. Margin crenulated for a short distance on each side the hinge; afterwards simple, wavy. Upper valve thin anteriorly, thickened posteriorly, with a deep angular longitudinal groove in the centre. *Loc.* Marbat, from the miliolitic deposit at the end of a fissure in the granite plain.

I should also mention another formation here, which is seen on the inner side of the group of granite hills next the base of the table-land. It forms part of a deposit prior to the miliolitic on the granite plain, and is better seen a little further on, for here it only peeps above the sand close to the sea at the part I have mentioned. It consists of a coarse cellular limestone, in which are sparsely scattered rounded portions of hyaline quartz, and particles of other minerals from the igneous rocks, together with a few remnants of small fossilized shells. Its color, which is of a dark brown, like that of moist brown sugar, as well as its appearance, at once characterizes it among the other deposits, and not less so the extreme craggedness into which it wears by the action of the waves. It is sometimes saccharoid, and generally effervesces slowly with acids.

Having described this rock, let us now proceed along the coast; and, leaving the granite hills of Marbat, we cross the bed of the torrent mentioned to the base of the table-land, following which for four miles over a narrow plain between it and the beach, partly obscured by drift-sand, we at length arrive at an abrupt elevation of this plain to 100 feet above the level of the sea, and presenting a sea-cliff of the same height. This cliff is continued on, broken through here and there by a torrent bed, to the village of Takah, about twelve miles distant. Four miles west of Marbat I examined it, and afterwards a rock, called the island of Guena, which is of the same height, close to it, and the geological section of both, from above downwards, is as follows:—

First, five feet of a granular calcareous sandy deposit, like the

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miliolite mentioned, in which are imbedded rounded pebbles of the older limestone. Then a narrow stratum of compact, coarse, shelly, impure limestone, of a light whitish color, resting on a little thicker stratum of dark brown limestone, of the kind stated to exist behind the granite hills at Marbat, which, in its turn again, reposes on a compact white limestone, breaking with a conchoidal fracture, and an even surface. The brown limestone here is more saccharoid in its structure than at Marbat, and contains a little magnesia ; in its upper part is sparingly scattered small rounded quartz gravel, from the igneous rocks, and below it presents white spots, which are but large pebbles of compact limestone, from the older formation, now almost indistinguishably blended with it.

When we approach the end of this sea-cliff, which is at Takah, we might expect, as it appears to be all of the same height, to find the same strata again, but instead of this we find a complete absence of them, and in their place an entirely different limestone, which extends to the summit of the cliff. This limestone, which is more or less earthy, and of a white pinkish color, is richly charged with Orbitoides of the following description :—

Orbitoides.— 1st *Species ?* Flat, circular, compresed, more or less wavy. Breadth $\frac{6}{10}$ inch, thickness in the centre $\frac{1}{10}$ inch. Gradually sloping to a thin circumference. External surfaces tuberculated towards the middle ? Presenting a horizontal plane of rectangular chambers, passing through the centre, with laminiform cells on both sides. *Loc.* cliff at Takah.

——— 2nd *Species ?* Circular, doubly convex, terminating in a rim of unequal breadth. Convexities sub-central. Breadth $\frac{6}{10}$ inch, thickness $\frac{3}{10}$ inch. External surfaces tubercled over the convexities. Internally presenting a horizontal line of chambers, passing though the centre, from which white lines of laminiform cells radiate to the circumference. *Loc. idem.*

——— 3rd *Species ?* A little larger than the foregoing, but with the rim turned up, like that of a hat. *Loc. idem.*

——— 4th *Species ?* The same kind, but one side only presenting the hemispherical elevation. *Loc. idem.*

Operculina.— *Species ?* Sub-elliptical, very thin. Length $\frac{2}{10}$ inch, breadth $\frac{1}{10}$ inch. Consisting of two whorls. Chambers apparent externally, long, narrow, and much reflected, increasing in length suddenly after the first whorl. Externally presenting minute tubercles, disposed over the commencement of the whorls, and then following the lines of the chambers. *Loc.* cliff at Takah.

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Obs.—The second species is *Lycophris dispansus*, which abounds at Lukput, in Cutch. (Grant's Geol. Cutch. pl. xxiv. fig. 16. Geol. Trans. vol. vi. 4to.) What I have described as several species may be after all but varieties of one animal, for they appear to assume all kinds of shapes. They abound in Sindh, and one extraordinary form of them there resembles two convexo-concave disks, joined together by their convexities. The first species is not improbably a nummulite, as both *Lycophris dispansus* and large nummulites occur together in Cutch, and appear to pass into each other, while my description is chiefly taken from sections and half exposed specimens imbedded in the parent rock. Dr. Carpenter, who has given some beautiful sections of Orbitoides in the Quart. Jour. Geol. Soc. vol. vi. Plates 4—8, considers, page 36, these fossils to be allied "rather to the nummulites than to the orbitolites," and in his concluding paragraph states: "The Foraminiferous character of Orbitoides appears further to be indicated by the presence, in all the species I have examined by sections taken though the centre, of the large globular cavity (fig. 35, a), resembling that which is stated by M. D'Orbigny and Mr. Williamson to be the ordinary form of the first segment of the Foraminifera, whatever may be the form which the compound structure may subsequently present."

The character, however, on which I would place most reliance, in pronouncing these fossils to belong to Foraminifera, is the spiral arrangement of the central plane of cells, which I think not quite so satisfactorily shown not to be the case in fig. 31 of the sections to which I have referred, wherein Dr. Carpenter states, p. 32, the cells may be seen "arranged in regular concentric rows," as one could wish. No doubt it is very difficult to hit upon the centre of this plane in specimens where it is very thin, but until I can do this myself, or see that it has been done by others, I shall not be satisfied that Orbitoides are without this character, which the imperceptible gradations of nummulites into them would *à priori* lead one so strongly to suspect.

Whatever the structure of these fossils may be, or however numerous their varieties and species, their presence at Takah, not far from the centre of the South-east Coast of Arabia, is sufficient proof of the existence of the Nummulitic Series here; though I am ignorant of the exact position in the series which these fossils occupy. Hence we must regard the cliff at Takah, which has only an elevation of 90 feet above the level of the sea, as a part of this formation, and, moreover, we must regard it as a part of the compact white limestone, breaking with a conchoidal fracture, on which some miles back in this cliff we saw the dark brown limestone reposing. The end of the cliff at Takah, that is the part

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under consideration, has undergone much disturbance, and, though low, has fallen forward in great square blocks, which present a large quantity of corals in their composition, while the rents in the plain between the base of the table-land, here transformed into mountains, and the sea, a distance of about two miles, bear ample testimony of the distorting forces to which this locality has been subjected. It is opposite Takah, as before stated, that the bed of recent Operculina exists, in twenty-five fathoms water, with a fine sandy bottom, which are identical with that species which forms whole strata almost, in the Nummulitic Series at Măskat. Hundreds of them came up on the grease of the sounding-lead at each throw, and for several miles in extent, when this part of the coast was surveyed.

At Takah, as just mentioned, the sea-cliff ends, and the maritime plain between the base of the high land and the sea sinks from 100 to about 10 feet above the latter; it also expands westward from this point, for the mountains recede, and give place to a flat area, twenty-two miles long, and from ten to fifteen miles deep in the centre: this is called Dofar, and is the most fertile district on the coast. Over this plain is spread a continuation of the miliolitic deposit, which we have seen topping the plain at Marbat, and the low cliff just passed, but it is more uniform in its composition, and more free from dark particles of the igneous rocks; hence it closely resembles the miliolite at Ras Abu Ashrin. On it are the remains of several towns, one of which, called El Bălăd, I have described.* They were built of this freestone, and they contain a vast number of columns, ornamented in arabesque, which have nearly lost their figured surfaces where exposed to the weather. This deposit seems to average about 10 or 12 feet in depth. In many parts of it there are extensive cracks, or *khors* as they are locally called, some close to the beach, which are always full to the brim of fresh water; that, for instance, at El Bălăd, is more than two miles long, and in one part about 100 yards broad, and flows over the beach, though no stream can be seen running into it. It is the presence of these *khors*, and the looseness of the soil, which renders Dofar so fertile, in comparison with the rest of the coast.

Passing along the cord, or sea shore of this half-moon-shaped plain, we at length arrive at its opposite or western extremity, where the high land, as at Takah, comes out again to within nearly the same distance of the sea; we also find this end of the plain elevated again to about the same height as at Takah, and consequently a sea-cliff

* Journal Royal Geograph. Soc. Vol. VI. Trans. Bombay Geograph. Soc. Vol. VII.

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in front of it, which presents a similar geological section to that examined four miles west of Marbat; commencing from below upwards, it is as follows:—

At high-water-mark, or a little lower, is a white compact limestone, of a fine structure, and breaking with a conchoidal fracture, on which rests the dark brown limestone first seen beside the granite hills at Marbat, close to the sea; this is ten and a half feet thick here, and presents, in its upper part, a stratum, two and half feet thick, of large rounded pebbles; these pebbles are of compact white limestone, and are from the older formations. On them lies a bed of large oysters, one and a half feet thick, and with these the color of the limestone changes from dark brown to a greenish reddish dirty white; it also now becomes shelly, and presents radiated masses of columnar coral, with a great number of casts of smallish bivalve shells (Conchacea et Ostrea); further it is rendered more or less impure, and derives its reddish color from the presence of red argillaceous earth, disseminated here and there throughout the whole mass; this stratum, including the bed of oysters, is seven and a half feet thick. Next above it comes seven feet of still more impure limestone, composed chiefly of small rounded gravel from the older limestone, mixed with an increased quantity of red argillaceous earth, which gives the whole stratum a red color. And on it again comes twenty feet of white shelly limestone, similar to that first described. This forms the section of the cliff, and against the upper part of the dark brown limestone and lower white shelly limestone rests the miliolitic deposit of Dofar, six or eight feet above high-water-mark, filling many holes in the former, which have been made by lithodomous animals, and containing oysters of the same kind as those of a bed close by. Walking inland from the cliff, however, for about a mile, we come to fifty feet of limestone gravel, and pieces of flint, imbedded in red argillaceous earth, similar to that mentioned, and this is capped again by five feet of limestone pebbles and flints of a large kind, with less red earth. These deposits add to the thickness of the section, but will be found by-and-bye to depend probably on local causes.

Hence we see that here, about the centre of the South-east Coast of Arabia, we not only have the miliolite, but we have, in addition, another littoral deposit, viz. the compact brown limestone, with the whiter shelly limestone above it, making in all about fifty feet in thickness of a deposit totally different from, and lying inferior to the miliolite; and that it rests on a compact limestone, belonging to the older formation, must be inferred from the presence of the nummulites? and orbitoides in the cliff at Takah, on which a few miles back the brown lime-

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stone is seen to repose, but this will become more evident as we proceed.

I have stated that the mountains advance towards the coast here, but the coast-line also turns here from running east and west, to south, and then south-east, a little way before it resumes its original direction; that is it is reflected to form a little bay here, called the Bay of Resut; and hence the maritime lowland, which is narrowed at this end of Dofar, is widened again, not in this instance by the mountains receding from the shore, but by an advancement of the lowland upon the sea, and with this advancement the lowland also is bordered externally by a ridge, which in one part is 700 feet high, and scarped upon the sea throughout. Thus, then, we have a valley between the sea-cliff of this ridge and the mountains; a small promontory formed by the end of the ridge, called Ras Resut, and inside it the bay mentioned of the same name. Now into this bay we have the opening of a torrent bed a mile wide, coming not only from the valley itself, but from among the mountains, and the section of the cliff just given is taken from the inner corner of the opening of this torrent bed upon the sea. This, then, accounts for the additional strata of red earth, flints, and pebbles, before mentioned, and which we did not see in the section taken four miles west of Marbat, where the cliff is within two miles of the base of the mountains, and on a straight part of the coast, far removed from the influence of any great torrent deposit. We therefore must not include in this littoral deposit this 50 feet of red earth, pebbles, &c., because it is evidently a local accumulation.

Passing across the sandy beach which lies in front, and in the dry weather closes the mouth of this torrent bed, we arrive at its opposite or external corner, which is close to the base of the ridge mentioned, and that of the small promontory which shelters the bay. This corner, like the other, presents a low cliff, consisting of little more than the dark brown limestone we saw on the other side, and which, running along the base of the promontory parallel to the sea, and scarped upon it for about eight feet, is washed by the waves into that extreme cragginess so characteristic of the stratum in other parts. This deposit rises no higher, while the height of the promontory is two or three hundred feet above the sea at its base, and two hundred at its extremity. Here, then, we have compact white limestone rising up to form the ridge of the promontory, while we have the dark brown limestone remaining in a horizontal line at its base. Nothing, therefore, can be more plain than that this white compact limestone, which we have seen all along underlying the dark brown limestone, is a part of another series, and the presence of

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the nummulites ? and orbitoides at Takah, as before stated, shows that this is the Nummulitic Series.

Hence there are here, nearly in the centre of the South-east Coast of Arabia, two distinct littoral formations, later than the white limestone strata forming the tops of the mountains; and as this part of the coast, in which they are so evidently seen, is also circumscribed by natural limits, I will briefly recapitulate what I have stated respecting it, before proceding further.

We have just seen that there are two bays here, which look towards each other, the one called Marbat, the other Resut; and they are separated by forty miles of coast, running E. and W., which is straight, and backed by the table-land the whole way. At Marbat we have seen a plain of igneous rocks, and the precipitous face of the table-land, which lies behind them; and in the bottom of the bay we have seen a dark brown compact limestone formation peeping above the sand close to the sea on the inner side of the granite hills, at the base of the table-land; a miliolitic deposit capping the granitic plain, and a still more modern deposit towards its circumference. We have also seen, four miles west of Marbat, the cliff of the maritime plain there, narrow, raised 100 feet above the sea, and presenting a dark brown, rough limestone, resting on a compact white one breaking with a conchoidal fracture; above the brown limestone, a stratum of a lighter color, but still compact, and then five feet of the miliolite, with rolled limestone pebbles of the older formation. Following this cliff for a certain distance, we have found the compact white limestone at the base rising to 90 feet high at Takah, and denuded of the other strata, but giving us decided evidence of its nummulitic character, by the presence of nummulites ? and orbitoides. Then we have the miliolitic deposit spreading out over the district of Dofar; and at Resut the dark brown limestone again forming part of the sea-cliff, and resting, as before, on the compact white limestone, which, in the outer half of the bay, rises from below it to form the upper part of the promontory of Resut. Above the dark brown limestone here also we have an impure white compact limestone, as in the cliffs between Marbat and Takah; and adhering to the side of the cliff, which is partly formed by these two in the Bay of Resut, a portion of the miliolitic deposit. Thus we have the same kind of littoral deposits throughout the straight part of this portion of the coast, and the same at the bays of Resut and Marbat, but with this difference, that the fundamental rock of the former is limestone, and that of the latter granite. There is an entire absence of igneous rocks at Resut, whereas at Marbat there are hardly anything else.

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From Ras Resut, which at its extremity is about 200 feet high, a sea-cliff is continued on for twenty-three miles, to the base of the great promontory called Ras Sejăr, which is formed by the advancement of the mountainous tract upon the sea. This cliff I had not an opportunity of examining much, as it is perpendicular, and rises directly out of the water. What I did observe, however, is interesting.

I have just stated that there is an entire absence of igneous rocks at Resut, but, though this is the case, they are not far distant, one would think, for not only the limestone of the cape is shivered into atoms, and rendered pink by heat, but six miles further on the base of the cliff is similarly fractured where it is 700 feet high. This point is called Ras Hammar, and is the maximum altitude of the cliff. Ras Hammar is composed of compact white limestone above, and of the comminutely fractured limestone mentioned below, but I am ignorant of what lies between, further than that the whole is white calcareous strata, and that among these there are some of a marly cretaceous nature, from which the Bedouins cut their pipes, similar to that at Marbat. The brecciated limestone, for such it is, from the crevices having been filled up by a cement, and that too of the same material, is of a dense compact fine structure, lithographic, but breaking with a splintery fracture, heavy and hard, and of a light grey color. By a rough analysis, it contains from 12 to 15 per cent. of magnesia. Its specific gravity is 3.3. It scarcely effervesces with acids until pulverized, and its great weight and hardness appear to be owing to the presence of silex.

In this limestone is a cavern, similar to those which abound in the mountains, and one of which I visited near Takah. Its base is just above high-water-mark, and its roof is about 30 feet high, and hung with stalactites, not of magnesian limestone, but of sulphate of lime. From the face of the cliff presenting innumerable excavations of lithodomous animals, on a parallel with the upper part of the roof, and the brecciated state of the limestone, it is probable that this cavern commenced with the latter, and was subsequently washed out by the waves, while the cliff was rising from the sea. That which I visited, near Takah, is in the mountains, and I have given a description of it in this Journal.* It was inhabited, and is about 150 feet span and 50 feet high, (not yards, as stated from oversight in the description to which I have referred,) and 30 yards deep. Its roof is also smoothed, and hung with thick stalactites : another cavern, of equal dimensions, close by, had fallen in. We saw some from the vessel in the elevated scarps of the mountains in different localities, which, judging from the size

* Vol. III. No. xiv. p. 253.

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they appeared at the distance we were from them, must be of enormous dimensions. They form the principal habitations of the Bedouins of these parts, and descend from father to son as hereditary property.

From Ras Hammar we pass along the remaining part of this cliff to the base of Ras Sejăr, which it joins after a distance of twenty-five miles from Ras Resut ; diminishing gradually in height after Ras Hammar, until it arrives at this point. Ras Sejăr is the largest and highest promontory on this coast : it is an advancement upon the sea of the great mountainous tract which from this point south-westwards, for a distance of sixty miles, presents no maritime plain whatever, but descends directly to the sea in long slopes or in precipitous steps. The ridge of the promontory has been computed by trigonometrical measurement to be 3380 feet above the level of the sea, and the bluff at its extremity 2770 feet. The eastern side is scarped perpendicularly for 800 feet, and the strata, which are composed of white and grey limestone, are disposed horizontally. At one part of the talus of this cliff is a little island, on which exists the dark brown limestone and miliolitic deposits seen in Dofar, but the latter is much finer in structure. After this I did not recognise the brown limestone, though doubtlessly it or its representative exists here and there throughout this coast.

The south-eastern side of Ras Sejăr, which is parallel with the coast, and its south-western extremity, the highest point of the cape, present an almost vertical scarp, in which the strata are seen to dip towards the north-east ; while on the south-western side, the same horizontality is seen which we observed on the eastern side, but with a scarp rising by high precipices and narrow shelves to the ridge of the promontory, which I have before stated to be 3380 feet above the level of the sea. At the point where the coast line turns from running N. E. and S. W. to about N. W., for a short distance, is the great bluff of Ras Sejăr, and the following is its geological section, from below upwards :—

The first 25 feet above the sea is composed of a fine-grained micaceous sandstone or quartzite, of a blueish grey color, thinly stratified, and breaking with a rough fracture across the planes of stratification. It is weathered into holes indicative of the presence of organic remains, and in some parts is veined with white quartz. There is hardly any difference, except in color, between it and the upper part of the micaceous sandstone at Marbat. On this rests 175 feet of variegated argillaceous strata, principally of a red color, containing many fossils,

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and above all again the white limestone strata, which, deducting the thickness of the sandstone and colored deposit from the total height of the bluff, amounts to 2570 feet.

Having on the base of this section measured with my eye, as carefully as I could, the height of the lower projection of the bluff above the sea, for I had no means of obtaining it in any other way, I find, when I come to multiply this on the outlines of the bluff, which I made at different distances, that the latter does not amount to more than 1950 feet above the sea, which is 820 feet less than it was computed to be by trigonometrical measurement: possibly, and not improbably, from the place where the base was measured, the angle was taken from a point much higher than the summit of the real bluff. The height of the limestone bluff at the island of Hăllăniyah being 1645 feet, and the estimated thickness of the limestone at Marbat about 1800 feet, together with the trigonometrical measurement of the scarp of the next promontory we shall come to, which is limestone from the water's edge to its summit, being 1900 feet, seems also to indicate, from the thickness of the limestone at these places, that my measurement of the bluff at Ras Sejăr is more correct than that obtained by triangulation, but probably from the reason above mentioned.

I collected no fossils from Ras Sejăr, beyond some small imperfect specimens of the genus Turritella? from the colored strata.

It is to the blue grey sandstone of this promontory that the late Capt. Newbold alluded when hinting at the origin of the quartzite pebbles in the conglomerate underlying the nummulitic strata at Măskat, and resting on the euphotide and diorite of that locality.* A little further in from the extremity of Ras Sejăr on the south-west side, where the precipitous part of the promontory is much higher than at the cape, this sandstone is also raised to 300 feet above the level of the sea; and my impression is that here, as well as at Marbat, its strata are not parallel with those immediately overlying them, but dip towards the north; still I am far from being certain that this is the case.

As on the other parts of the coast, so on the lower part of Ras Sejăr, there is a thick line of the miliolitic deposit, adhering to the side of the cliff, 150 to 200 feet above the level of the sea. On the south-western side of the promontory I think I also saw it again, reaching down to the water, for there are dwellings excavated there in a yellowish white deposit, which can only be this or micaceous sandstone, and it is not likely to be the latter, from its hardness and dark color. At all events, it exists again at Rakot, a little village at the mouth of a

* This Journal, Vol. III. Part ii. p. 27.

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ravine-like valley, seven miles to the westward of Ras Sejăr. Here it is of considerable height and thickness, and of a finer structure than any on the coast. While I was knocking off some specimens, the Bedouins who were with me asked me if I wanted any *khat*, which means "white writing chalk," because, if I did, it was to be found in the upper part of Ras Sejăr. From this it would appear that the chalky stratum we have met with here and there from the island of Hammar el Nafur onwards also exists on the top of this cape.

Between the last named village and a town called Damkot, some miles further on, are more dwellings, close to the sea, at the bottom of the slope of the high land. These also appear to be cut out of the miliolitic deposit : the place is called Jādăb. The high land also presents a more extended tabular outline here than hitherto met with, and continues to do so on to the neighbourhood of Damkot, forty-five miles from Ras Sejăr, where it becomes broken, and thrown up into mountainous peaks again, the summits of which are about 3000 feet above the sea. This form of the coast continues on for some distance, viz. to the opening of a valley called Shagot, where the coast-line turns to the south, and the scarped mountainous ridge, here precepitous upon the sea, pursues its original course south-west, under the name of the Fattak range. A lowland shore, therefore, commences at this point, which, as the coast trends southward, is continued on till it meets the lower hills of a mountainous ridge called the Fartak range, a distance of forty miles. Between these two points, viz. the Fattak and the Fartak ranges, it extends inland or south-westward as far as the eye can reach, and is the only part of this coast where the mountain ridges which face the south-east appear to be separated by any great interval. The sea-cliff of this lowland varies with the height of the lowland itself, but seldom reaches 100 feet. I had an opportunity of examining it about its centre, where its cliff is 60 feet high, and the following is the section from above downwards :—

First six feet of a coarse sub-cellular limestone, breaking with a rough fracture, and of a light brown color, resembling in structure the dark brown limestone of Resut. This becomes mottled with red about its lower part, and passes into a red argillaceous chalky deposit, which at the water's edge becomes of a greenish white color, uniform in its dark appearance and structure, and of a moderate hardness. Here also, 15 feet above high-water-mark, is a line of the miliolitic deposit, adhering to the side of the cliff, and composed of the calcareous sandy material before noticed, in which are imbedded a number of shells.

There is a pebbly beach at this place, composed of rounded pieces

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of more or less compact limestone, and concretionary flints ; also here and there a large piece of extremely fine limestone, of a lithographic structure, from one to three feet in diameter, probably the altered remains of fossillized madrepore. I saw no pebbles or traces of igneous rocks here ; indeed this part of the coast seems to have undergone less disturbance than any other, although the line of miliolitic deposit shows that, like the rest, it is experiencing gradual elevation.

The cliff of which this is a section is more or less continuous from this point on to the lower hills of the Fartak range, which commences in an angle close to the sea. One side of it runs inland and south-westwards, which is the grand direction of the range, and the other southwards, to end in the cape called Ras Fartak. This angle is about fourteen miles from the cape. Here the strata of the lowland cliff also become elevated, broken up, and confused, and this confusion extends to within six miles of the cape, where the irregularity ceases, and the uppermost stratum of the white limestone series can be seen emerging from the water, and pursuing its course to the top of the escarpment, which is 1900 feet above the level of the sea, after which it assumes a horizontal direction, and continues on to the summit of the cape : in this way stratum after stratum of this cliff may be seen rising from beneath the water, until the lowest runs almost parallel with it ; so that no better place could be visited than this for examining deliberately and without interruption the strata of which this great limestone formation is composed. I had only an opportunity of visiting one part of it, and this was where the strata had become horizontal, and where a portion of the face of the cliff, having fallen off, enabled me to obtain from the talus thus formed a knowledge of a good extent of the lower part of it. It consists of more or less compact, more or less cavernous, and more or less saccharoid white limestone, which again is more or less mottled, or rather veined with dark brown saccharoid magnesian limestone. I saw no traces of fossils in it, except a few minute species of Foraminifera, of the genus Alveolina (d'Orbigny). In one part the rock is entirely saccharoid, sparkling, uniform in structure, and of a grey color, in fact dolomitic, and on a rough analysis yields 16.4 per cent. of magnesia, with a specific gravity of 3.07. It is an interesting fact, bearing, perhaps, upon the formation of dolomite, that the dark veined portions here are of magnesian limestone, effervescing feebly with acids, while the whiter portions bubble up as usual when touched with them.

As we approach this extremity of the Fartak range, which forms the cape called Ras Fartak, and which is also the south-western limit of

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the great bay of El Kammar, a reddish tint makes its appearance at the base of the cliff, close to the water, and on turning the corner we observe, by the truncated end of the cape, that this is the commencement of the argillaceous strata, which, rising towards the west at an angle of 45°, reach an altitude of from 1000 to 1200 feet on the opposite side of the cape. The base of the cape, I should state, is much in advance of the upper portion, and this advanced part consists of the series mentioned, to the geological section of which let us now turn our attention, having considered that of the white limestone strata which lie above and behind it, on the eastern side of the cape. Commencing from the summit of this advanced portion, and proceeding downwards, (though this section was obtained by following the base of the cape from east to west, and noting the strata as they emerge successively from the sea,) we have at first 300 feet of fine compact limestone, of a light violet color, breaking with a smooth conchoidal fracture, and containing small Orbitolites, and other fossils. Then a wide stratum (say 50 feet thick) of a red argillaceous limestone, presenting the same kind of fossils, but more numerous, with Echinodermata. Next follows 20 feet of greenish yellow argillo-calcareous strata, splitting into thin laminæ, on which are seen the remains of a few minute bivalve shells, and marks similar to those made on mud by small crabs and annelides. After this comes 10 feet of a red, ferruginous-looking, argillaceous limestone, and, following it, a stratum of a blueish grey argillo-calcareous siliceous shale, exhibiting, where exposed to the atmosphere, a jointed structure, and thick laminæ. This is succeeded by 30 feet of blue marl, compact above, and soft below, in which are remains of Echinodermata, Ostracea of the genus Exogyra, and pyrites. Next comes 300 feet of impure limestone, compact, and of a pinkish grey color, the lowest hundred feet of which (the only part I examined) is almost wholly composed of small Orbitolites, with the remains of a few small Echinodermata. This is the last stratum towards the west which emerges from the sea : it is opposite the little village of Khaisêt. After this, the remaining part of the extremity of the cape is confronted by a narrow sandy beach, from beneath and behind which the colored strata continue to rise in the same manner as from the sea, to the extent of 500 feet in thickness : this 500 feet is composed of impure limestone, compact, and of a dark red color, and ferruginous aspect ; fossiliferous, and abounding in large cavities and fissures, which appear to have been caused by some subterranean force, for the rock has been shattered throughout, and cemented together again by its own material. Among the more thinly stratified deposits of the upper part

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of these colored strata are bands of brighter colors, which have not been mentioned: these consist of much the same kind of material as that with which they are in contact, or form a part, and give to the whole a variegated appearance when near, but, when viewed at a distance, are lost in the prevailing red color of this series.

The following are the fossils which I gathered from these strata here and at Ras Sharwên, the next large cape, which is sixty miles further west, but a part of the same formation:—

ZOOPHYTA.

Astrea.— *A. textilis.* Goldf. (Tab. 23, fig 3.) mihi. Hemispheric, covered with conical projections, which are more prominent in the upper part than towards the base; and marked with striæ, which radiate from their summits. Horizontal diameter $\frac{6}{17}$ inch. *Loc.* Ras Fartak, from the pinkish grey limestone.

Orbitolites.— 1st *Species?* Conical, obtuse, excavated. Breadth $\frac{2}{17}$ inch, height $\frac{1}{17}$ inch. External surface presenting striæ in concentric rings; internal surface presenting striæ radiating from the centre to the circumference. Structure solid, composed of minute cells. *Loc.* Ras Fartak, chiefly in the pinkish grey limestone.

———— 2nd *Species?* Conical, acute, deeply excavated. Breadth $\frac{1}{8}$ inch, height $\frac{1}{10}$ inch. External surface presenting striæ in concentric rings. Structure solid, composed of minute cells. *Loc. idem.*

———— 3rd *Species?* Flat, circular, wavy, thick; diminishing in thickness towards the circumference. Breadth $\frac{2}{17}$ inch, thickness $\frac{1}{17}$ inch. *Loc. idem.*

———— 4th *Species?* Discoidal, flat, and extremely thin. Breadth $\frac{6}{17}$ inch. External surface presenting striæ in concentric rings. *Loc.* Upper red stratum, Ras Fartak.

ECHINODERMATA.

Spatangus.— 1st *Species?* (Spec. imperfect.) Oval. Length nearly $1\frac{1}{2}$ inch, breadth anteriorly $1\frac{1}{2}$ inch. Truncated posteriorly, slightly grooved anteriorly, ridged posteriorly. Ambulacra five, sub-petaloid, all the same length, in deep furrows. Vent sub-dorsal. Base impecfect. *Loc.* Ras Sharwên.

———— 2nd *Species?* Thick, round, heart-shaped. Length $1\frac{3}{4}$ inch, breadth anteriorly $1\frac{6}{17}$ inch, and height 1 inch. Grooved antero-dorsally. Ambulacra five, two anterior shortest. Buccal orifice sub-terminal, simple. Base not carinated. Vent sub-dorsal. Genital pores four. *Loc. idem. Obs.*—There is another specimen similar to this, and from the same locality, $1\frac{1}{2}$ inch long.

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Spatangus.— 3rd *Species?* Thick, round, heart-shaped, like the foregoing, but much smaller. Length $\frac{1}{10}$ inch, breadth anteriorly $\frac{9}{10}$ inch, and height $\frac{6}{10}$ inch. *Loc. idem.*

Discoidea, (Gr.)— 1st *Species?* Sub-pentagonal, excavated. Breadth 2 inches, height 1 inch. Ambulacra extending to the buccal orifice, which is median. Vent sub-marginal, pear-shaped, convex posteriorly. Genital pores five. *Loc.* Ras Sharwên.

——— 2nd *Species?* Conical, circular, elongated towards the apex, which is acute. Breadth $1\frac{7}{10}$ inch, height $\frac{3}{10}$ inch. Ambulacra, buccal orifice, vent, and genital pores the same as in the foregoing. *Loc. idem.*

——— 3rd *Species?* Sub-pentagonal, conical. Breadth $1\frac{1}{2}$ inch, height $\frac{8}{10}$ inch. Buccal orifice, vent, &c. the same as in the foregoing species. *Loc. idem.*

——— 4th *Species?* Sub-pentagonal, convex. Breadth $1\frac{4}{10}$ inch, height $\frac{5}{10}$ inch. Buccal orifice, vent, &c. the same as in the foregoing species. *Loc. idem.*

——— 5th *Species?* Conical. Breadth $1\frac{1}{2}$ inch, height $\frac{8}{10}$ inch. Vent sub-marginal, longitudinal, pointed at each extremity. Buccal orifice, pores, &c. as in the foregoing species. *Loc. idem.*

——— 6th *Species?* Circular, convex. Breadth $1\frac{4}{10}$ inch, height $\frac{5}{10}$ inch. Buccal orifice, vent, genital pores, &c. the same as in the last. *Loc. idem.*

——— 7th *Species?* Circular, depressed. Breadth $1\frac{4}{10}$ inch, height $\frac{5}{10}$ inch. Buccal orifice, vent, genital pores &c. the same as in the two last species. *Loc. idem.*

Pygaster, (Ag.)— *Species?* (Specimen imperfect.) Small, circular, thick, convex. Breadth $\frac{7}{10}$ inch, height $\frac{3}{4}$ inch. Slightly excavated. Ambulacra five, narrow, extending to the buccal orifice, each presenting a double row of small tubercles. Inter-ambulacral spaces furnished with a double row of large tubercles, each tubercle sunk within an elevated ring, and the latter bordered on both sides by a small circle of tubercles. Buccal orifice median. Vent pear-shaped, margino-dorsal, longitudinal, round posteriorly. Genital pores five. *Loc.* Ras Fartak.

Echinus.— 1st *Species?* Circular, depressed, slightly excavated. Breadth $1\frac{4}{10}$ inch, height $\frac{5}{10}$ inch. Tubercles small throughout. Ambulacra narrow, and extending to the buccal orifice, which is median; their extremities widely separated at the vent, which is medio-dorsal. *Loc. idem.*

——— 2nd *Species?* (Spec. imperfect.) Hemispheric, circular. Breadth $1\frac{1}{10}$ inch, height $\frac{1}{10}$ inch. Tubercles small throughout. Am-

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bulacra five, rather broad, bordered by four lines, or two double series of pores, extending to the buccal orifice, which is median; their extremities widely separated at the vent, which is medio-dorsal. *Loc. idem.*

Diadema, (Gr.)— 1st *Species?* Circular, depressed, slightly excavated. Breadth 1½ inch, height ½ inch. Tubercles small, perforated. Ambulacra bordered on each side by four lines of pores, extending to the buccal orifice, which is large and median; their extremities widely separated at the vent, which is medio-dorsal. Vent broken. *Loc. idem.*

——— 2nd *Species?* Circular, depressed, slightly excavated. Breadth 1¼ inch, height $\frac{8}{17}$ inch. Tubercles large, perforated, almost all of the same size, sub-equidistant, and in vertical lines. Ambulacra bordered by two lines of pores, sinuous, extending to the buccal orifice, which is large and median, and widely separated at the vent, which is medio-dorsal. Vent broken. *Loc. idem.*

Salenia, (Gr. et Ag.)— 1st *Species?* Circular, thick, convex. Breadth 1 $\frac{1}{17}$ inch, height $\frac{8}{17}$ inch. Two vertical lines of large tubercles in each inter-ambulacral space, four tubercles in each line, imperforate. *Loc. idem.* Found in the pinkish grey limestone.

——— 2nd *Species?* Circular, thick, convex. Breadth 1 $\frac{2}{17}$ inch, height ½ inch. Two vertical lines of large tubercles in each ambulacral space, four tubercles in each line. *Loc. idem. Obs.*—The only difference which I can distinguish between these two specimens, excepting in size, is, that the plate resting on the dorsal extremity of the ambulacral space is concave in the centre in the latter species, and pointed in the former one. For a further description of Salenia, see Mongraphies d'Echinodermes, par Louis Agassiz, 1838; and for the genital plates of these two species see Tab. 1, figs. 1 and 22, respectively. The specimens above noticed are much worn and imperfect.

——— 3rd *Species?* Smaller than the foregoing, circular, compressed. Breadth $\frac{8}{17}$ inch, height $\frac{6}{17}$ inch. Three large tubercles in each line. Resembles the last specimen described in the form of its genital plates. *Loc. idem.*

CONCHIFERA.

Tubicola.— *Species?* Tube cordiform, or subcircular, simple; smooth internally, crenulated externally; dilating gradually from a small orifice to $\frac{6}{17}$ inch in diameter, and then expanding suddenly. Wall composed of successive additions, imbricated; internally presenting minute parallel longitudinal lines, running throughout. *Loc.* Ras Fartak, in the dark red ferruginous limestone. *Obs.*—A transverse section of the dilated part

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gives a deep crenulated margin, presenting angular costæ and circular intervals, within which are several layers of the same form, (10—12), and white lines rading from the internal margin, which is even, to the circumference. These are the lines which appear longitudinally on the inner side of the tube. Tubes 3 to 4 inches long.

Isocardium.— 1st *Species?* (Cast.) Breadth $2\frac{5}{7}$ inches, height $2\frac{1}{2}$ inches, and depth $2\frac{5}{7}$ inches. Umbos $\frac{5}{7}$ inch apart. *Loc.* Ras Sharwên.

———— 2nd *Species?* (Cast.) Breadth $1\frac{1}{2}$ inch, depth $1\frac{1}{4}$ inch, height a little greater than the breadth. Presenting thin striæ on the surface. *Loc. idem.*

———— 3rd *Species?* (Cast.) Breadth $1\frac{2}{7}$ inch, depth 1 inch. Smooth. *Loc. idem.*

———— 4th *Species?* (Cast.) Breadth $\frac{2}{7}$ inch, height $\frac{2}{7}$ inch. *Loc. idem.*

Cardium.— *Species?* (Cast.) Breadth $\frac{2}{7}$ inch, height $\frac{2}{7}$ inch. Costæ few, and wide apart. *Loc. idem.*

Pecten quinquicostata, Sow.— mihi. (Inferior valve?) Breadth $\frac{6}{7}$ inch, height $\frac{3}{7}$ inch, depth $\frac{2}{7}$ inch. Margin hexangular; costæ prominent, formed by three narrow ridges, and the intervals by three broader ones. *Loc. idem.*

———— 2nd *Species?* (Inferior valve). Breadth $\frac{3}{7}$ inch, height $\frac{5}{7}$ inch, and depth $\frac{3}{7}$ inch. Margin hexangular; penticostate, a single wide ridge forming the prominent ribs, and two smaller ones occupying the intervals. *Loc. idem.*

———— 3rd *Species?* (Inferior valve.) Shell deep. Breadth 1 inch, and height $1\frac{3}{4}$ inch. Margin sub-hexangular, sub-quinquicostate, costæ narrow, regular. *Loc. idem.*

Ostrea.— *Species?* (Lower valve, imperfect.) Ovato-acuminated. Plicated, plaits radiating from an indistinct sharp umbo; striated concentrically, striæ lamellose, and imbricated towards the border, the latter crenulated. Length $3\frac{1}{2}$ inches, breadth $1\frac{1}{2}$ inch. *Loc. idem.*

Exogyra.— *E. flabellata*, Goldf. (Tab. 87, Fig. 6.) mihi. *Loc.* Fartak. *Obs.*—These abound in the blue marly stratum, and are of various sizes. The largest found is $2\frac{3}{4}$ inches long, and $2\frac{1}{4}$ broad, and the smallest 1 inch long, and of proportionate breadth.

GASTEROPODA.

Solarium.— *Species?* Breadth $\frac{1}{7}$ inch. *Loc.* Ras Fartak, in the deep red ferruginous limestone.

Turritella.— 1st *Species?* Slender. Length $1\frac{1}{4}$ inch. Whorls 12,

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10—11 costæ in each whorl. *Loc.* Ras Fartak, red ferruginous limestone.

Turritella.— 2nd *Species* ? Slender. Length $1\frac{1}{4}$ inch. Whorls 18—20, three costæ in each whorl. *Loc. idem.*

Ammonites.— *Species ?* A small portion of the whorl, $\frac{1}{4}$ inch wide ; just enough to show that the suture is sinuous. *Loc.* Ras Sharwên.

Thus we see that the advanced or lower half of Ras Fartak is composed of marls, clays, sandy shales, and impure limestone strata, containing the above fossils, and of a variety of colors, but principally red, terminating above in violet-colored and almost white limestone. We have also seen, when facing this cape, that the strata of the range, of which it is the extremity, dip from west to east, and that the uppermost of the red or colored series, which is not more than 200 feet above the level of the sea on the east, is 1000—1200 feet above it on the west side of the cape. Passing on to the white limestone behind and above these strata, we find the latter denuded for some distance in from their upper edge, both on their southern and western sides, and not continuous with the white strata, as at Ras Sejăr, and at Marbat. This denudation of the upper part of the colored strata, and position of the white limestone series, I could not understand, until, from my sketches of the cape on different sides, I perceived that the strata, both white and red, of the range, dipped not only towards the east, but towards the north. We have already seen them at the extremity of the cape dipping from west to east. Hence, when we come to connect the inclination of all these strata with the existence of an argillaceous deposit about their centre, we cannot be surprised to find that the upper half has slid towards the north-east, and left the whole of the lower or colored strata in advance, which is the case; and this not only accounts for our not seeing the red strata at the bottom of the great scarp which faces the eastern side of the range, towards the Bay of El Kammar, but also for the presence of the sub-range of mountains which exists on its western side.

Difficult as it would have been to have joined these two series with the absence of the micaceous sandstone, and to have accounted for their relative position at this point, without having seen the inclination of the strata, yet the existence of Orbitolites in the white limestone at Marbat, and their abundance throughout the colored strata here, is sufficient to connect the two; and if any further proof be necessary, the finding of a piece of blue limestone at Marbat, almost entirely composed of small Orbitolites, and identical with the pinkish grey limestone of the same kind here, at once identifies the colored strata of both places, and establishes the position of the colored strata of Ras Fartak.

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It is remarkable here, however, that the colored strata should be so expanded, and that the micaceous sandstone should not appear.

Thus we see that there are 1900 feet of white limestone strata in the cliff on the eastern side of the Fartak range, and from 1000 to 1200 feet of colored strata forming the advanced part of the cape, and that of the western side of the range. The additional height, therefore, of the main ridge, which has been computed by triangulation to be 2500 feet above the sea, must be accounted for by the inclination of the strata; for although the base of the white limestone is about the level of the sea on its eastern side, it must neverthless, from the dip of the strata in this direction, be elevated for some hundreds of feet above the sea, where it rests on the colored strata on the western side of the range.

Before leaving Ras Fartak, I should state that the pinkish grey limestone, which is filled with small Orbitolites, and which rises from the sea just opposite the little village of Khaisêt, is perforated by the holes of lithodomous animals 30 feet above the level of the sea, and adherent to its side at the same height is a band of the miliolitic deposit mentioned, containing shells, which are in a white pulverulent state, and pieces of the adjoining rocks. This deposit, though not very compact, is sufficiently tenacious to form a building stone, of which the little tower now in ruins on the top of this limestone, which forms a conical hill here, was composed.

From Ras Fartak south-westwards, the coast line forms an obtuse angle with that just passed, and for some distance presents no cliff, but a low sandy shore, reaching back to that part of the Fartak range which I have before stated to run south-west. This sandy shore, which reaches inland for about six miles, continues along the coast for twenty-five miles, when it is limited by a tract of low rocky limestone mountains, which extend outwards from the range just mentioned. I should here state that the mountainous tract of this part of the coast, commencing with the Fartak range, is continuous on to the Yaffai mountains, at Bāb el Mandeb, with the exception of three great valleys, which here and there open upon the sea. The point which limits this low shore is called Ras Darjah; it is about 300 feet high, and composed of limestone. The following is a brief description of the cliff close to it, from above downwards, viz. pink, grey, white, and yellow compact limestone, in parallel strata from three to twelve feet thick, with here and there large round concretionary flints, peeling off in concentric layers. Some of the strata are friable, loose, and gritty, not unlike those at Hammar el Nafur and Ras Kariat, 432 miles off, and in like manner also contain a great number of small Echinodermata of the following kinds:—

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Echinocyamus Annonii, Mirian, mihi. (Tab. 27, figs. 37—40. Ag. Mon. d'Echinodermes.) Length $\frac{1}{14}$ inch, breadth $\frac{1}{14}$ inch, and thickness $\frac{1}{24}$ inch. Vent a little distance from the margin. *Loc.* Ras Darjah.

E. alpinus, Ag., mihi. (Tab. 27, figs. 41—43. Loc. cit.) Length $\frac{1}{12}$ inch, breadth $\frac{1}{24}$ inch, and thickness $\frac{1}{24}$ inch. *Loc. idem.*

Obs.—Of this fossil Agassiz states, p. 135: "Mais ce qui rend surtout cette espèce intéressante, c'est son gisement. Je n'en connais que deux exemplaires qui font partie du Musée de Berne; ils ont été recueillis dans la chaîne des Alpes Suisses, à Burgenberg, près Stanz (canton d'Unterwalden), dans une sorte de conglomérat fossilifère noir appartenant au terrain crétacé, et contenant une quantité de fossils triturés, entre autres une grande nummulite." This remark is not less interesting here, where we find these little fossils in a similar deposit to that which exists at Hammar el Nafur and Ras Kariat, and which contains the same kind of fossils and nummulites; from which we might infer, if I am right in the identification of the species, that the cliff at Ras Darjah is formed of the upper part of the white limestone series, and that the loose and gritty part is identical with that in which similar Echinodermata, with nummulites, are found at Hammar el Nafur and Ras Kariat.

This group of rocks, and the sea-cliff which they present, do not extend far from Ras Darjah before they diminish in height, and become covered with a plain of yellow sand, of four or five miles in extent. The sand appears to be nothing more than a disintegrated part of the miliolitic deposit before mentioned, which here has been raised on the tops of the rocks, on which it was deposited, and, like that at Ras Abu Ashrin, has become loose on the surface, and now forms a smooth uneven tract, which, in its irregularities, correspond to those of the harder rocks beneath. It presents a sea-scarp of about 30 to 40 feet high, and ends at the little plain of Kashn; after crossing which we arrive at the mountainous tract again, which now advances to form the cape called Ras Sharwên.

This cape consists of a long narrow mountain, of a wedge-like shape, sloping towards the point, and presenting on its upper end two pinnacles; it is about two miles long, and scarped on both sides, as well as at the extremity; the latter at its lowest point is about 200 feet above the level of the sea, and the pinnacles about 1800 feet. Its longitudinal direction is about east and west, so that its inner face is opposite the main land, and it shelters a little bay inside it, which is called the Bay of Kashn. This mountain is composed of colored strata, identical with those which form the advanced part of Ras Fartak, and in like manner seems to have been denuded of the white limestone; but what has become of

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the latter the land above water does not indicate; no doubt this wedge-shaped mountain was covered by it, as the next mountain to it inland presents the white limestone *in situ*. I might here content myself with referring the reader to the description of the colored strata at Ras Fartak, for those of Ras Sharwên, as I have placed the list of fossils from both places after the former, but it will be more satisfactory, perhaps, to give the observations which were made on the spot respecting their composition.

About a quarter of a mile inside the cape, where we landed, the upper part, which is not very high here, is composed of fine compact limestone, of a white or light grey color, presenting small Orbitolites, and a few remains of Echinodermata. This, after some distance down, passes into a violet, and then red colored argillaceous limestone, containing a great number of the same kind of fossils, together with bivalve and univalve shells; after which comes a yellow stratum, with blue and red bands intermixed, and then a blue deposit, almost entirely composed of small Orbitolites, like the pinkish grey limestone at Ras Fartak. The whole of these colored strata contain more or less argillaceous matter and siliceous sand. A little further in, where the red colored ferruginous strata emerge from the water, the same shattered appearance of the limestone is seen as at Ras Fartak, with calc-spar coating, and more or less filling its cavities.

Here, too, on the inner side of the cape, as on the pinkish grey limestone at Fartak, is seen a band of the miliolitic deposit adhering to the scarp 40 feet above the level of the sea, and containing in some parts, as at Fartak, large shells, and portions of the adjoining rock; while between it and the sea there is, as at other places, an interval of some yards, where it either never existed, or has been washed off by the waves.

Having finished with the inner side of Ras Sharwên, let us now go to the outer side of the cape, and here, too, a mile or two west of the latter, the red strata are again seen, but in the utmost confusion. This is owing to a mass of black scoriaceous basalt, which has forced itself up among them; and although it has not managed to reach the surface, yet, from being in the sea-cliff, a good lateral view is seen of it. It is about 300 or 400 yards long, and about 200 feet high. I had hunted in vain for a disturbing agent of this kind at Ras Fartak, and on the inner side of Ras Sharwên, but could see nothing *in situ* at either, though, from the presence of pebbles of black basalt about the base of the latter, I was led to infer that it could not be far distant.

This is the first place where we have seen an igneous rock since leaving

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Marbat plain, a distance of 200 miles, and the first time we have met with black basalt on the coast; but we shall soon see that we have come to the commencement of a series of vents, which have poured forth large tracts of this igneous rock.

As we saw a raised sandy plain of the miliolitic deposit covering the low rocks east of Kashn, so we have a similar one west of Sharwên. It is coarser in structure than the miliolite of Ras Abu Ashrin, but otherwise almost identical with it. It begins close to the western side of the black basalt, which indeed it partly covers, and extends a short distance inland, and about ten miles along the sea, where it presents a cliff about 100 feet high. As before stated, it is raised, and, though smooth on the surface, takes the form of the harder and older rocks which lie beneath, while the presence of particles of basalt in it would seen to indicate that it has been formed since the eruption of that rock.

Leaving Ras Sharwên, and this tract of sand, the limestone formation continues to rise abruptly from the sea for twenty miles, when it falls back, and leaves a narrow strip of maritime plain, which is continued all the way to Ras Makalla, a distance of 140 miles, backed from one end to the other by the raised tract of limestone mentioned,—sometimes in the shape of mountains, at others in that of long portions of tableland; while extending along this narrow plain is the series of basaltic effusions to which I have alluded.

These commence immediately west of the opening of the great valley called Wadi Masilah, and about twenty miles from the beginning of the maritime plain, or forty miles from Ras Sharwên. They are three in number, and are called by the Arabs the "harieq," or "burnt place," from a superstition that they mark the sites of seven pagan cities, which were burnt down by the Imam Ali at the commencement of the Mahomedan Æra. They form the most remarkable objects of the kind on this coast, and are continued on to a little beyond the village of Raidah, a distance of forty-five miles from their commencement. The striking features of them are their intense black color, their flatness, and horizontal extent, defined borders, and the contrast they form with the white color of the plain, and that of the limestone mountains behind them. Each tract presents one or more cones in the centre, which do not appear to be more than 200 feet above the basaltic plain immediately surrounding them.

The first cone is about four miles from Saihut, or about 50 miles west of Ras Sharwên, and the tract of basalt which surrounds it has extended nearly to Wadi Masilah on the east, and joins the following tract on the west.

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The next cone is opposite the opening of the valley called Wadi Shikawi, about nine miles from the last, and about three miles inland: its tract extends westward to Raidah, a distance of about eighteen miles, and eastward joins that of the foregoing, as already mentioned. I examined a part of this tract opposite the valley of Shikawi, where it extends into the sea, and its highest part, not including the cone, did not appear to be more than 30 feet above the level of the sea. The whole of the maritime plain here is covered with large and small boulders of black and grey basalt, more or less compact, more or less scoriaceous, breaking with a rough coarse fracture, and presenting olivine in its cavities. Some pebbles which I picked up on the beach were composed of fine compact basalt, in which distinct crystals of pinkish white felspar were imbedded. All the boulders were weathered smooth, and more or less round.

The third tract begins west of Raidah, and here the maritime plain, being raised from two to three hundred feet above the level of the sea, the basalt has not only overflowed it, but found its way into the watercourses, and appears in black rocks at their openings on the beach, contrasting strongly with the whiteness of the low limestone cliffs on each side of them. There are five cones in the centre of this effusion, which are all higher I think than either of those mentioned.

Here also the maritime plain widens out to an extent of fifteen miles between the base of the high land and the sea, and, being raised, presents a cliff which at the cape called Ras Bu Gashwa is 300 feet high, but diminishes gradually on either side for a few miles, until it subsides to the level of the beach. There are several portions of this part of the plain raised in isolated mounds 700 or 800 feet high, and the whole seems to have undergone much disturbance from subterranean causes: the district is called Hammam, from the number of hot spings here. I had not an opportunity of going on shore, so I can say nothing of the sea-cliff further than that above it is red, in the middle white, and below yellow; but we shall find it again at Makalla, and perhaps may be able to infer its geological character from the composition of the cliff at that place.

I have before stated that this maritime plain ends at Ras Makalla, to which we now arrive, and on turning which we observe that it consists of a ridge of igneous rocks, supporting limestone. This ridge presents an irregular scarp of two and a half miles in extent on its western side, and on its eastern side limits the maritime plain we have just left.

When we examine it from within outwards, that is from its base to

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its extremity, we find that it is made up successively of granite, limestone, and green serpentiniferous diorite.

The granite forms the base of the cape, and is a part of a group of igneous rocks which extend a little further inland. It appears here in the form of a mountain capped with limestone, the summit of which is 1300 feet above the level of the sea ; that of the granite appears to be about 1000 feet. It is of a dark grey color, and uniform fine structure, and, from its amphibolitic admixture and freshness, seems more allied to syenite or diorite than old grey granite. Be this as it may, it is dyked with the green earthy diorite of the locality, and, suddenly sinking towards the cape, disappears in low peaks beneath the limestone, while the latter then forms the ridge for some distance, and is about 600 feet high. After this follows the green diorite in round topped hills, which compose the outer third of the cape, still diminishing in height, and supporting an isolated portion of the limestone between them, a little distance from the extremity. The diorite presents an earthy base of a greenish color, with crystals of dark green hornblende scattered through it ; it is richly serpentiniferous, and sometimes appears like green euphotide. Where it forms a breccia with the calcareous material of the loccality, an amorphous thin layer of calc-spar, with grass green serpentine, exists between the two; indeed the serpentine appears to tinge the former.

The limestone strata, which appear to be between 300 and 400 feet thick, are, in the immediate vicinity of the granite, fractured throughout, and united again by their own material, so that all appearance of continuity in their stratification has been destroyed; but in the cliff which they present in the central third of the cape, and which is about 250 feet high, they are entire, and composed as follows, viz. above of compact cellular limestone, of a pink color, presenting in one part a stratum filled with the moulds of small shells, in which there is more or less crytallized gypsum. This part also effervesces slowly with acids, and is identical, as before stated, with the same kind of limestone sent me by Lieut. Grieve from Ras Markas, near Ras Jazirăh, that is as far as structure and mineralogical characters are concerned. Beneath this compact pink limestone comes a more siliceous one, filled with large cavities, which are lined with hyaline quartz and calcedony. Then follows a white stratum of more or less impure siliciferous limestone, and beneath this a dark red-colored deposit, chiefly composed of fine siliceous sand, which rests on the granite.

Though there are no separate fossils here, the upper strata abound in traces of them, and in some parts they are almost entirely composed of

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small Foraminifera, allied to Nummulina. In another part of the limestone formation here, close to the granite rocks, but not in contact with them, or forming part of the ridge of the cape, small Foraminifera also abound, as at Mäskat, and particularly the Operculina of that locality. I did not see any nummulites, but I think it will hereafter be found that they are not more a character of the Nummulitic Series than the abundance of small Foraminifera which exist in the limestone strata belonging to it, and indeed of which many are, with the addition of microscopic species, almost entirely composed.

Besides this limestone, we have here again the miliolitic deposit, forming in one part a bank 30 feet above the level of the sea, and in another adhering to the upper part of the scarp of the limestone cliff, extending to the cape from 60 to 100 feet above the level of the sea; while we have blocks of it on the shore on the inner side of Makalla, which have fallen down from the limestone on the top of the granite, 1300 feet above the level of the sea, slightly changed in structure, but still easily recognizable, and of a delicate color, like that of the pink or cream colored limestone in the same situation. The coarseness of the structure of these deposits at their three different heights, and the shells, pieces of coral, and parts of the old limestone rock which they contain, together with their modern appearance generally, indicate that they all belong to the same formation; but there is one difference, independent of the changes produced by heat, in the pieces which have fallen from the limestone on the top of the granite, viz. that it does not, like the other two, present portions of the green diorite. Thus it must have been raised up with the other limestone rocks before the eruption of the diorite took place, or all traces of particles of the latter must have been subsequently effaced. Still this does not interfere with the fact that this formation, which we have hitherto seen raised only 150 feet above the sea, viz. at Ras Sejär, is here in one part 30, in another from 60 to 100, and in a third 1300 feet above its level, and in the last place so changed in color, that however young it may be considered to be, it must have preceded the eruption of the granite, and the elevation of the limestone on which it rests.

About three miles inland, north-east of Makalla, just at the outskirts of the group of igneous rocks which are continued into the formation of the cape, and among the lower hills of the great limestone tract, is a spring, from which the inhabitants of Makalla obtain their supply of water. This issues from a ravine situated among the lower limestone mountains of the table-land, which are fractured and fissured in all directions, and cemented together again by their own substance, except in some

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places, where there are holes and caverns which have not been so filled up, and are more or less filled with water, both in the sides of, and leading into the interior of the mountains. The water of the spring mentioned is somewhat above the temperature of the air, but without taste or smell: in its course along the ravine it passes through sand, which has more or less accumulated on its sides, and in this sand is a quantity of botryodal magnesian limestone. The spheroids are of different sizes, up to an inch in diameter, which is the measurement of the largest obtained. They are of a coarse structure, formed of concentric layers, and present a rough arenaceous exterior. Some appear as if they had been formed in halves, from the two hemispheres not having been applied to each other in complete apposition. They are more or less adherent, and seem as if they were formed in the sand of the stream in which they were found.

Among the igneous rocks at Makalla exists a porphyry, with a dark red base, and large tabular crystals and nodules, of greenish felspar; also epidote with calc-spar, as at Masira. Mica prevails in some parts, and various other earthy minerals, which are generally found in company with such rocks.

Leaving Makalla, and proceeding south-westwards along the coast for about six miles, we meet with no sea-cliff whatever, but a sandy shore, with scattered hills interiorly, and then sub-ranges of mountains; behind which, and towering above all, is the brink of the table-land, here about 6000 feet above the level of the sea.

At Ras Brum, however, which is at the termination of this sandy shore, and which is opposite Ras Makalla, as the coast runs, igneous rocks again make their appearance, and from thence are continued on to Ras el 'Assidah, a distance of about fifty miles, after which they subside gradually in dark peaks, scattered here and there among the sand-hills of the coast.

This tract of igneous rocks fringes the shore for the distance mentioned, and is continued inland for two or three successive ranges, mixed more or less with limestone, to the base of the table-land, here fifteen miles from the sea. From their brown color and peaked appearance they closely resemble the granite of Makalla; and about Ras Brum, before stated to be opposite Ras Makalla, is the same kind of green-colored rock as that forming the outer third of the latter cape, viz. green diorite: at Ras Brum also it is in round-topped low hills like those of Ras Makalla, and separates the brown peaked mountains behind, which are 1000 feet high from the sea. In all probability these rocks are but a repetition of those forming Ras Makalla, but at Makalla my actual exami-

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nations cease, and I can only now state that which I have seen of this part of the coast while sailing leisurely up and down it two or three times, and from the sketches I then made of it.

I have observed that these rocks are more or less mixed up with limestone,—the limestone no doubt through which they have been forced,—so that here and there white ridges appear among the dark brown rocks, and occasionally come to the sea, as at Ras Răttle, which is a conspicuous white mass of limestone five miles east of Ras el' Assidah. The islands, too, off Hisn Ghorab, a little east of Ras Răttle, viz. Hăllani, Jibus, and Baragah, are all of white limestone. Jibus, which is perhaps the largest, is five miles off shore, hardly a mile long, and about 300 feet high.

A little west of Ras Brum there is a long low level piece of pink or red-colored strata, bordering on the sea, and presenting a cliff similar to that of the raised part of the maritime plain at Ras Bu Gashwa ; it is probably an undisturbed part of the same formation.

The dark mound on shore, called Hisn Ghorab, famous for bearing the longest Hamyaritic inscription that has been met with, is stated (Wellsted's Trav. in Arab. vol. ii. p. 423) to be composed of a dark greyish compact limestone, 500 feet high ; and in further proof of the general elevation of this coast, which from what I have stated must now, however, be pretty apparent, it is also mentioned that "The action of the sea might be plainly seen [at the foot of this mound] in the cavities and hollows exhibited by a ridge of rocks now some distance from the water, but which evidently at some not very remote period must have been covered by it."

Between Ras el 'Assidah and Aden, the coast is almost wholly unknown to me, except from a distance ; there is no sea-cliff there, and not much on the maritime plain to interrupt the view from the sea to the base of the mountains after leaving the neighbourhood of Ras el 'Assidah. About sixty miles north-east of Aden the high land advances to within a few hundred yards of the shore, and affords a grand view from its rapid and almost uninterrupted descent from three, four, and six thousand feet to the plain below. The sea, too, just here, is vastly deep, and admits of close approach to the shore without danger.

Not more than twenty-five miles on from this, the seaward boundary of the mountains recedes from the direction of the coast, and stretching over to the Straits of Bāb el Mandeb, ends in the south-western extremity of the great elevated tract of Southern Arabia, while the coast, continuing on in its original course some miles further, before it takes a similar turn, leaves a triangular plain, at the apex of which is

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the town of Aden, situated in the crater of an extinguished volcano, the sides of which reach about 1700 feet above the level of the sea. This crater opens towards the east, and presents a tail of peaks, ridges, and low cones, in the opposite direction, the whole of which amount to about six miles in extent.

I had not an opportunity of examining much of this mass of volcanic rocks, but I could see that they were principally composed of basalt, pierced with dykes of the same material, in a more compact state. The external side of the crater is more or less scarped, and separated from the high peaks and ridges which flow from it, and in this scarped portion may be seen lines of horizontal stratification: also some distance up the side of the slope which descends towards Back Bay may be seen a a small series of strata, consisting of pisolitic peperino, cemented together with glassy crystallized gypsum, and from the manner in which the pieces of pumice, basalt, and obsidian of which it is composed are arranged, together with the fact of the cement being sulphate of lime, leaves no doubt that it was deposited in the sea, and afterwards raised to its present position; at one part it is at least 200 feet above the level of the sea, though it descends to the water's edge in another. The stratification of the walls of the crater, which is very high up, would also lead us to the conclusion that the greater part of this igneous mass has been poured out under the sea, and has been gradually raised to its present height.

Through the kindness of Dr. Malcolmson, whose name I have already had occasion to mention, and who resided at Aden for some time, I am in possession of specimens of all the rocks and minerals which this gentleman after a long search was enabled to collect; and, having been permitted to inspect his valuable assortment when at Aden, I am enabled to state that the igneous rocks of this peninsula consist of basalt in almost all its forms, compact, black, grey, peridotic; rough, cellular, scoriaceous, variolitic; tephrine, with small crystals of glassy felspar, which forms some of the high peaks in the interior of the crater; leucostine, which forms part of the lavigenous effusions in the north-west part of the peninsula, where the last vents of the volcano appear to have existed; pumite and stigmite, simple, variolitic, and pisolitic, which form small deposits in various parts of the general mass, and semiopal and calcedonies, which abound in the island of Sira, opposite the opening of the crater.* To these may be added brown carbonate of lime, in columnar stratified crystalline deposits, with transverse wavy lines;

* For the characters of the rocks here mentioned see Brongniart's classification, Art. "Roches," Dict. des Scien. Natur.

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massive and fibrous gypsum ; and fluor spar, in minute crystals of an amethystine color, on the surface of calcedonies.

The recent littoral deposit here, as elsewhere on this coast, appears in several parts of the north-west part of the peninsula, raised fifteen or more feet above the level of the sea.

About four miles west of Aden there is another group of volcanic rocks, said to be partly composed of granite, and their peaked forms would indicate this; it is about the same size as Aden. Last of all on this coast comes the small dark group, probably also of igneous origin, which forms the eastern promontory of the Straits of Bāb el Mandeb.

Having thus come to the termination of the South-east Coast of Arabia, let us now pass over to the African Coast ; and, commencing from Berbera, which bears nearly due south of Aden, see if the rocks extending from this part eastward to Socotra have any resemblance to those on the coast we have just left.

Personally I know nothing of this coast, but Lieutenant Grieve, who surveyed a good part of it between Berbera and Guardafui, kindly collected specimens for me from the principal headlands between Berbera and Ras Sărai, and from all the islands excepting Socotra.

From these, and the observations which accompanied them, it appears that the top of the bluff at Syara, which is 300 feet high, and about eighteen miles east of Berbera, is composed of a coarse heavy sub-saccharoid magnesian limestone, effervescing very feebly with acids, and of a reddish color, and ferruginous aspect ; while the base is composed of the same kind of rock, but of a greyish brown color : both are without any appearance of fossils.

The top of a hill on the coast seven miles further on is composed of a fine compact limestone, of a yellowish white color, breaking with a smooth conchoidal fracture.

That of Hamarah bluff, which is 500 feet high, and twelve miles further on, of a fine compact sub-cellular limestone, of a cream color, mottled with spots of red and white, with frosted cavities of calc-spar ; also effervescing slowly with acids.

The top of Ras Khanzir, about 200 feet high, and seven miles further, of a fine compact limestone, of a yellowish color, like that of the hill on the coast seven miles from Syara. Some portions appear, from their veined structure, and opaque appearance, to have been exposed to volcanic influence. There is another portion from this cape, too, which, from its open structure and fossiliferous composition, is evidently of a later formation, and resembles much the modern deposit at Makalla. It has in like manner been exposed to heat, and its cavities and

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fossils are more or less soldered together by an amorphous white crytallization of carbonate of lime.

The next specimen is from the hills near Ras Shalla, fifty miles further on. This is a compact limestone, of a pinkish color, and uniform structure, breaking with an even granular fracture.

Hais Bluff, 500 feet high, and fifteen miles further on, affords a compact heavy limestone, of a granular sparkling structure, and a greyish brown color. It is highly magnesian, scarcely effervesces with acids, and closely resembles that of the base of the white limestone cliff on the east side of the Fartak range. Hais Island, close to this bluff, is 300 feet high, and composed of a sparkling, black green amphibolite, fissile, laminated, and very much resembling gneiss, but serpentiniferous at the joints, and closely allied to the sparkling hornblende rock of Ras Jazirăh, on the South-east Coast of Arabia.

Meyt or Burnt Island, about twenty-six miles further on, and seven miles off shore, yields a pegmatite in composition, but not graphic in structure, and a compact limestone of a fine uniform saccharoid structure, and grey color, effervescing feebly with acids. This yields by a rough analysis 15.32 per cent. of magnesia, and its specific gravity is 2.775 : it is a dolomite.

In the Museum of the Bombay Asiatic Society are specimens of limestone from Mărriyah, two hundred miles further east, and forty-five miles west of Guardafui. They were presented by Lieut. Cruttenden, of the Indian Navy, and are of a cream color, and compact fine structure, identical with the limestone on the top of the granite peaks at Makalla.

From this place we pass on to the islands between Cape Guardafui and Socotra, the first of which is Abd el Kuri, from which Lieut. Grieve sent me specimens, as well as from the islands called Kal Farun, and "The Brothers," situated between it and Socotra.

The summit of Abd ul Kuri is 1600 feet high, and composed of a fine white compact limestone, breaking with a smooth conchoidal fracture, dry, and opaque, as if it had been exposed to heat ; and the lower hills, which are from 200 to 400 feet high, yield grey and red granite ; fine and coarse-grained diorite, composed of black hornblende and whitish semi-transparent felspar, ophiolitic diorite, and euphotide ; indeed all the kinds of igneous rocks that we have seen on the Arabian coast north of Marbat.

There is also a coarse, compact, sub-cellular, and sub-saccharoid limestone, of a light cream color, which comes from the higher parts of this island ; it probably overlies the igneous rocks, and owes its color to the

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action of heat; otherwise in structure it is just like the upper stratum of the low cliff in the Bay of El Kammar, and the dark brown limestone of the shores of Dofar.

The island of Kal Farun, fifteen miles north of Abd el Kuri, seems to be entirely composed of sulphate of lime. One specimen, coming from a height of 400 feet, is massive, compact, sub-saccharoid, and of a brown color; the other, which comes from high-water-mark, is earthy, white, and contains moulds of small shells, with particles of igneous rocks.

Turning to "The Brothers," which lie between Abd el Kuri and Socotra, we find the largest, or westernmost of these two islands, to present pink granite rocks, 1000 feet high, with limestone above them, reaching in all to 1600 feet; also diorite, as at Abd el Kuri; and a white compact limestone conglomerate, raised 300 feet high. The latter consists of small rounded gravel, shells, and corals, which have been firmly cemented together, and more or less opalized, probably by heat; while the same kind of conglomerate, with a few particles of igneous rocks, exists at high-water-mark in the easternmost island, still possessing its original loose, dull, and recently-formed appearance.

Of Socotra I know nothing more than can be gleaned from the late Captain Wellsted's account of this island, (Jour. Roy. Geograph. Soc. vol. v. 1835.) In the vicinity of Tamarinda, a town situated towards the centre of the northern coast of the island, there are granite mountains, 5000 feet high by measurement. "Connected with the granite range, and extending form north to south, a lower range is found, averaging in height about 1900 feet, and composed of a compact cream-colored primitive [?] limestone. From this the hills diverge in short ranges to the sea-shore, their outline being mostly smooth, with table summits and rounded sides, except those nearest the sea, which mostly present a steep wall. The whole of the hills in the western part of the island are similar in their appearance, elevation, and construction."

In the neighbourhood of Goobet Koorma the limestone appeared to be borne up upon the granite, and the line of junction between the two was seen 3000 feet above the place where Captain Wellsted stood.

Syenite, porphyry, and trap, were seen in different parts of the island, and the soil of the mountains is clayey, stiff, and of a red color.

Returning to the Somali coast, it is stated, that after a short but variable distance in-shore, the land from Berbera to Cape Guardafui is raised to a height averaging between four and seven thousand feet, and attaining its maximum elevation midway between these two places. It is composed of limestone, and the specimens I have seen from it have been more or

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less fine and compact in structure, and of grey and white colors, similar in every respect to the limestone of the elevated tract on the South-east Coast of Arabia; while the cream-colored limestone in like manner seems to come from the tops of the lower hills, where it is probably in closer proximity with the igneous rocks.

Thus we see that the same kind of igneous rocks, and the same kind of limestones, exist on this part of the coast of Africa and its adjoining islands, as are found on the South-eastern Coast of Arabia and its adjoining islands; the same kinds of magnesian limestone, and a modern formation, corresponding to our miliolitic deposit.

There is also a spheroidal concretion of magnesian limestone, about the size of a walnut, which Lieutenant Grieve sent me from the coast of Africa, similar in every respect to that which has already been described as existing in the course of the hot spring near Makalla.

This concludes all that I have to offer on the geology of the North-east Coast of Arabia without the Persian Gulf, the South-east Coast and its adjoining islands, and the Somali or North-eastern Coast of Africa and its adjoining islands. Let us now briefly review what has been stated respecting the South-east Coast of Arabia.

The first thing that strikes us here is the continuity of the white limestone formation, which we may reasonably infer to be the same from one end to the other, a distance of 1125 miles; secondly, the eruption of igneous rocks along the great line of fracture, or fault, which forms the coast; and, lastly, the elevation of the land from four to six thousand feet above the level of the sea, which has brought into view other formations, lying beneath the white limestone.

Turning our attention first to the igneous rocks, we find that they comprise all the principal kinds, and probably most of the varieties, included under this denomination; and that by far the greater part of them are hypogene, (Lyell,) the rest volcanic. The presence of gneissic strata in the granite at Marbat also shows that some of this rock is at least secondary; and being mixed up with limestone in the same neighbourhood, identical but for the changes which such formations undergo when similarly situated, with some of the white limestone series above, further shows that there is granite here, which may be of still later date even than that enveloping the gneiss. The gneiss itself *in situ* I did not see.

We have also witnessed the dioritic and euphotide rocks, which prevail on the north-eastern third of the coast, enveloping jaspideous strata at Masira and Ras Jibsh; at the same time we have seen nummulitic strata resting on them at Mäskat and Masira, but in no instance have

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we observed either the granite or the dioritic rocks overlying the white limestone series; while on the south-western third of the coast we have seen a chain of volcanic vents up to Aden, inclusive, pierced through everything, and an issue of black basalt and other volcanic rocks from them, which have overflowed the maritime plain in different places to a great extent. What the nature of the igneous rock may be at Ras Shuamiyah I know not, having only seen it from the sea.

Lastly, we have observed that the original localities of eruption of igneous rocks on this coast appear to have been the principal ones of the subsequent eruptions, with the exception of the volcanic rocks, which have come to the earth's surface, where the older igneous rocks do not appear.

Let us now go to the aqueous formations, and these we may separate into three *Groups*, viz., 1st, the strata of which the highest scarps are composed; 2nd, those of the compact littoral deposit on the shores of Dofar; and, 3rd, the loose, or miliolitic deposit.

1*st Group*.—This admits of three divisions.

The first or uppermost includes the white limestone series, which extends from the summit of the table-land to the commencement of the colored argillaceous strata. This consists, from above downwards, of compact white limestone, more or less composed of the remains of minute and small Foraminifera, with here and there concretionary flints, ex. gr. Mäskat, Masira, Hammar el Nafur, Ras Kariat, and Ras Shaherbataht; and that the flints also occur in the summit of the table-land above Marbat may be inferred from their presence in the talus beneath, separate, or combined with pieces of the limestone in which they were imbedded; also generally throughout this coast, from their presence at Resut, the beach in the Bay of El Kammar, and the cliff at Ras Darjah. Below, this passes into a soft white limestone, and then into a gritty loose chalky or sandy deposit, becoming more or less argillaceous towards its lower part, at Mäskat, Masira, Hammar el Nafur, and Ras Kariat, where it presents nummulites; also at Ras Shaherbataht, Jibal Jinjäri, Marbat, and Ras Hammar, (the argillaceous pipe-strata,) and Ras Sejär, (the *khat* or chalk on the summit of the cape,) where the existence of nummulites has not been determined. Then follows a deposit of clay of a greenish white color, at Hammar el Nafur and Ras Kariat; also at Masira, where it is colored dark green and red, while at Mäskat it is replaced by a siliceous sandy conglomerate. (Mäskat is included here for the sake of comparison.)

Here, then, we have a distinct, though little series, passing from pure calcareous material above to pure clay below, with siliceous matter between; and in this series we have at Mäskat, Masira, Hammar el

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Nafur, and Ras Kariat, the presence of nummulites; while the existence of the so-called chalky stratum and flints in the more elevated and inaccessible parts of this coast would lead us to infer that the same little series existed there also, though as yet it has not been explored for nummulites. The presence also of nummulites (?) and orbitoides in the cliff at Takah, which is but an unraised portion of the great limestone formation, further favors the inference; and with this evidence of the existence of this little series on the high land of Southern Arabia we must be content until further observation can prove it more satisfactorily.

The presence of the clay here, too, not only serves to mark a subdivision in the white limestone series, but also seems to point out the time in its formation when the dioritic and euphotide rocks were erupted, as well as the origin of the clay itself; for from the strata in which the nummulites are imbedded having been deposited after the eruption of these rocks, as seen at Mäskat and Masira, and also after the deposit of the clay, as seen in the white limestone series at Hammar el Nafur and Ras Kariat, taken in connection with the change in the nature of the sediment in the latter, just preceding the appearance of the nummulites, it is plain that an eruption did take place about this time, affording the material of which the clay is composed, for had this not been the case the formation of the white limestone strata would have gone on uninterruptedly to the pure deposit above the nummulites. Hence we also see that this may actually be the case in places to which the material composing the clay might not have extended, and there the nummulites alone, or their allied fossils, must mark the upper division of the white limestone series. That this eruption was that of the dioritic and euphotide rocks may also be reasonably inferred from the nummulites overlying the latter, as well as the clay of the white limestone strata; and from their having been deposited in both places, just about the time the disturbance had become quieted, the remains of marine animals had begun to accumulate, and the siliceous material was beginning to disappear. The depth of this little series, overlying both the limestone strata and the igneous rocks, also seems to correspond, and this led to my remarking in my observations on the igneous rocks of Mäskat, (loc. cit. p. 126,) that the Nummulitic Series appeared much thinner at Mäskat than in many parts of the South-east Coast of Arabia. Let us now see whether there is anything to make us think that this is a fact, and that the great mass of white limestone strata, upwards of 1500 feet thick, which underlies the clay there, is but a continuation of the Nummulitic Series.

I have stated, p. 42, that impressions of Orbitolites exist in the marl

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which passes into this clay at Hammar el Nafur and Ras Kariat; also that a spheroidal Alveolina in company with large Orbitolites and an Operculina abounds in the white limestone series at Marbat, and that this is exactly the case in a part of the Nummulitic Series (?) in the Hala range of mountains, near the Buran River, in Lower Sindh. Lieutenant Grieve also sent me specimens of white limestone from the summit of the table-land at Marbat, which contain numbers of Alveolina. Now the presence in this marl of Orbitolites which we have seen to increase, and that of the specimens of Alveolina with Foraminiferous tests generally which we have seen to decrease in number as we descend the white limestone series, seems to point out, that where these fossils commence to appear and the latter is most numerous, is the passage from the nummulitiferous strata into the inferior sub-division of the white limestone series, or orbitolitiferous strata; more properly termed perhaps alveolitiferous strata, for, plentiful as we have seen specimens of Alveolina in the white limestone strata at Marbat, they are probably much more plentiful in it in other parts of the coast, since they are so abundant in a part of the Nummulitic Series in Lower Sindh that there whole strata almost are made up of them, while in Arabia we have also seen them exist from the summit of the table-land (at Marbat) to the base of the white limestone cliff (at Fartak), though probably largest and most abundant between the two; at the same time we have observed the Orbitolites to reach their maximum density in the colored argillaceous series, which therefore more particularly deserves the term of orbitolitiferous strata. But, call these strata what we will, the point in question here is whether or not the whole of the white limestone belongs to the Nummulitic Series, and this must be left for future exploration to determine: all that can be deduced from the previous observations is, that the same kinds of fossils are to be found together in the talus of the great limestone scarp at Marbat as are found in the nummulitic limestone of Lower Sindh, and that the presence of Orbitolites with them seems to point out that they come from strata below the green clay, and therefore from the lower division of the white limestone series. I regret that I cannot state more of this sub-division than that the strata of which it is composed chiefly consist of fine white compact limestone, breaking with a smooth conchoidal fracture, more or less lithographic in structure, and of different shades of white and grey colors; it is generally scarped and inaccessible. At Fartak, we have seen that the lowermost of these strata are more or less magnesian, and in some parts dolomitic; but this, which we have frequently observed in this series on other parts of the coast, seems to be owing to local causes.

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We now arrive at the second division of the *Group*, which comprises the colored argillaceous series, and this we have estimated at 300 feet at Marbat, 175 feet at Ras Sejăr, and 1000—1200 feet at Ras Fartak.* We have also observed it to consist of red, blue, green, and yellow argillaceous strata, sandy shales, and impure limestones, in which a red color is most predominant; and to contain, in addition to Orbitolites, throughout, but most numerous in the lower part, species of Echinodermata, Isocardium, Pecten, Exogyra, Ostrea and Ammonites, probably all of the cretaceous age: hence, if we consider the whole of the foregoing division as belonging to the Nummulitic Series, or Lower Eocene, this division must here be considered as the upper member of the Cretaceous period.

The third and last division of this group is the micaceous sandstone, of which we have seen so little that all that can be stated is that it is of great thickness, and, though laminated in some places, is for the most part massive throughout. As before observed, it fines upwards as it passes into the argillaceous division, and becomes coarser towards the bottom, where the gritty particles of which it is chiefly composed are evident to the naked eye. At Marbat it is mostly of a ferruginous yellow ochreous color, and at Ras Sejăr its upper part, which is the only portion of it exposed, is of a light greenish blue color, and veined with white quartz.

2nd Group.

We now come to the *2nd Group*, which we have seen best developed between Marbat and Resut. It consists of two kinds of limestone, both of which are more or less coarse and compact; the upper one is also more or less impure, shelly, and of a reddish white color, and the under one of a dark brown color, containing here and there pebbles of the older limestone formation, and particles of igneous rocks. Both together do not occupy a thickness of more than 50 feet at the utmost, and no part of this little group that I saw is raised more than 100 feet above the level of the sea. It rests on the compact limestone of the Nummulitic Series, and is chiefly characterized by the dark brown color of the lower stratum, and its extreme cragginess where exposed to the action of the waves.

We must be content with the mineralogical characters alone of this *Group* for its separation from the others, since the few fossils obtained

* Almost all the heights and thicknesses given, with the exception of those stated to have been computed by trigonometrical measurement, have been assumed, or obtained in a rough way, for as these observations formed no part of the survey, the means of making them accurately were of course very limited.

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from it are too imperfect to be of any service in this respect. From the *1st Group* it is easily distinguished by its superposition, and the presence of pebbles of the older limestone; and from the *3rd Group* it is distinguished by its compactness, and the thoroughly fossilized state of its organic remains, together with its inferior position. My impression is that it belongs to the Older Pliocene age.

3rd Group.

Lastly comes the *3rd Group*, or miliolitic deposit, which is chiefly characterized by its loose structure. In its purest state, as at Ras Abu Ashrin, that is where it is not mixed with coarse littoral debris of shells, or aqueous or igneous rocks, we have seen it to be composed of minute grains of calcareous matter, with which is mixed a small quantity of hyaline quartz; the former being nothing more than the tests of microscopic Foraminifera, loosely cemented together by a partial dissolution and re-crystallization of the external parts of their shells. The purity and whiteness of this deposit is of course in proportion to the distance it has been formed from the shore, or the neighbourhood of coarse loose material; hence, in addition to the locality mentioned, it is very pure in the plain of Dofar, on the western side of Ras Sejăr, and in the sandy plains on each side the port of Kashn, while in most other parts we have seen it mixed with large shells, pieces of coral, and rocks of the neighbourhood. Perhaps 100 feet is about its average thickness. It exists at various degrees of elevation, from 15 to 150 feet high, throughout the coast, and the fact of its having been raised up at one place, viz. on Jibal Ghara, at Makalla, to the height of 1300 feet, seems to point out that it does not belong to the *Recent* deposits, though probably to the Post Pliocene formations. At Resut it is found filling the lithodomous excavations in the coarse shelly limestone of the *2nd Group*, and there also it contains oyster shells of the same species as those of a recent bed close by. At Marbat, where it fills the fissures of the granite plain, it contains a number of shells and corals, many of which are very large, Hippopus, Ostrea, &c. One species of the latter is perhaps the largest known: it exceeds in size *Ostrea latissima*, (Desh.) We have also seen that it is not only met with throughout this coast, but that it extends to the peninsula of Kattyawar, in India, from whence it is imported at Bombay for building stone; and from forming the lower part of the Desert of Akhāf, opposite Masira, it may perhaps be continued into the heart of Arabia. It is also this deposit which, from its modern appearance, and elevation above the sea at different places, forces upon our attention the gradual elevation of the whole coast; not less so, however, than the *recent* deposit itself, which, though less

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striking, may be seen in many parts above high-water-mark; but these limited elevations sink into insignificance when considered with the extent of elevation and depression which the cracked sandstone at Marbat proves this coast to have already undergone.

From the foregoing data, then, and in the absence of more extended and precise information, we obtain the following table of the aqueous strata on the South-east Coast of Arabia:—

POST-PLIOCENE ? *Miliolitic Deposit*, 100 feet ?	Loose granular deposit of white calcareous particles, chiefly consisting of the remains of microscopic Foraminifera; with which is mixed a variable quantity of colored siliceous particles of igneous rocks, and, in some places, shells, corals, and rounded pebbles of the neighbouring formations, far exceeding in proportion the finer material; shells and corals more or less loosely imbedded in the latter, and retaining, for the most part, their original whiteness and structure.
OLDER PLIOCENE ? 50 feet ?	Coarse, compact, whitish limestone, more or less mixed with red argillaceous earth, containing shells and corals, resting on a brown compact limestone, imbedding pebbles of the older calcareous formations, and rounded gravel of igneous rocks in the locality; shells and corals more or less consolidated with the rock, and for the most part deprived of their original whiteness and structure.
LOWER EOCENE ? 2000 feet ?	*Upper Division.*—Consisting of fine compact white limestone, with concretionary flints, the former more or less composed of the remains of small and microscopic Foraminifera; a soft calcareous limestone or grit, with Nummulites; and a stratum of greenish white marl and clay, with impressions of Orbitolites. *Lower Division.*—Fine compact limestone strata, more or less lithographic in structure, of different shades of grey and white, containing large Orbitolites and Foraminifera of the genus Alveolina, together with fossils of the Nummulitic Series.
CRETACEOUS PERIOD. 1000 feet ?	Argillaceous strata, composed of impure limestones, clays, and shales, of different colors, principally red, richly charged with small Orbitolites, and containing Echinodermata of the genera Discoidea, Pygaster, Diadema, and Salenia; Pecten,* Ostrea, *Exogyra flabellata*, &c. and Ammonites.
1700 feet ?	Compact micaceous sandstone.

* For "*Pecten quinquecostatus*, Sow. mihi," p. 74, read "Pecten.—1st *Species*?" and, in the same paragraph, for "three broader ones" read "two broader ones."

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Such is a faint outline of the Geology of the South-east Coast of Arabia; the few fossils collected from whence will, I trust, sooner or later reach the Geological Society of London, where they will meet with that attention which they deserve. I have given some of their characters here for local reference, but we must look for more useful and authentic descriptions of them from a higher source.

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